SCIENCE AND TECHNOLOGIC PARKS IN REGIONAL INNOVATION SYSTEMS: THE CASE OF FOLLOWER REGIONS

Alexandre Almeida
University of Porto – Faculty of Economics
alex.fep@gmail.com

Cristina Santos
University of Porto – Faculty of Economics
cris.fep@sapo.pt

Mário Rui Silva
University of Porto – Faculty of Economics
mario.rui.silva@ccdr-n.pt

Abstract

Follower (in EU terms, convergence) regions face the challenges of structural change and of strengthening regional innovation capabilities through the consolidation of Regional Innovation Systems (RIS). Following the successes of Silicon Valley, Grenoble or Cambridge, Science and Technology Parks (STP) have been built across Europe with very different outcomes. To add even more confusion, the concept of STP and of its functions in a RIS remains blurry. In this paper we aim to contribute to the literature on three levels. Firstly, we identify a set of functions of STPs in order to fine tune the concept. Secondly, we discuss the specific case of follower regions, addressing to what extent STP's functions are different in frontier and follower regions. Finally, we discuss the results of cluster analysis for 55 STP located in Portugal, Spain and the UK aiming to uncover patterns that reveal differences between STPs located in frontier and follower regions regarding the compliance with the identified functions and their performance.

Keywords: Science and Technology Parks, Regional Innovation Systems, Follower Regions

1. Introduction

The concept of Regional Innovation System (RIS) builds upon an integrated perspective of innovation, acknowledging the contribution of the knowledge production subsystem, the regulatory context and of the 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 and for this it is crucial to create platforms that foster interactions between academic research and the economy. Science and Technology Parks (STP) emerge as infrastructures designed to co-locate University research centres and highly innovative firms, creating an innovative milieu. The appealing conceptual contours along with the demonstration effects of success cases like Silicon Valley, Cambridge or Grenoble elevated STPs to the status of "panacea" and led a boom of STPs across Europe promoted by both universities and regional development agencies. This proliferation of STP has assumed different models with associated very different results that have raised doubts on the actual value added of these infrastructures. Despite this proliferation of STPs, the definition of STP and its functions within a RIS remains unclear in literature and also in practice. Furthermore, the role and characteristics of STP may need to be fine tuned when applied to follower regions and may, in some cases, prove inadequate as a policy tool.

In this paper we aim to contribute to literature on three levels. A first level regards the blurriness of definition. We attempt to fine tune the concept by proposing a functional definition that includes infrastructural and location features, as well as the availability of advanced support services, the involvement and the amount of resources allocated to the project. A second level of analysis focuses on the contribution of STP to the RIS, discussing the specificities associated with follower regions. In this particular case, we discuss which functions are more relevant in follower regions where STPs, more than an innovation-enhancing platform, works as a structuring element of the RIS. Finally, on a third level we apply our functional definition to a set of 55 STP across Portugal, Spain and the UK. This allowed us to construct a database and use cluster analysis to uncover patterns that reveal features that are particularly important in follower regions and also characteristics correlated with a better performance.

In line with these goals, we structured the paper as follows. In section 2 we review the literature on STP which highlights the profusion and blurriness of concepts. In section 3 we discuss the functions of a STP, distinguishing between the role and characteristics of STPs within a consolidated RIS of a frontier region and a structuring RIS within a follower region. In section 4, preceding conclusions, we use two-step cluster on a 55 STP dataset we perform cluster analysis on 55 STP located in Portugal, Spain and the UK. We also analyze the results, providing a brief characterization of each cluster and analyzing the different patterns across follower and frontier regions.

2. STP: literature review

2.1 STP: a concept yet ambiguous

The first STP dates back to 1950 and was established in Stanford, United States. Cambridge STP 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 STPs 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). This led to a profusion of definitions and misconceptions regarding STPs and given rise to a proliferation of sites labeled as STP but which lack the necessary elements to be an effective pivoting element within the RIS. In this subsection we review and synthesize some of the existing definitions of STPs.

The International Association of STPs 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 STP 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 STP Association (UKSPA provides a similar definition defining STP 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), STPs' 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 STP to the university's reservoir of technology.

UNESCO's definition states that a STP 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, STPs 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 STP 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 STPs 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 STP, 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 STP 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 STPs 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 STP 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 STPs (AURP) also stress the property dimension, stating that a STP (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 STP as “an infrastructural mechanism for transferring technologies from universities to firms”. Also focusing the infra-structural dimension, Phan et al. (2005) define STPs 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 STPs 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 STPs (Fukugawa, 2005) nor a clear perception of what is in fact the role of a STP within a RIS and, in particular, in the setting of a follower region.

