SCIENCE AND TECHNOLOGIC PARKS IN REGIONAL INNOVATION SYSTEMS: A CLUSTER ANALYSIS

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Abstract

The concept of Regional Innovation System (RIS) builds upon an integrated perspective of innovation, acknowledging the contribution of knowledge production subsystem, regulatory context and enterprises to a region's innovative performance. Science and Technology Parks (S&T) can act as pivots between academic knowledge and enterprises, easing technology transfer and spillovers. Following the success of Silicon Valley, Cambridge or Grenoble, several European regions have developed and supported the creation of S&T parks as a tool for economic development though with questionable success.

In this paper we explore the potential functions of a S&T Park within a RIS, using cluster analysis to identify the different implementation models across a sample of 55 S&T parks in the UK, Spain and Portugal.

1. Introduction

The concept of Regional Innovation System (RIS) builds upon an integrated perspective of innovation, acknowledging the contribution of knowledge production subsystem, regulatory context and enterprises to a region's innovative performance. The regional approach stresses the importance of proximity to maximize synergies and spillovers, highlighting the need for deepening collaboration and networking to innovation. The importance of easing technology transfer to the productive system emerges as a policy priority.

Science and Technology Parks (S&TP) can act as a platform to the production of knowledge and its transfer to the economy in the form of spin-offs or simple knowledge spillovers, enhanced by the co-location of R&D university centers and high technology enterprises on site. Although S&TP reflect mainly a science push perspective, they may constitute central nodes in an infrastructural system of competitiveness that articulates other entrepreneurial location sites and bridges Universities to the economy in a more efficient and effective way, being crucial to increasing technology transfer and interchange speed, promoting the technological upgrading of the regional economy.

In this paper we try to devise which are the functions of a S&T park that may increase its probability of success and its impact on the RIS. We use cluster analysis over a set of 55 countries to identify distinctive features and correlate them with the more or less success of the infrastructure.

2. Models and definitions of S&TP

The first science park dates back to 1950 and was established in Stanford, United States. Cambridge Science Park was the first European example to be established still in the 60s. Nevertheless, it was only in the 80s that this concept became popular as a policy instrument designed to promote technological transfer between universities and other research facilities and firms. Storey and Tether (1998) accounted for 310 science parks in 15 European Union Countries. This boom aimed to promote reindustrialization, regional development and synergies (Castells and Hall, 1994). However, even though this policy instrument's increasing popularity, its concept is still blurred (Hanson et al., 2005), creating confusion with other concepts like technopole, technology park, innovation centre or even business park (Stockport, 1989). In this section we review the different concepts proposed for S&TP and identify essential characteristics that distinguish science parks from other typologies.

2.1 S&TP: a concept yet ambiguous

A wide range of definitions and conceptions regarding S&T Parks exist and the absence of an accurate concept as led to a proliferation of sites labeled as S&T parks but which lack the necessary elements to be an effective pivoting element within the RIS. Hence, in this subsection we review and synthesize some of the existing definitions of S&T Parks.

The International Association of Science Parks define this concept as "an organization managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation … a science park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities". The UK Science Park Association (UKSPA provides a similar definition defining science park as "a cluster of knowledge-based businesses … associated with a centre of technology such as a university or research institute". According to the UKSPA (1996), science parks' goals include the encouragement and promotion of New Technology Based Firms (NTBF), the creation of an environment that may attract international R&D facilities and linking the science park to the university's reservoir of technology.

UNESCO's definition states that a science park is "an economic and technological development complex that aims to develop and foster the application of high technology to industry … formally linked a centre of technological excellence, usually a university". Thus, science parks would be a platform to establish a set of links between firms and universities, thus providing access to knowledge and fostering technology transfer.

According to UNESCO, a science park aims at promoting the cooperation of Universities and industry in R&D activities, fostering the creation of NBTFs, stimulate technology transfer and constitute a space of close interaction between firms and with R&D centers. Link and Scott (2006) use the definition of the National science Board that acknowledges science parks as a "cluster of technology-based organizations that locate on or near a university campus in order to benefit from the university's knowledge base. The university not only transfers technology but aims to develop knowledge more effective given the association with tenants…". Stockport (1989) highlights the infrastructural aspect of a science park, namely the close geographical proximity to universities, the low ratio of buildings with high quality design and landscaping. In the "software" aspect, Stockport (1989) states that a science park must provide a comprehensive range of services to support NBTFs, as well as accommodate firms with high level of R&D and low level of in-park manufacturing. The support to NBTFs also lays in the centre Bakouros et al. (2002) definition which describes science parks an infrastructure in the proximity of universities, which provides a range of administrative, logistic and technical services and most importantly, convey a technology transfer function.

More recently, Monck et al. (1998) defined a science park as a property based infrastructure with close links to university, designed to promote knowledge-based firms through the provision of technology transfer and business support services to firms. The United States Association of University Science Parks (AURP) also stress the property dimension, stating that a science park (in this case, university owned) convey a planned land, buildings and a range of support services designed for R&D activities by public and private organizations and high technology firms. It should have a formal link to a university or research centre of excellence, promoting its link to industry and the interactions between firms and the university in terms of R&D cooperation and technology transfer.

In simpler terms, Link et al. (2003) defined science park as "an infrastructural mechanism for transferring technologies from universities to firms". Also focusing the infra-structural dimension, Phan et al. (2005) define science parks as property-based organizations with an administrative centre which goal is to promote knowledge production and interactions that promote NBTFs. Asheim and Coenen (2005) defined science parks as planned innovative milieu comprising firms with a high level of competences. The role of these infrastructures is to provide proximity between academic organizations and firms and thus promoting interactions and formal and informal links (Hanson et al., 2005).