2.2 The doubts on effectiveness

One of the main contributions of a STP is to enable a higher return on academic research through technology commercialization and transfer and through 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. However, the presence of business R&D activities within the park can generate a crucial increase in effectiveness. Business R&D will generate an impulse for academic research, acting for a more applied research and for collaborative research. As said before, co-location of academic and business research facilities could also allow some resource gathering effect. Following this line of thought, we have witnessed a boom of STPs during the 80s and the 90s (Bakouros et al., 2002). However, 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 STPs 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 STPs. Massey et al. (1992) characterized STP as high tech fantasies 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 STP concluded that there was no significant differences in terms of R&D intensity. More recently, Bakouros et al. (2002) in a rare analysis of STP effectiveness in a follower country concluded that STPs 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 STP 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 STP would supposedly convey on a region. As pointed out by Castells and Hall (1994) the low performance of STPs can be attributed to the low density of firms.

Nevertheless, though we must acknowledge that there have been poor results, other studies have confirmed that a STP can be an effective tool of regional development. Fukugawa (2006) states that NBTFs located on a STP have a higher propensity to participate in joint research with other institutions. Similarly, Löfsten and Lindelöf (2002) assessed positively the performance of Swedish STPs, 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 STPs.

Hence, the controversy is still ongoing. This controversy is justified by the coexistence of successful and unsuccessful cases. Successful cases have been better studied and are almost all located in frontier regions. Even, some comparative analyses in a dynamic perspective are available, like the comparison between Cambridge and Grenoble (Druilhe and Garnsey, 2000) or between Oxford and Grenoble (Lawton Smith, 2003).

The increasing doubts on the effectiveness of STPs along with different practical interpretations of what STPs are creates the need to precise the concept and to highlight the necessity of adapting it to the local context. In order to precise the definition of a STP we will systematize its possible functions within the regional innovation system (RIS).

3. A STP in RIS: a functional definition

Following Saviotti (1997), an innovation system can be defined as a set of actors and interactions that have as the main objective the generation and adoption of innovations. This definition recognizes that innovations are not generated just by individuals, organizations and institutions but also by complex patterns of interactions between them. So, within an innovation system we can define their elements, the interactions, the environment and the frontier. The concept of innovation system was born under the analysis of the National Innovation System (Freeman, 1987 and 1995; Lundvall, 1992; Nelson and Rosenberg, 1993).

The RIS concept is more recent and in great part derived from the former concept of National Innovation System. As referred by Cooke (2001), the recent idea of RIS results from some convergence between works of regional scientists, economic geographers and national systems of innovation analysts. RIS have its relevance based on the fact that proximity plays a major role on networks and interactions density; this fact is in general attributed to the tacit nature of a relevant part of knowledge. Tacit knowledge "is best shared through face-to-face interactions between partners who already share some basic commonalities: the same language, common "codes" of communication and shared conventions and norms…" (Asheim and Gertler, 2005, p. 293) The regional dimension also generates a more "focused" knowledge basis, as a cumulative result of the clustering of economic and innovation oriented activities. Asheim and Gertler develop analogous arguments and do not hesitate to stress that "the more knowledge-intensive the economic activity, the more geographically clustered it tends to be" (Asheim and Gertler, 2005, p. 291). A STP, by definition, implies a co-location of firms and of firms and other knowledge organizations. So, if effective, STP can be at the centre of a RIS building process, playing a major role on the provision of certain functions that an innovation system must insure. Edquist (2005), in his attempt to systematize functions and activities that an innovation system is expected to insure, considers a list of 10 functions, covering the fields of knowledge inputs provision, demand side factors, provision of constituent (e.g. organizations and institutions) of SI and support services for innovating firms. Adapting Edquist's list, we can consider central to the scope of functions of a STP those mentioned in following subheadings.

A) Provision of Research and Development (R&D)

Formal R&D activities are the main source of new knowledge creation. In a STP this function relies both in University R&D and Business R&D.

A1) Knowledge creation: University R&D

The presence of University research centres in STP is an extension of academic research but, at the same time, is potentially more applied, because co-location of University facilities and firms generates a closer perception of firms' technology needs. Universities have seen recognized the potential to function as a major input for innovation and STPs 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, 2005).