In light of these examples, it is clear that there is no consensual definition on science parks (Fukugawa, 2005). Nevertheless, some essential and common features may help clarify the concept. In terms of objectives of a science park, it must foster technology transfer from universities or other research centers to firms stimulate start-ups and spin-offs and ultimately cater for reindustrialization and boost regional innovative performance. In terms of characteristics, a science park, university owned or not, must have formal links with relevant knowledge production infrastructures, providing a low construction density high quality infrastructure and a range of services that support innovation and firm NBTFs. Finally, science parks must restrict access to knowledge intensive activities. Table 1 synthesizes the main features of a science park resulting from our literature review.

Synthesis of important features
Goal: enhancing knowledge transfer from universities to the companies , fostering NTBFs
Infrastructural: High quality, low building construction ratio, coupled with a wide range of business support services, including, technological and adequate scale.
Links: university or a adequate scale R&D centre must be formally committed to collaborate with the science park and firms (commonly, universities should have an important role in the science parks management).
Access: restricted to knowledge intensive activities, with possible sectoral preferences (if knowledge base is significant across different scientific fields and there is entrepreneurial critical mass – not likely in many "follower" regions)

Table 1: Synthesis of the most important features regarding the concept of S&T Park.

Contributing to the dense thicket of concepts, a set of related concepts also increase the diffuseness of the concept, namely, technopole, innovation centre or technology park. Hence, we explore what may make of S&T a distinct approach. Starting with the overlapping concepts of research or science parks (Stockport, 1989) these are property-based infrastructures, usually developed by Universities and which focus is on concentrating excellence academic R&D along with R&D units from enterprises which aim to tap into the knowledge of the University. The S&T version of the concept conveys an area for enterprise deployment of high tech production units along with the companies R&D Centres and the Universities Scientific resources. Both bearing a science-push perspective, it arises as a sine qua non issue for the success of S&T Parks, the deployment or availability of academic scientific critical mass.

Technopoles, the French approach, differentiate themselves from the previous concepts in scale and scope (Oh, 1995). A technopole is a far more ambitious project, comprising a completely new settlement, involving the setting up of an industrial site, research institutions and also a residential component. It is the creation of completely new city, following a concept similar to an innovation hub. Its larger scale makes them, usually, a national rather than a regional political endeavor (Oh, 1995).

An Innovation Centre is an infrastructure built on a restricted space, usually an industrial building where a more emphasis is placed on innovation instead of invention. Though a science park aims to tap university's knowledge, concentrate R&D and translate it into innovation, the focus on innovation is not so intense than in an innovation centre.

A technology park is a property development that presents similarities to science parks in terms of the high technology profile of its tenants but where a smaller emphasis is put on the University's role, also being less restrictive in terms of accommodating production facilities rather than just R&D centers. A high quality business park may present a low construction density but usually does not accommodate technological infrastructures, nor is near or closely linked to a university or to other research centers. Still, it is a quality property that conveys some amenities and facilities, thus distinguishing itself from a less qualified and overcrowded industrial area. Table 2 summarizes the main distinctions between S&T parks and these other typologies.

Other Typologies	Distinctive features
Science and Technological Park	Access: unlike Science parks, small production units in high tech sectors are admitted.
Technopole	Infrastructural: project comprises a complete new deployment of activities, including residential.
Technology Park	Goal: provide a quality environment to attract technology intensive companies that install production units and not necessarily R&D centers.
	Links: not necessarily linked to university or research centre.
Innovation Centre	Goal: Innovation – in the R&D spectrum, intense focus on innovation rather than invention, allowing less R&D intensive but highly innovative activities.
	Infrastructural: smaller scale, comprising a building.
Business Park	Less demanding in all features, simply aims to develop a quality and attractive environment for firms to install production units, taking advantages of economies of scale in certain common use infrastructures

Table 2: Distinctive features of other infrastructures in relation to the science park's concept

Finally, figure 1 resumes the distinction between science parks and other infrastructures in terms of position along the R&D spectrum.

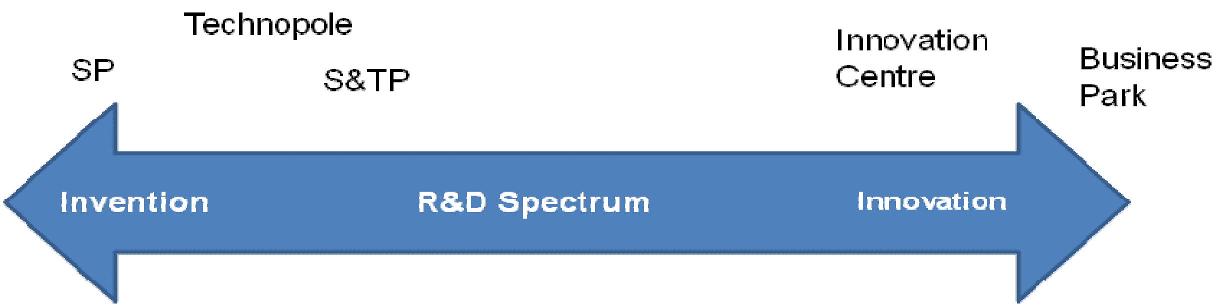

Figure 1: Science Parks and other typologies along the R&D Spectrum line.