A2) Knowledge creation: Business R&D

Firms are the central organizations of the innovation system. STP stimulates R&D activities lead by firms, through demonstration and collaborative effects and by facilitating the access to technological inputs such as researchers and specialized equipments. In the opposite direction, the presence of firms potentially generates a demand pull rationale for academic research.

B) Networking

Networking is what distinguishes an innovation system from a simple collection of elements. In a broad sense, networking can include several mechanisms.

B1) Technology transfer

In absence of market failures, technology transfer would be a market transaction and it would be inappropriate to classify it as networking. STP frequently includes organizations called technology transfer offices (TTO). These are often seen under a linear conception of the innovation process. TTO are meant to favour knowledge transfer from universities or other research centers to firms. Even within this limited perspective, the co-location of academic research facilities and firms and the existence of brokerage entities such as TTO inside the campus of a STP favor technology transfer by reducing transaction costs. In the long run, TTO and organizations of that kind contribute to the building of market for knowledge.

B2) Networking (strictus sensus)

In innovation processes, networking correspond to a process by which knowledge is transferred through collaboration, cooperation and long term arrangements (OECD 2002, quoted by Edquist, 2005). The relevance of networking for innovation is usually associated to the reduction of uncertainty and to the transmission of tacit knowledge. In a STP, co-location of firms and of firms and the university or other research facilities favours interactions such as knowledge spillovers, informal networking such as interactive learning, formal networking such as R&D consortia, etc.). This perception of STP as 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 STPs across developed countries, in spite of increasing doubts regarding their actual effectiveness and value added.

STP can also enlarge networks by clustering external initiatives. As referred by Asheim and Coenen (2005), referring to the case of innovative activities based on analytical knowledge, the clustering of R&D laboratories of large firms and governmental research institutes in planned STPs normally located in close proximity to the universities can be seen as an example of a planned innovative milieu.

C) Creating and changing organizations

As pointed out by Edquist (2005), an innovation system must contain procedures for creating and changing organizations needed for the development of new fields of innovation, enhancing entrepreneurship and intrapreneurship, creating new research organizations and policy agencies.

A STP is itself an example of a complex organization devoted to the management of innovation. At the same time, STP often induces the creation or expansion of other non-profit organizations such as applied research centres and technology transfer offices. However, what really distinguishes a STP from University or other public-owned facilities is its role in creating, attracting and clustering firms.

C1) Creation of new firms

STP usually include incubating activities, through structured programs that include facilities, administrative and legal support and even access to financial instruments such as seed capital. Incubation of NTBF is favoured by this formal promotion and by demonstration and collaborative effects. STP is usually perceived as a milieu that favours the perception of new technological opportunities and its transformation into economic opportunities. Squiciarini's (2009) findings support for the existence of spillovers and for the positive role of incubators over those firms joining SPs very young.

C2) Clustering / attraction of external initiatives

An STP functions as an attractor for consolidated foreign / external firms that seek technologic inputs for their R&D activities. Also STP can attract external non-profit R&D activities. This function as "attractor" can have a major impact for the consolidation of a Regional Innovation System, especially if STP are able to cluster technology related activities.

The reasons why STP can functioning as "attractors" are probably more complex than the simple availability of technological inputs such as scientists, engineers or specific equipments and laboratories. One can think that STP will increase the external visibility of the region and signal the scientific and technological potential. In successful cases, this process is typically marked by increasing returns and becomes cumulative. According to Druille and Garnsey (2000) both the Cambridge STP 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).

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). Globalization of R&D activities conducted by the world leading firms is potentially increasing the role of STP as attractors of foreign initiatives.

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 other countries and regions.

D) Provision of consultancy services

The provision of business support services within a STP fosters business sophistication, especially for newly created firms. Business consultants that act inside an organization like a STP will be more aware about technological dimensions and will develop capabilities oriented to specific universes of firms such as those in their early stages.

The case of follower regions

The literature on STP that addresses the case of follower regions is quite scarce as results from our literature review. This fact stands in sharp contrast with the increasing popularity of this instrument among policy makers and the proliferation of STPs across Europe.

Follower regions are regions where the lower level of per capita GDP translates the structural deficiencies in systemic value creation through innovation. Follower regions have low levels of technological activities and need to increase their technological own effort. But, at the same time, these regions have a relative bias towards public R&D, mainly due to the weakness of business R&D and the low technological intensity of existing economic activities. This structural situation creates in some way a paradox: follower regions need a public push in order to increase technological levels and to break with "lock in" barriers generated by the fact that many of the economic activities do not induce the development of technological capabilities; but, at the same time, the risk of a low effectiveness of public efforts and academic research is higher than in frontier regions. Hence, the implementation of STP in follower regions will have, at this level, some additional difficulties/specificity[1].