2.2 S&T parks' effectiveness

Despite the booms of science parks during the 80s and the 90s (Bakouros et al., 2002) the discussion on their actual effectiveness in enhancing innovation performance and accelerating the emergence of new technology intensive clusters has been subject to intense criticism and discussion. To some extent the proliferation of S&T parks without an appropriate strategy beyond the simplistic linear perception of innovation and without guaranteeing large scale R&D resources may explain the flop of several S&T parks. Massey et al. (1992) characterized S&T parks as high tech fantasy that actually had a small effect on promoting technology transfer, linking universities to industry or enhancing the performance and growth of NBTFs. Westhead's (1997) survey on NBTFs on and off a science park concluded that there was no significant differences I terms of R&D intensity. More recently, Bakouros et al. (2002) in a rare analysis of a follower region concluded that science parks in Greece presented poor results in terms of cooperation and networking. Hanson et al. (2005) attribute these poor results to the misconception of the innovation process presiding the science park which lead to the neglecting the support in terms of managerial skills to University spin-offs. Hence, different studies have challenged the catalytic role that a science park would supposedly convey on a region. Nevertheless, though we must acknowledge that there have been poor results, other studies have confirmed that a science park can be an effective tool of regional development. Fukugawa (2006) states that NBTFs located on a science park have a higher propensity to participate in joint research with other institutions. Similarly, Löfsten and Lindelöf (2002) assessed positively the performance of Swedish Science Parks, stating that the parks milieu had a positive impact on the growth of sales and employment. Also Squicciarini (2008) acknowledges a superior performance of firms located in Finish science parks. Hence, the controversy is still ongoing. However, some insights have been provided by literature and we will also put forward some possible explanations for the limited effects of science parks. Castells and Hall (1994) attribute the low performance on science parks to the low density of firms. Low managerial skills of universities regarding technology transfer and NBTF's support (Bakouros et al., 2002) together with flawed conception of the innovation process (Quintas et al., 1992) may account for at least part of these bad results. To these explanations we further ad two. On one hand, for NBTFs it is important to identify proximity demand. Science parks development has targeted mostly less developed territories where low levels of cooperation exist. The disregard of the demand pull, namely, the creation of a technological market, may hinder the developments of NBTFs and negatively affect science parks' performance. Nevertheless, Squiciiarini's (2009) findings support for the existence of spillovers and for the positive role of incubators over those firms joining SPs very young. On the other hand, a closed and restrictive view of the role of a science park has presided its implementation policy. Even empirical assessments have mostly focused on the within impact of a science park, not paying much attention to its role beyond the physical boundaries or the relevance of articulating it with a set of other regional knowledge infrastructures. In following, Hanson et al. (2005) argue that maybe science parks role is to cater the development of the social capital required to enable future networking.

2.3 Discussing the functions of a science park and its central role in RIS development

In line with the doubts concerning S&T parks value added, we devote this section to defining which are the functions of a S&T park within a RIS. Universities have seen recognized the potential to function as a major input for innovation and S&T parks have become the policy tool to bridge science to enterprises, strengthening linkages and accelerating knowledge transfer and diffusion as well as economic exploitation of academic research and competences (Mowery and Sampat,). This perception of Science parks as seedbeds for innovation (Felsenstein, 1994) and promoters of systemic industry-university cooperation and NBTFs (Asheim and Coenen, 2005), have put this type of infrastructure on the political agenda on regional innovation policies, contributing to explain the proliferation of science parks across developed countries, in spite of increasing doubts regarding their actual effectiveness and value added.

In the following paragraphs, we review the literature on S&T parks aiming to synthesize which are the functions of a S&T park within a RIS and thus develop the framework that will be the base for our cluster analysis.

A science park is supposed to enable a higher return on university R&D through the commercialization, transfer and spin-offs promotion. In a sense this is a view founded on a linear conception of innovation (MacDonald and Deng, 2004, Hanson et al., 2005) and leaning towards a science push policy type. According to Hanson et al. (2005), the science park is usually perceive in a narrow and closed way, as an infrastructure where the simple proximity to a university will allow firms to innovate and profit on that knowledge, disregarding the relevance of interactions and dynamic learning processes among tenants. Quintas et al. (1992) had already pointed out the flaws on the conception of such parks not only in terms of the linear conception of innovation, but also in terms of the closed perspective on this infrastructure. This “enclave” perspective neglected the importance of articulating science parks with other infrastructures and firms off park and the RIS in general.

In essence, a science park follows a science push perspective, assuming that knowledge production access will lead to innovation and its economic exploitation. In other words, and in line with the underlying linear conception of innovation, a science park would be a platform where the knowledge and basic research outputs of Universities would be tapped by firms that would undertake applied and experimental research and ultimately, innovate (Quintas et al., 2002). But even when considering the importance of networking, science parks are still implemented following a science push approach. Löfsten and Lindelöf (2005) state that it is assumed that providing the science park infrastructure and the knowledge base will be enough to enable firms to establish the necessary networks and develop. Westhead (1997) synthesized this perspective claiming that science parks were based on the assumption that innovation is a result of scientific research and that parks are the perfect “habitat” to catalyze the transformation of pure research into innovation and production. The poor results of different science parks, even though literature is focused in frontier and fast catching-up regions, have highlighted the need to balance the science push perspective with a demand pull consideration (Watkins-Mathys and Foster, 2006). If the return on R&D, especially, public R&D must be maximized, Watkins-Mathys and Foster (2006) state that governments need to pay more attention to entrepreneurship in the process of innovation and technology transfer. This is extensive to the promotion of technological spin-offs, to the attraction and clustering of external R&D initiatives (from multinationals but also from public and nonprofit institutions) and also to off-park firms. In follower regions, the demand pull consideration seems to us even more pressing since the regional economies specialization is usually characterized by industries locked in trajectories, with limited absorptive capacity. Adding to this, in lagging regions where R&D execution is imbalanced in favor of universities and other state-owned research centers, promoting knowledge transfer and exploitation of universities knowledge is even more important to accelerate the catching-up. Underlying this, the appropriate scale of resources is required and a major determinant of success and this depends on the dimension of academic installed capabilities and the effective access given to enterprises. The effort to aid the development of emerging sectors should lead to a concentration of resources rather than a profusion of initiatives of a wide sectoral spectrum.

Science parks may also carry an important role in the clustering of external initiatives which can be a major scope for RIS implementation in follower regions. Frontier regions have built RIS in a international context in which locations of R&D activities largely relied on endogenous initiatives. Since the 90s, foreign direct investment flows in R&D have increased significantly and changed their scope (e.g. Serapio and Dalton, 1999, Meyer-Krahmer and Reger, 1999, Kuemmerle, 1999, Gerybadze and Reger, 1999 and Hedge and Hicks, 2008). Even though multinationals global R&D investments are still mostly focused on developed countries (Meyer-Krahmer and Reger, 1999), these flows are now being extended to less developed regions (e.g. Indian ICT cluster in Bangalore - Kumar, 1996). The role of science parks in attracting these initiatives is a signaling one. Public driven R&D and the investment in higher education as allowed some follower regions to develop important human capital stocks. Follower regions thus may possess excellence in some fields and also a significant cost advantage, creating the perfect scenario for attracting multinationals R&D laboratories. The demonstrating research excellence may be accomplished through science parks NBTFs success, signaling the scientific regional capacity and the economic potential of the knowledge base. This is the insight we derive from the Cambridge science park evolution. According to Druille and Garnsey (2000) both the Cambridge Science Park and the Grenoble infrastructure first succeeded in creating an innovative milieu, providing incentives to entrepreneurs to stay in the region and there develop their NBTFs. After the success of these NBTFs and of their solid scientific capabilities, multinationals perceived the excellence of regional research centers and further established high tech industries' R&D corporate centers (e.g. Xerox, Oracle, Toshiba, Microsoft, AT&T), in order to augment their knowledge base and capabilities (Druille and Garnsey, 2000). In a more moderate way, even public or non-profit R&D institutions are beginning to exploit the advantages of outward locations, following the same principle of home base augmenting and exploiting opportunities generated by high skilled human capital reservoirs in follower countries and regions.

Thus science parks role may actually comprise different dimensions than the usually assessed and be an important instrument in the core of a follower region innovation strategy.

Additionally, science parks may also contribute to the building up of social capital that will facilitate future cooperation between agents.

In sum, some of these aspects are common to both frontier and follower regions. However, follower regions structural deficiencies imply that the success of science parks in creating NBTFs is dependent upon demand pull policies creating the technological market for them. Furthermore, science parks may in follower regions convey a larger role in interlinking and articulating regional infrastructures, promoting the technological transfer from universities to the regional economy as a whole. Finally, besides signaling competences and attracting FDI R&D, science parks may constitute the bridge to join universities, firms and enhance social capital in terms of cooperation and interactions density, a deficitary aspect of more fragile Regional innovation systems. The functions of S&T parks differ according to different regional developmental goals encompassing the nurturing SMEs or the incubation of NTBFs, promoting commercial R&D by universities and enhancing technology transfer, attracting private R&D companies, exploiting universities knowledge resources and patent portfolios, serving as a prime location for high tech enterprises, managing or facilitating venture capital access.

3. Cluster analysis

Cluster analysis, also called segmentation analysis aims to pinpoint homogeneous subgroups of cases in a population. Cluster analysis seeks to identify a set of groups which both minimize within-group variation and maximize between-group variation. In this paper we aim at identifying common characteristics across a pool of 55 affiliated members of APTE (ES), UKSPA (UK) and TECPARQUES (PT) and use this information to analyze which distinctive features may help us fine tune the concept as well as identify elements that are crucial to the S&T park success in serving as a true lever of structural change and technological interface within a regional Innovation System. We execute these statistical procedures, further detailed in the subsection below, using two sets of variables comprising physical characteristics such as area or location as well as functional characteristics in line with the functions a S&T park can deliver to act as a lever of structural change and a pivot within the RIS.

3.1 Sample

Our sample comprises a total of 55 S&T parks located in Spain (24), Portugal (8) and in the UK (13). For each of these infrastructures we retrieved and constructed a set of categorical variables based on information collected from the Reports and publications by APTE, TECPARQUES and UKSPA as well as from the websites of each of parks. In particular, our set of variables comprises 17 features including:

- infra-structural characteristics: country, urban location, proximity to the University, occupancy rate, main promoter, number of promoters, area, area for enterprises location besides incubation;
- functional characteristics: incubation, technology transfer programs and technology transfer offices (TTO), patent offices, explicit commercial R&D projects developed by Universities, presence of private R&D firms, venture capital enterprises and scientific domain of specialization.

In line with the goals of this paper, we proceed in the following sub-section with a description of statistical procedures used before presenting and analyzing the results from the cluster analysis.

3.2 Statistical procedures

There is a wide set of clustering methods available and the selection depends upon the characteristics of the sample and the goals of the study. In this paper we aim at grouping a set of S&T Parks in order to identify distinctive features that may help, on one hand, precise the concept and on the other hand pinpoint features that are either associated to a higher success (roughly measured by occupancy rate) or a potential dynamo role within a RIS. In this sense, we aim at identifying homogeneous groups using cluster analysis.