In follower regions, a STP is a part of a necessary “public push” for R&D activities in order to break the inertia of the “lock-ins”. However, this “public push” must not follow a university-driven perspective but instead a systemic approach that aims to catalyze and the different territorial dynamics, namely, in terms of regional demand for technological inputs. A STP following a systemic approach will also contribute to focus resources on a reduced number of scientific domains / economic sectors. This need is more pressing in follower regions where resources (financial, economic and scientific) are far more limited than in a frontier region (e.g. Madeira spends 0,3% of GDP in R&D whereas Cambridge spend 4,25%). The scarcity of scientific resources, human capital and other technology intensive activities leads to a lower attractiveness. This has implications on the importance of the instrument STP being capable of effectively promoting start ups in new activities. Follower regions have not only a challenge of fostering innovation but also have more severe structural change needs. In frontier regions, STP can expect to attract external firms (both national and foreign firms) and, at the same time, stimulate start-ups and spin-offs. Follower regions have a more scarce presence of high-tech firms and entrepreneurial resources can be concentrated in sectors that generate a low demand for technological services and for knowledge. So, in what concerns entrepreneurial resources, follower regions have a severe challenge: they need to insure structural change and the emergence of new and more technology-intensive sectors; but, at the same time, proximity demand for new activities and other impulses to new entrepreneurship (like, for instance, intrapreneurship) are weaker than in frontier regions. This means that new entrepreneurship, through the creation of NBTF, must be a central target to STP in follower regions and will be crucial to the STP effectiveness. Low managerial skills of universities regarding technology transfer and NBTF’s support (Bakouros et al., 2002) together with flawed and linear conception of the innovation process (Quintas et al., 1992) may account for a lack of effectiveness in creating

[1] For a discussion on the specificities of follower regions in what concerns the implementation of a Regional Innovation System see Almeida, Figueiredo and Silva (2008).

NBTFs. So, STP in follower regions must be aware of the need to establish structured programmes to support NBTF, following successful international methodologies.

Second, follower regions structural deficiencies imply that the success of STPs in creating NBTFs is dependent upon demand pull policies creating the technological market for them. Proximity demand for new activities must include opportunities generated by public demand, implying a good coordination with the public sector[2]; this is also valid to frontier regions but is even more relevant for regions where a private demand for new products and services is weaker. Finally, 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. So, a well defined focus on a knowledge basis is needed, due to the scarcity of technological inputs.

As said in section 2.2, STP 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 an international context in which locations of R&D activities largely relied on endogenous initiatives. 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).

Follower regions, due to the lower level of income and the lower technology level, face a problem of lack of visibility and attractiveness, even though public driven R&D and the investment in higher education have allowed some follower regions to develop important human capital stocks and excellence in some scientific domains. In a global context in which often follower regions have a poor external visibility, a STP can signal the scientific potential of a follower region, hence contributing to the increase in external visibility of a region's potential and also to the attraction of multinationals' R&D and technology development centres.

The assessment on the effectiveness of STP as instruments for fostering innovation and structural change is far from being done. Besides the fact that many STP, namely in European countries, are of recent creation, two main set of considerations must be taken into account. The first one has to do with the vagueness of the STP concept. The second one relies on the different economic and social contexts in which the STP is

[2] For instance, e-government and both the health and the educational sectors make a strong demand for ICT.

implemented and, namely, on different challenges that the innovation system presents in frontier or follower regions.

We have attempted to precise the concept of STP by discussing its functions and its potential effectiveness in assuring these functions. In its minimal definition, a STP 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 STP 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, STPs are still implemented following a science push approach. Löfsten and Lindelöf (2005) state that it is assumed that providing the STP 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 STPs 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 STPs, even though literature is focused in frontier and fast catching-up regions, have highlighted the need to balance the science push perspective with demand pull considerations (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 policy makers and STP managers need to pay more attention to entrepreneurship in the process of innovation and technology transfer. So, facilities oriented for the creation of NBTF and the ability to attract external firms must be underlined.