There is a wide range of methods for cluster analysis. In this paper we opted to use SPSS TwoStep cluster procedure which is more adequate to handle categorical data and simpler binary data (Chiu et al., 2001). This method is based on a scalable cluster analysis algorithm which groups observations into clusters based on a nearness criterion. The algorithm applies a hierarchical agglomerative clustering procedure in which individual cases are successively combined to form clusters whose centers are far apart. We opted to use log-likelihood distance instead of Euclidean distance because the former is more adequate to deal with datasets of categorical variables. The TwoStep cluster implements the algorithm in two steps.

Step 1: Pre-cluster

Pre-cluster consists on a sequential clustering approach where records are individually analyzed and a decision to merge to a previously formed cluster or to start a new cluster is based on the compliance with a threshold distance. In this stage, the algorithm forms pre-clusters, constructing a modified cluster feature (CF) tree (Zhang, Ramakrishnon, and Livny, 1996). The cluster feature summarizes information on a given cluster and the cluster feature tree consists of nodes further decomposed into a number of leaf nodes and leaf entries. A leaf entry represents a final sub-cluster. Each entry is recursively guided by the closest entry in the node to find the closest child node, and descends along the CF tree. Upon reaching a leaf node, it finds the closest leaf entry in the leaf node. If the record is within a threshold distance of the closest leaf entry, it is absorbed into the leaf entry and the CF of that leaf entry is updated. Otherwise it starts its own leaf entry in the leaf node.

Step 2: Cluster

In this step, the algorithm used the pre-clustering information resulting from step 1 and groups the set of pre-clusters using an agglomerative hierarchical clustering method into a number of clusters compatible with the information of Akaike Information Criterion (AIC).

Finally, w*e validated our analysis following* three basic criteria:

- *Cluster size: accordingly, the clusters retrieved* should include enough cases to be meaningful; otherwise it would indicate that the researcher had predefined too many clusters. Also a cluster very large may indicate that too few clusters have been requested;
- *Meaningfulness*. As in factor analysis, ideally the meaning of each cluster should be readily intuited from the constituent variables used to create the clusters.
- *Criterion validity*: we used cross tabulation of the cluster id numbers by other variables known from theory or prior research to correlate with the concept which clustering is supposed to reflect should in fact reveal the expected level of association.

And to increase certainty regarding the robustness of our results we applied Kruskall-Wallis Chi-square test to assess the significance of the differences between the clusters retrieved (see annex).

3.3 Cluster analysis: results and comments

The Akaike Information Criterion reaches its lowest level for a set of 6 clusters indicating this to be the best solution in statistical terms for our cluster analysis (see annex 1). Hence, our cluster analysis retrieves 6 clusters which members we indicate in the following table.

Cluster 1	- Aston Science Park (UK) - Ciudad Politecnica de la Innovacion (ES) - Liverpool Science Park (UK) - Madan Park (PT) - Parc Cientific Barcelona (ES) - Parc d'innovació La Salle (ES) - Parque Cientifico de Madrid (ES) - TecMaia (PT) - UPTEC (PT)
Cluster 2	- Begbroke Science Park (UK) - Cambridge Science Park (UK) - Oxford Science Park (UK) - Parc Cientifico Alicante (ES) - Parque Cientifico y Tecnologico de Leganes (ES) - Parque Tecnologico de Ciencias de la Salud de Granada (ES) - TagusPark (PT) - University of Cambridge - West Cambridge Site (UK)
Cluster 3	- Avepark (PT) - Biocant (PT) - Coventry University Technology Park (UK) - Longhboroughs’s Science and Entreprise Park (UK) - Parque tecnologico de Asturias (ES) - Parque Tecnologico y Logistico de Vigo (ES) - Southampton Science Park (UK) - Tecnoalcalá (ES) - University of Warwick Science Park (UK) - Wolverhampton Science Park (UK) - York Science Park (UK)
Cluster 4	- Cambridge Research Park (UK) - Kent Science Park (UK) - Liverpool Innovation Park (UK) - Longbridge Technology Park (UK) - Madeira Tecnopolo (PT) - Parc Cientifico-tecnologico de Gijon (ES) - Parc Tecnologic del Vallés (ES) - Parkurbis (PT) - Parque Balear de Innovacion e Tecnologia (ES) - Parque Cientifico e Tecnologico Albacete (ES) - Parque Tecnologico Castilla y Leon (ES) - Parque Tecnologico Walqa (ES) - Parque Tecnoloxico Galicia (ES)

Cluster 5	- Aberdeen Science and Energy Park (UK) - Aberdeen Science and Technology Park (UK) - Manchester Science Park (UK) - Cartuja 93 (ES) - Chesterford Research Park Cambridge (UK) - Colworth Science Park (UK) - Cranfield Technology Park (UK) - Edinburgh Technopole (UK) - Parque Tecnologico de San Sebastian (ES)
Cluster 6	- 22@barcelona (ES) - Parque Tecnologico de Álava (ES) - Parque Tecnologico de Andalucia (ES) - Parque Tecnologico de Bizkaia (ES) - Valencia Parc Tecnologic (ES)

Using this segmentation of our sample, we apply descriptive statistics in order to identify the main distinctive features between clusters and derive insights. In annex we present the cross tabulation results of our analysis, presenting here only a short summary and our analysis.