Many European follower regions are making strong advances in their endowments of technological inputs but they still have a lack of real innovation systems because interactions between higher education and academic research outputs, on one hand, and technological activities of existing firms, on the other hand, are weak. However, STP in follower regions can be seen as a major contribution to the consolidation of a RIS and, in doing so, as a major impulse to structural change. In order to be successful in that perspective, STP should integrate in its conception the functions of promoting university technological spin-offs, and attracting and clustering external R&D initiatives (from multinationals but also from public and nonprofit institutions). In follower regions, demand pull mechanisms are weaker since the regional economies specialization is usually characterized by industries locked in trajectories with limited absorptive capacity. So STP activities should include some public support in order to create and attract new economic activities.

Furthermore, STPs may in follower regions convey a larger role in interlinking and articulating regional infrastructures. 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 STPs with other infrastructures and firms off park and the RIS in general.

Table 1. The functional interpretation of an STP in the context of a follower region

Functions / Caracteristics	Contribution for the (Regional) Innovation System	Specificities for "follower" regions
Knowledge creation: University R&D	Presence of University research centres in STP is an extension of academic research but, at the same time, is potentially more applied; creation of technologic opportunities following a technology push rationale; closer perception of firms' technology needs.	Follower regions must increase substantially their own technological effort. However, there is a clear bias towards public and academic R&D. Because of the weakness of demand pull rationale, academic R&D is often made under scientists' bottom up agendas, neglecting strategic goals and valorisation opportunities. So, STP contributes to the need of a "push" for R&D activities but, at the same time, can contribute to a more strategic oriented and more applied effort for academic R&D.
Knowledge creation: Business R&D	STP stimulates R&D activities lead by firms, through demonstration and collaborative effects and by facilitating the access to technological inputs such as researchers and specialized equipments.	In follower regions, firms' access to technological inputs is often limited by an information and assessment gap. The STP offers information and access to scarce technological inputs as well as an innovative milieu that stimulates firms to develop their internal R&D capabilities.
Technology transfer	STP favours technology transfer and interactive learning. STP can promote a market for knowledge, reducing transaction costs.	Knowledge market and technological services market are barely existent in follower regions. STP can be a major impulse to fill those gaps, bridging science and knowledge creation to firms technological needs.
Networking	Co-location of firms and of firms and the university favours interactions (knowledge spillovers, informal and formal networking such as R&D consortia).	In follower regions, density of interactions is lower, with an absence of private brokers. So, STP function as a networks promoter is crucial.
Creation of new firms	Incubation of NTBF is favoured by formal promotion and by demonstration and collaborative effects. STP are usually seen as a milieu that favours the perception of new technological opportunities and its transformation in economic opportunities. Creation of NTBF is a main impulse to structural change.	In follower regions, structural change challenges are much more severe than in frontier regions. Through a structured and publicly supported programme for incubating new technological firms, STP can provide an emergent entrepreneurial basis to new sectors and overcome "lock in" effects coming from former entrepreneurial resources.
Clustering / attraction of external initiatives	An STP functions as an attractor for consolidated foreign / external firms that seek technological inputs for their R&D activities. Also STP can attract external non-profit R&D activities.	In follower regions the STP can signal the scientific potential of the region, in a global context were often follower regions have a poor external visibility. However, in the new context of R&D globalization, these regions can present considerable cost advantages that may attract external R&D centres. Additionally, besides

		attracting companies and other external players, the STP can actively seek to cluster firms and resources around an external anchor.
Business support services	The provision of business support services within a STP fosters business sophistication, especially for newly created firms. Business consultants are more aware of technological aspects.	The incidence of services provided by the STP or public agencies has to be larger since business services market (and in particular KIBS) is less organized and extended in follower regions.
Common infrastructures	STP generates some agglomeration economies through the existence of common infrastructures and amenities. High quality, low building construction ratio.	No specificity for follower regions
Land for business location	STP provides land for R&D centres of firms and for NTBF in its early stages.	Besides R&D centres and NTBF, STP in follower regions may also agglomerate medium high and high tech production facilities.
Restricted access / focus	Restricted to knowledge intensive activities. Some sectoral focus or scientific domain focus can generate a certain degree of specialisation or related diversity, favouring interactions.	In follower regions, because R&D activities and technological firms are fewer, STP can present a more hybrid set of sectoral or scientific priorities. Nevertheless, STP should promote selectivity in order to concentrate the few existing resources around a related variety of activities.
Community involvement	STP's contribution for RIS will be increased by the involvement of other players other than University and firms located within the park. Involvement of local or regional governments and of external non-profit agencies can make of the STP an important node of the RIS.	In follower regions there is a higher community involvement in the promotion of these parks. In fact, given the low level of demand and the fewer scientific resources, the divide between university's and the economy is greater. Hence, STPs are usually promoted by regional authorities hoping to accelerate structural change. The STP, besides a node within the RIS, becomes a fundamental structuring element for public policies.

4. Uncovering patterns across STP: correlating performance, functions and regions

In the preceding sections we have proposed a functional definition for STP that combines features relevant to its role in the RIS. In this section we aim at uncovering some patterns that characterize STP across Europe. In particular, we apply cluster analysis on a dataset of 55 STP located in Portugal, Spain and the United Kingdom. Our sample was built based on the information published by STP's national associations regarding its affiliated (TECParques, APTE and UKSPA). We retrieved information on a set of proxies for each of the functional characteristics as well as locational and performance proxies that we match in the next table.

Table 2. Identifying proxies to the functions of an STP and to other location/infra-structural features

Functions / Caracteristics	Variable for cluster analysis	Comments
Knowledge creation: University R&D	Number of academic R&D units located in the park	Number of researchers not available in many cases
Knowledge creation: Business R&D	Presence of R&D centres of private companies	Number of researchers and of firms not available in many cases
Technology transfer	Co-location of TTO and/or formal program for transferring technology Commercialization of Universitarian	

	R&D	
Networking	Scientific/sectoral domain focus Number of sectors with 20 or more firms	Focus on specific scientific or sectoral domain favours interactions
Creation of new firms	Existence of incubators with technological entrepreneurship support programs	
Clustering / attraction of external initiatives	Number of well known FDI / Foreign agencies	A well established STP functions as an attractor for other companies wishing to tap that knowledge/innovation reservoir.
Business support services	Patent offices Venture capital	Advanced services
Land for business location	Total area	Area Park
Micro location	Proximity to the University Urban location	
Community involvement	Main promoter Number of co-promoters	Different kind of promoters Universities, Local governments, Public Agencies, others
Period of operation	Time period (years) since creation	STP have long maturation periods for what concerns firm's presence
Region	Type of Region % R&D Expenditures on GDP	We consider three categories based on the development level: convergence, phasing out / phasing in, competitiveness.
Country	Country	Characteristic "Country" will be relevant for clusters composition if the National Innovation System effect is strong.
Effectiveness	Occupancy rate Total number of firms	No standardized and widely available measure of innovative output is available. Nevertheless, the quality of tenants can be inferred from their economic activity.

4.1 Methodological considerations: 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.

Our sample comprises a total of 55 STPs located in Spain (24), Portugal (8) and in the UK (23). 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 (SP), TECPARQUES (PT) and UKSPA (UK) as well as from the websites of each of parks. Variables are those indicated in Table 2, and as much as possible they capture the spectrum of functions and other characteristics of STP.

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 STP 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 Two Step 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 Two Step 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 appendix).

4.2 Cluster membership results: descriptive analysis

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 the following 6 clusters (see table 3).

Table 3. Cluster membership

Cluster 1	Cluster 2
- Aston STP (UK) - Ciudad Politecnica de la Innovacion (ES) - Liverpool STP (UK) - Madan Park (PT) - Parc Cientific Barcelona (ES) - Parc d'innovació La Salle (ES) - Parque Cientifico de Madrid (ES) - TecMaia (PT) - UPTEC (PT)	- Begbroke STP (UK) - Cambridge STP (UK) - Oxford STP (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	**Cluster 4**
- 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 STP (UK) - Tecnoalcalá (ES) - University of Warwick STP (UK) - Wolverhampton STP (UK) - York STP (UK)	- Cambridge Research Park (UK) - Kent STP (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	**Cluster 6**
- Aberdeen Science and Energy Park (UK) - Aberdeen Science and Technology Park (UK) - Manchester STP (UK) - Cartuja 93 (ES) - Chesterford Research Park Cambridge (UK) - Colworth STP (UK) - Cranfield Technology Park (UK) - Edinburgh Technopole (UK) - Parque Tecnologico de San Sebastian (ES)	- 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 are a small scale operation, mostly restricted to NBTF. 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 terms of performance and also the potential impact on the RIS we observe that the fact that these facilities are restricted to small NBTF, mostly university spin-offs limits its impact. In most cases, occupancy rate is relatively high and the type of tenants is, in the vast majority, operating in medium-high or high technology sectors. 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 STP. Though the scale may be adequate across regions on different stages with a good university, the economic valorization of scientific inputs and consequently the actual impact of these parks within the RIS seem to be limited. These parks follow mostly a university-driven perspective lacking the systemic approach that is of utmost importance to a significant contribution to the consolidation of a RIS in a follower region setting. Nevertheless, this can be a good starting point for follower regions, namely when compared to the more extensive approach of the parks of cluster 3 since the pressure to occupy land has led, in some cases, to a loss of focus and to a degradation of standards in follower regions where high tech clusters of firms are inexistent.