- Cluster 1:

In general, the parks assigned to this cluster comprise relatively small infrastructures (8 out of 9 cases are below a 10 ha area) and all located in proximity to the university in urban perimeter. With the university as the main promoter in 6 out of 9 cases and as a co-promoter on the remaining 3, these parks follow a model closer to the Science Park concept. A stronger focus is placed on a model that functions as an extension to the University and where the presence of companies is overall restricted to start-up companies in incubation. 7 out of 9 of these parks have no area for enterprise location, apart from start-up companies. The proximity to University and the actual model underlying most of these parks provides a reasonable deployment of University R&D units or shared access to R&D laboratories. The underlying model of these parks focusing more on the university perspective than on technology transfer has repercussions on the functional features provided. Technology Transfer offices are available in less than half of these 9 parks and commercialization of R&D is absent on 7 of them, a number identical to the absence of patent offices. Venture capital is not available on site on any of these 9 parks which constitutes, mainly in laggard regions, an important constraint on start-up development.

In sum, the parks of cluster 1 are closer to the Science Park concept, not contemplating space for the installation of private companies besides the ones incubating and being mostly led and focused on universities. Occupancy rates are high but this conception follows a University-centric perspective which puts a lower emphasis on technology transfer and on the linkages to private companies hence diminishing the technology pivoting role of the Science Park, probably reducing the economic valorization of scientific inputs and consequently the actual impact of these parks within the RIS.

- Cluster 2

Within our second cluster of parks we have a set of parks which constitute a reference in terms of Science and Technology Parks (e.g. Cambridge Science Park, Oxford Science Park). In terms of infrastructures the majority of these 8 parks are located in proximity to the University but outside the urban perimeter, comprising an area bigger than 40 ha in 6 out of 8 cases. The infrastructural characteristics along with the functional features make of these facilities a distinct model in relation to the other clusters which we find to be closer to the S&T park concept. With the university as main promoter (in most cases actually the only promoter), these parks combine an area of University R&D units with a large space for companies installation capable to accommodate both incubating companies as well as large companies R&D centers or high tech small production units. We observe in these parks a higher degree of specialization in terms of scientific domain and the highest occupancy rates and the highest concentration of both University R&D resources and private companies R&D resources. All of the 8 S&T parks have technology transfer programs and offices and some have instituted patent offices. Most importantly, 6 out of 8 cases provide direct commercialization of R&D which means that the university sells its expertise to private companies in line with one of the characteristics of the successful models of Stanford and MIT in the US. Nevertheless, unlike these two examples, the overwhelming majority of parks in our sample have no on site operating venture capital provider which severely constrains technological entrepreneurship and start-ups growth.

In sum, cluster 2 comprises a set of 8 parks that in our opinion are closer to the S&T park concept and which infrastructural and functional features are more adequate to enhance the technology transfer and promote an accelerated structural change process, particularly important in follower and laggard regions. This model, coupled with an adequate scale of R&D capabilities and the commitment to promote technology transfer, is likely to have a higher impact in shaping and dynamizing the RIS and also contribute to the attraction of multinational companies R&D centers.

- Cluster 3

The parks grouped under cluster 3, in relation to the previous 2 clusters, constitute a group more heterogeneous. In terms of infrastructures and facilities these parks tend to be outside the urban perimeter and in 7 out of 11 cases also distant to the university. Again the university is one of the main promoters but now municipalities are also a major player in supporting and creating these places. With different sizes ranging from the less than 10 ha to above the 40 ha thresholds, the occupancy rate is generally high (above 75%). These parks have a large accommodation area for enterprises and an onsite incubator in more than 60% of the 11 parks. However, there are clearly distinct features that depart these parks from the ones in the previous cluster. The smaller scale of university R&D resources deployed combined with the higher distance to university indicates a smaller flow of scientific inputs to the parks activities. This is also associated with a smaller relative presence of private R&D units. Most of these parks have neither explicit technology transfer program nor patent office and R&D services are available only in a more technological rather than scientific sense (e.g. quality control instead of direct participation of university in private R&D projects). But, in what concerns risk capital 3 of these parks have on site providers. These characteristics are closer to a model of a technological park with some science but which the focus is on accommodating high tech and medium high tech companies in an excellence infrastructure rather than on promoting the articulation of university's resources with private companies, fostering technology transfer and stimulating a knowledge market. The maximization of synergies among tenants have led to a higher degree of scientific specialization of these parks.

In sum, these facilities are closer to the concept of technological park, though in some cases aiming to evolve into a S&T park. The role of these parks within a RIS may be enhanced through a closer articulation with universities and a stronger emphasis on technology transfer.

- Cluster 4

The set of parks grouped in cluster 4 present important distinguishing features in relation to the previous clusters. The different model is perceivable in the dropping of the term "science" in almost all the labeling but it is evident when analyzing the characteristics. These parks are developed relatively distant from universities and city centers and occupy an area either small (4 cases below 10ha) or very large (8 cases above the 40ha threshold). The concept underlying these facilities seems closer to a somehow selective business park that aims to attract high tech companies, mostly in territories where local economic activity is scarce on that particular typology. This, associated with an emphasis on technology may account for the low occupancy rates registered on most of these parks. These parks are also promoted mainly by other promoters (e.g. private or government development agencies) than universities, being rooted in places where scientific capabilities are far from abundant. Adding to this, the dispersion of resources through a miscellaneous focus, the absence of incubation facilities in 10 out of 13 parks, a reduced number of University R&D units and also a small and questionable number of private R&D contribute to a possible illusory label of business parks and creates a distraction in terms of focus that instead of inducing innovation, actually leads to a set of vacant business parks that detract the location of less knowledge intensive businesses as well as it is not sufficiently attractive for knowledge intensive firms. Hence, in this cluster we find that, apart from some exceptions (e.g. Liverpool Innovation Park), the absence of an adequate scale of R&D resources is determinant to the parks success and importance in the RIS. The misconception of some of these parks not only in terms of resources added but also in terms of the regional characteristics leads to low occupancy rates, low levels of regional economic impact and to a small return from publicly financed projects.