- 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 STP, Oxford STP). 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 STP 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 STPs 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. We also observe that these parks are located in regions with strong R&D investment level (the NUT2 average is 2.4% of the GDP, with Cambridge reaching 4.25%). These capabilities and the awareness that, for instance, Cambridge University's STP gathered led to the attraction of several multinationals R&D centres that created a cumulative effect on the consolidation of the RIS. In our analysis, it is clear that this cluster of parks is the one which has attracted more and more significant FDI. These are also parks located in frontier regions or fast catching-up followers that have opted for concentrating resources around a narrow set of scientific fields and in a close association with private companies. Hence, the STP of cluster 2 gather the best examples of STP accroos Europe both infucntional terms but also in terms of effectiveness.

- 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 has led to a higher degree of scientific specialization of these parks.

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

This cluster of parks is an example of the attempt to use STP to structure RIS in follower regions with weak technological capabilities and undergoing structural change processes. This is the case of Norte and Centro regions of Portugal or Galiza in Spain where STP have been used in moderate success. Though some of these initiatives are recent and a STP takes a long time to mature, we observe that these STPs lack a strong and effective commitment of Universities in deploying R&D resources. Furthermore, as we would expect in a follower region, the focus on a university driven perspective instead of a systemic approach has conducted to a low attractiveness both for local and foreign firms. Unlike STP of cluster 1, the approach here was based on a more extensive conception with the deployment of these parks in a large area of terrain. Despite the scientific quality of some research units (e.g. in Avepark we have the European Excellence Centre for Tissue Engineering and Regenerative Medecine with 200 researchers from 13 countries and state-of-the-art facilities), in the context of follower regions with a thin layer of more knowledge intensive activities and with a low demand for technology this approach may be less adequate than the approach followed in cluster 1. The pressure to occupy land and justify the public push has led some of these STP to downgrade and loosen the focus to increase occupancy. In contrast, parks in cluster 5 that follow this same perspective reach a far greater level of success in terms of occupancy and the technology intensiveness of tenants. However, not only the R&D level of those regions in cluster 5 is superior (R&D investment averages up to 2,9% of GDP), but also regional high tech clusters of firms are denser, creating a sufficient demand pull effect. STP of cluster 3 constitute an example of how a public push disregarding a systemic conception may, in a context of a follower region with scarce scientific resources and low percentage of high tech firms, be inadequate as a first stage of public push. These types of parks should function as second or third stage interventions, following the consolidation and need to expansion of the typoe of STP of cluster 1.

- 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 observe a combination of a weak local R&D basis (both in Universities and companies - the regions where these parks are located have the lowest total expenditure in R&D in percentage of the GDP of this analysis, less than 1%) with functional gaps in the parks. If we assess performance in terms of occupancy rates and the type of tenants we observe that most of these parks present an occupancy rate below 1/3 and that some of them managed to increase occupancy by lowering standards of acceptance and providing location for less knowledge intensive activities.

Many of these parks are situated in follower regions that attempt to transform its structural profile in favor of a more knowledge intensive and thus innovation prone economy. Nevertheless, these parks are not only located in regions with weak RIS, in particular, with low technological capabilities but also they are detached from universities and diffuse in focus. This scattering of resources and not involvement of the community (inherent to a systemic approach) has led, in most cases, to “white elephants” with null contribution to the RIS and with no effect upon the visibility or the attractiveness of the region in national and international terms.

In sum, these parks are very weak in functional terms, distinguishing from the parks in cluster 3 for the lack of university effective support which adds additional problems to its success in follower regions.

- Cluster 5

Within this cluster we grouped 9 large 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 (also in regional terms, the average is the second highest, 1.9%), constituting technology parks with more knowledge intensive activities, partially also justified by the context of being inserted in a region with an economic structural profile richer in knowledge-intensive activities. This minimizes the weaknesses (still present) typical of a follower region RIS though the need for a systemic approach is still very important in order to elevate the STP to a status of an actual beacon of excellence.

- 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 and are inserted in convergence regions. 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. The concentration of resources in scientific fields has allowed to create critical mass and obtain visibility potentiated by the use STP as an attractor to R&D FDI and as a clustering driver for knowledge intensive activities (for instance, the *Parque Tecnologico de Bizkaia* has several pharmaceutical companies onsite – e.g. BIAL)..

5. Conclusions

STPs have been presented as the panacea for follower regions seeking to catch-up and accelerate costly structural change processes. The demonstration effect from Cambridge's success has led many policymakers to invest in STPs. However, in territories with deficient R&D capabilities these investments have proven highly controversial. The strong focus on science in follower regions where the link of companies to universities is weak and where the technological market is shallow has led to poor results. There are many potential reasons but we focus our discussion on 3 topics.

Firstly, the concept of STP remains blurry and narrow in the sense that the focus is on the infrastructure and not on the functions. From a systemic perception of innovation, we try to contribute by adapting Edquist's function of a RIS in order to devise the functions of a STP in a RIS. We argue that a STP can be a privileged tool to structure and rationalize a RIS, contributing to the concentration and accumulation of resources as well as function as a beacon that, on one hand signals technological capabilities and on the other hand attract multinationals' R&D centres.

Secondly, we address the particular case of follower regions. Follower regions face the challenge of conducing structural change processes that break technological "lock-ins" and build new competitive advantages around knowledge and innovation. Additionally, many follower regions, not only endure harsh processes of structural change, as also depart from low regional level of scientific resources and technological demand. The weak technology push and the limited and many times diffuse scientific push translate into an unstructured and ineffective RIS. We believe that a STP can be an effective tool within in the implementation of the necessary public push, working as a focal point in the RIS and hence contributing to overcome the scattering of resources. A STP can function as a structuring and rationalizing element of the RIS, focusing resources but also signaling capabilities and hence directly contribute to overcome the poor visibility of follower regions. This function is of utmost importance, transforming the STP in an attractor for technology-intensive FDI, which may lever the structural change and the construction of the RIS.

Finally, we used cluster analysis on a set of 55 STP in order to try to identify patterns that could shed some light on more suitable approaches to STP in the context of follower regions. Our results seem to indicate that in follower regions with thin or inexistent high tech clusters of firms and limited scientific inputs, starting from a more moderate approach, in close association with universities as the parks of cluster 1 maybe a better solution on a first stage. It is clear that STP, I order to have a significant role in the RIS, must enlarge its density and evolve to a layout similar to STP in clusters 3 and 5. However, as observed in STP of cluster 3, if the regional economic profile is scarce in terms of technology intensive activities (as it happens in most follower regions), the approach that consists on a vast area being reserved for technology firms creates pressure to increase visible results (e.g. occupancy rate) which leads to the loss of focus and the downgrade of tenant requirements. STP of cluster 5, located in regions with a considerable more technology intensive profile, present good occupancy rates and a higher proportion of medium and high technology firms, also attracting some R&D FDI. It is also important to highlight cluster 4. The popularity of STP concept as also led to the proliferation of functionally poor parks labeled as STPs. These parks, mostly in cluster 4, are basically "premium or good land sites", lacking critical mass in terms of technology inputs as well as local demand of more technology intensive firms, failing to attract activities and presenting low levels of effectiveness (occupancy rate and technologic profile of tenants).

Thus, in light of our results, we conclude that a STP is a valid and useful policy tool in a public push attempt to build a RIS in follower regions. The STP may have significant impacts in concentrating and focusing resources, hence creating critical mass and cumulative processes of clustering that can potentiate the effects of the public science push with also a demand pull (possibly created through the orientation of public demand for technology, for instance e-government). It is also clear that in follower regions where the RIS is too thin, the over-ambitious extensive conception present in STP of cluster 3 may be inadequate since it develops a large area, creating political pressure to large scale results which has led to the loss of focus of those STP, which will limit their role and effectiveness as a structuring element of a follower region's RIS.

The success and structural change impact of STP requires a systemic approach that also creates the setting for the STP to function as an attractor of R&D FDI, exploring significant cost-advantages and the increased tendency of R&D globalization. This may be an important catching-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. Hence, STPs can be important tools in developing RIS in follower regions but a lot more is needed, being crucial to increase scientific resources and networking and also define the functional characteristics in accordance to the local context and RIS limitations.

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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: Some descriptive statistics (partial)

		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]

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

a. Kruskal Wallis Test

b. Grouping Variable: Ward Method