- Cluster 5

Within this cluster we grouped 9 parks, many of them with the “science” label. Comprising parks of relatively large areas (6 above 40ha and none below 10ha), these have been built usually in periphery and at some distance of university’s. Again the university does not appear as the main promoter but unlike in cluster 4, the university now is a co-promoter in many of the cases. In comparison to previous clusters, these parks have been created earlier in time, having in general no particular scientific/economic activity focus but registering a high occupancy level. In terms of R&D capabilities on site we observe an intermediate level of University R&D resources being deployed as well as some private R&D performed by tenant companies. Nevertheless, these infrastructures appear not to perform technology transfer (observed in 8 out of the 9 parks), not stimulate the commercial linking of university’s R&D resources to private companies (8 out of 9 have no explicit program for R&D services commercialization) and none of the parks has a patent office or a privileged access to risk capital. Thus, despite the upgrade in relation to the parks in cluster 4 these parks’ current model still lags behind the one in cluster 2. In relation to cluster 3, there are some similarities in model with these parks differing in terms of area (usually bigger), proximity to university (these parks are close to the university) and promoter (university is not the main promoter) and also in terms of R&D resources. Cluster 5 parks have a higher concentration level of R&D resources, constituting technology parks with more knowledge intensive activities, partially also justified by the constext of being inserted in a region with an economic structural profile richer in knowledge-intensive activities.

- Cluster 6

If we reduce the number of cluster to 5, this cluster would be merged with cluster 5. The members of this cluster are parks that have a higher rate of R&D transfer programs and an intermediate level of R&D resources but have a considerably lower occupancy area. Nevertheless, the functional similarities to the previous cluster are significant. However, the distance to university, the high importance of municipalities as main promoter, the lower specialization level (miscellaneous approach) and the urban location of 40% of the parks were sufficient for Akaike's information criterion to indicate the presence of 6 clusters.

The lower performance in terms of occupancy may be related to, on one hand, the deployment of only an intermediate level of R&D resources and not in all parks and to the more urban location that heightens accommodation costs to companies.

From our analysis and synthetic comments we conclude that in order to have a significant effect and justify the investment, the conception of a S&T park must ensure the deployment of a large scale of R&D resources and must be supported by a university or universities with strong scientific capabilities, being also advisable to concentrate resources along some specific scientific domains. The absence of critical mass and of an emphasis on technology transfer and on establishing active links with the industry diminishes the importance of an S&T parks as a structuring interfacing and R&D enhancing element within the RIS. Furthermore, our cluster analysis indicates that according to the concept of S&T park presented in the previous sections and the functions associated to this kind of facilities, there has been a proliferation of parks which misconception leads to a low performance and a small multiplier effect, especially, from public or ERDF funding and a low level contribution to the structuring of a RIS being an additional element misplaced in already feeble RIS of follower regions.

4. Conclusions

S&T parks constitute an important instrument in the diffusions of technology and in maximizing social return on public R&D. However, the narrow and closed approach underlying science parks implementation restrains its potential in contributing to the upgrading of the regions economy's technological specialization pattern. In follower facing a process of structural change, science parks may account as a catalytic device bridging science to economy, fostering interaction and the emergence of new knowledge intensive sectors. In a modern and integrated conception of innovation policies, we proposed that science parks be articulated with a range of other organizations, creating synergies and enhancing the returns on R&D.

The success and structural change impact of S&T parks depends upon the capacity to deploy a sufficient amount of R&D resources, emphasizing the commercialization of R&D, active linkages between Universities and Industry and providing an evolutionary framework that adapts the S&T park to the new reality of globalization in order to exploit R&D internationalization. This may be an important cathing-up opportunity for follower regions, also interested in increasing the return on public-led R&D but that have tended to disperse resources and to pursue dreams unmatched by internal capabilities. S&T parks can be important tools in developing RIS but are not a panacea and their result depends on the scale of R&D deployed or available to the S&P tenants.

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Annex 1: Determination of optimal number of clusters (AIC's results)

Number of Clusters	Akaike's Information Criterion (AIC)	AIC Change[a]	Ratio of AIC Changes [b]	Ratio of Distance Measures [c]
1	1586,557			
2	1497,487	-89,070	1,000	1,506
3	1461,856	-35,632	,400	1,018
4	1428,064	-33,791	,379	1,095
5	1403,278	-24,786	,278	1,178
6	1392,815	-10,463	,117	1,322
7	1401,932	9,116	-,102	1,197
8	1421,084	19,152	-,215	1,059

a. The changes are from the previous number of clusters in the table.

b. The ratios of changes are relative to the change for the two cluster solution.

c. The ratios of distance measures are based on the current number of clusters against the previous number of clusters.

Annex 2: Descriptive statistics

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Country	0	3	1	2	2	0	0	8
	1	4	3	3	7	2	5	24
	2	2	4	6	4	7	0	23
Total		9	8	11	13	9	5	55

Note: 0- Portugal; 1- Spain, 2- UK

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Location	0	8	1	0	0	2	2	13
	1	1	7	11	13	7	3	42
Total		9	8	11	13	9	5	55

Note: 0- urban location; 1- outskirts location

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Proximity to University	0	9	7	4	1	9	1	31
	1	0	1	7	12	0	4	24
Total		9	8	11	13	9	5	55

Note: 0- proximate to a University; 1- distant to the University

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Date of creation	0	0	1	0	0	2	0	3
	1	1	0	1	0	1	1	4
	2	0	0	0	1	3	1	5
	3	1	1	5	1	2	2	12
	4	1	6	1	2	1	1	12
	5	5	0	4	7	0	0	16
	6	1	0	0	2	0	0	3
Total		9	8	11	13	9	5	55

Note: 0- before 1980, 1- between 1981 and 1985; 2- between 1986 and 1990, 3- between 1991 and 1995, 4- between 1996 and 2000; 5- between 2001 and 2005, 6- after 2005.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Main promotor	0	6	6	9	0	0	0	21
	1	1	0	2	0	5	4	12
	2	1	1	0	5	1	1	9
	3	1	1	0	8	3	0	13
Total		9	8	11	13	9	5	55

Note: 0- university, 1- municipality, 2- other public agency, 3- others

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Number of promoters	0	1	6	2	7	0	0	16
	1	1	1	5	0	4	1	12
	2	3	1	0	1	0	4	9
	3	4	0	4	5	5	0	18
Total		9	8	11	13	9	5	55

Note: 0- none, 1- one, 2- two, 3- three or more.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
area	0	8	1	4	3	0	0	16
	1	1	0	2	1	1	0	5
	2	0	0	1	1	2	0	4
	3	0	1	2	0	0	0	3
	4	0	6	2	8	6	5	27
Total		9	8	11	13	9	5	55

Note: 0- less than 10ha, 1- between 10ha and 20ha, 2- between 20ha and 30ha, 3- between 30has and 40ha, 4- above 40ha.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Incubation	0	7	6	7	3	3	5	31
	1	2	2	4	10	6	0	24
Total		9	8	11	13	9	5	55

Note: 0- presence of incubation facility, 1- absence of incubation facility.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Business park	0	2	8	11	13	9	4	47
	1	7	0	0	0	0	1	8
Total		9	8	11	13	9	5	55

Note: 0- includes business park area, 1- absence of business park area.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
University R&D units	0	2	0	6	7	0	2	17
	1	3	2	5	6	9	1	26
	2	4	6	0	0	0	2	12
Total		9	8	11	13	9	5	55

Note: 0- less than 5, 1- between 5 and 10, 2- above 10.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Private R&D units	0	6	8	8	8	9	4	43
	1	3	0	3	5	0	1	12
Total		9	8	11	13	9	5	55

Note: 0- presence of private companies R&D laboratories, 1- absence of private companies R&D laboratories.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Scientific Domain	0	2	3	1	0	0	0	6
	1	1	1	3	1	2	0	8
	2	1	0	2	0	1	0	4
	3	0	0	2	0	0	0	2
	4	5	4	2	12	6	5	34
	5	0	0	1	0	0	0	1
Total		9	8	11	13	9	5	55

Note: 0- physics/ICT, 1- Health/Biotech, 2- Energy/Environmental Sciences, 3- Other, 4- Miscellaneous, 5-Design.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Explicit R&D commercialization	0	2	6	4	1	0	0	13
	1	7	2	7	12	9	5	42
Total		9	8	11	13	9	5	55

Note: 0- explicit sale of R&D services by the university, 1- absence of indications regarding explicit sale of R&D services by the university.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
TTO	0	4	8	3	1	1	2	19
	1	5	0	8	12	8	3	36
Total		9	8	11	13	9	5	55

Note: 0- presence of a technology transfer office or a similar program/office, 1- absence of technology transfer function.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Pat Office	0	2	2	1	0	0	0	5
	1	7	6	10	13	9	5	50
Total		9	8	11	13	9	5	55

Note: 0- presence of a patent office or a similar program/office to manage IPR, 1- absence of a patent office.

		TwoStep Cluster Number						Total
		1	2	3	4	5	6	
Venture Capital	0	0	0	3	0	0	1	4
	1	9	8	8	13	9	4	51
Total		9	8	11	13	9	5	55

Note: 0- presence of a risk capital office or a similar program/office, 1- absence of risk capital institution.

Annex 3: Kruskall-wallis Chi-Square Test results

Test Statistics[a,b]

	Proximidade à univaersidade	taxa ocupação	Ano de criação	promotor principal	nº de promotores
Chi-Square	38,000	11,547	5,925	6,550	4,017
df	3	3	3	3	3
Asymp. Sig.	,000	,009	,115	,088	,260

a. Kruskal Wallis Test

b. Grouping Variable: Ward Method

Test Statistics[a,b]

	área	incubação	AAE	unidades de I&D Univ	Private R&D units	Domínio cientifico
Chi-Square	13,268	9,091	32,484	8,159	26,000	4,997
df	3	3	3	3	3	3
Asymp. Sig.	,004	,028	,000	,043	,000	,172

a. Kruskal Wallis Test

b. Grouping Variable: Ward Method

Test Statistics[a,b]

	Prestação explicita de srviços I&D	TTO	Pat Office	Cap risco	Ward Method
Chi-Square	9,201	12,502	6,390	,000	38,000
df	3	3	3	3	3
Asymp. Sig.	,027	,006	,094	1,000	,000

a. Kruskal Wallis Test

b. Grouping Variable: Ward Method

Test Statistics[a,b]

	País	localização
Chi-Square	7,269	17,753
df	3	3
Asymp. Sig.	,064	,000

a. Kruskal Wallis Test

b. Grouping Variable: Ward Method