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Abstract

The effectiveness of Science and Technology Parks (STPs) as instruments of innovation policy has generated thriving debate among academics, practitioners and policy makers. However, research mostly does not consider STPs' heterogeneity. The present paper analyses the influence of different STP characteristics on their tenants' performance. Using data on 849 firms and 25 STPs from the 2009 Community Innovation Survey for Spain and a survey of STP managers respectively, we find that: (i) firms located in very new or longer established STPs show better innovative performance; (ii) the size of the STP and its management company positively affects the innovative performance of tenants while services provision has no effect on firms' achieving better results; and (iii) firms in less technologically developed regions benefit more from location in an STP.

1. Introduction

Science and Technology Parks (STPs) have attracted the attention of academics and policymakers and have increased around the world (Wainova, 2009). STPs are policy-driven agglomerations (Huang et al., 2012), designed to encourage the formation and growth of on-site technology and knowledge-based firms, and have a management function that is actively engaged in achieving these goals.

In spite of their wide diffusion and the considerable investment involved, there is no consensus on the effectiveness of this technology and innovation policy instrument. On the one hand, some argue that STPs have no relevant impact on firms' results since they do not encourage the creation of synergies that might result in added value for tenants (e.g. Macdonald, 1987), which questions the actual STP model (Massey et al., 1992; Hansson et al., 2005) and led Quintas et al. (1992) to describe STPs as 'high-tech fantasies'. This view is supported by several empirical studies that find no significant differences between on- and off-park firms in relation to the inputs to the innovation process (Westhead, 1997; Colombo and Delmastro, 2002) and the outputs of innovation activity (Westhead, 1997; Löfsten and Lindelöf, 2002; Colombo and Delmastro, 2002).

On the other hand, there are those who claim that STPs provide a supportive environment for new knowledge- and technology-based firms, facilitating technology transfer, encouraging firm growth, attracting firms involved in leading-edge technologies, and fostering strategic alliances and networks (Siegel et al., 2003a; Hommen et al., 2006; Del Castillo Hermosa and Barroeta, 1998). Some empirical studies show that an on-park location creates externalities that can have positive effects on the innovation activity of firms related to the inputs to the innovation process (Fukugawa, 2006; Leyden et al., 2008; Yang et al., 2009), higher research productivity (Siegel et al., 2003b; Yang et al., 2009) or a higher likelihood to patent (Squicciarini, 2008, 2009).

We propose an explanation that reconciles these contrasting views,[1] that is, that parks are heterogeneous. Some parks are efficient, and do generate value for their tenants; others do not. Although the literature on STPs is growing rapidly, to our knowledge there have been no attempts to systematically analyse which characteristics of STPs contribute to improving the performance of innovative firms. This paper tries to fill this gap in the literature by assessing how several STP characteristics, namely age, dimension, location and management, affect the innovation performance of tenants.

[1] An alternative, complementary explanation might be that some firms benefit from location in a STP and others do not. This issue is explored in Barge-Gil et al. (2011) and Huang et al. (2012).

We exploit two main data sources: the 2009 Community Innovation Survey (CIS) for Spain (available since 2011), and the 2009 Survey of the Characteristics and Results of Science and Technology Parks, a Spanish Government internal survey administered to STPs by the then Department of Science and Innovation since 2008.

The rest of the paper is organized as follows: Section 2 reviews the literature; Section 3 presents the data and the methodology and describes the variables used. Section 4 presents the empirical results which are discussed in Section 5. Section 6 highlights some implications of the study and suggests directions for further research.

2. Literature Review

As referred to above, analysis of the effects of parks' heterogeneity on innovation performance of firms, is novel in the literature on STPs. We selected four characteristics to analyse: park age and size (traditionally considered as factors related to organizational performance in various disciplines, e.g. Stinchcombe, 1965; Blau, 1970; Evans, 1987); park location, which would seem important since STPs are geographically bounded technology and innovation policy instruments; and park management, the importance of which is suggested in other studies of STPs (e.g. Westhead and Batstone, 1999; Löfsten and Lindelöf, 2002).[2] In what follows, we discuss the potential influence of these characteristics on park firms' performance in line with previous work on STPs and, more generally, the literature on agglomerations. Since there are several opposing arguments, no clear hypotheses have been formulated; however, we identify contradicting views that demand clearer empirical evidence.

2.1. Effects of park's age

Numerous studies analyse the relation between firm age and innovation behaviour (see e.g. Huergo and Jaumandreu, 2004), but the impact of park age on firms' results has been mostly ignored in previous studies of STPs, despite a general acknowledgement that the effect of agglomeration on firm innovation can vary over the agglomerations' life cycles (Pouder and St. John, 1996; Bresnahan et al., 2001).

[2] Note that the choice of specific independent variables had to fulfil the requirement of significant variability within our sample; thus, not all potential sources of heterogeneity are included. E.g., the presence of a business incubator within a STP is considered by some (e.g. Colombo and Delmastro, 2002) to be a critical success factor for STPs. However, this feature does not represent a source of heterogeneity in our sample because all the parks analysed have at least one business incubator. Similar arguments apply to consideration of specialization of STPs in a specific industrial sector; in our sample only one STP is specialized.

Some argue for a positive effect of STP age upon firms' innovation performance. The agglomeration literature suggests that one of the main benefits of agglomerations is to facilitate links with other organizations (Hervas-Oliver and Albors-Garrigos, 2009). The results generated by these links improve with their duration (Izushi, 2003; Barge-Gil and Modrego, 2011) because repeated interaction reduces the cost of each future interaction by generating routines (Dahl and Pedersen, 2004), improving users' capacity to acknowledge and explain their requirements (Lambrecht and Pirnay, 2005), and by contributing to the building of mutual trust (Mayer et al., 1995) and reducing the risk of dishonest behaviour (Narula and Hagedoorn, 1999). Also, according to the literature on organizational learning, older organizations are more likely to accumulate knowledge and apply it in innovative activities and to achieve superior performances (e.g. Calantone et al., 2002; Decarolis and Deeds, 1999) allowing STP managers to improve their understanding of tenants' needs (Gower et al., 1996) and firms to benefit from more effective business support.

On the other hand, the age of the park might have negative repercussions for tenants' performance. There might be the risk, for older parks, of ossification of park management routines, non-learning processes, blindness and conservatism, all of which could lead to worse performance (Durand and Coeurderoy, 2001) and would have negative consequences for firms.

Empirical studies are scarce. Some authors have found a positive effect of park age on total park employment growth (Link and Scott, 2006), and on university administrators perceived utility of interactions with firms for academic patenting (Link and Scott, 2003). Others, such as McCann and Folta (2011), include age of the agglomeration as a control variable to study firms' performance differentials and find either no or a negative effect.

Thus, neither the theoretical nor the empirical literature provides clear evidence of the effect of STP age on tenants' innovation performance. We explore the issue empirically allowing for the coexistence of both positive and negative effects.

2.2 Effects of park dimension

The role played by dimension has been acknowledged widely in the academic literature on agglomerations (Arthur, 1990; Beaudry and Breschi, 2003; Layson et al., 2008), the classical argument being that the positive externalities generated by co-location with other firms increase with the number of firms in the same location (Arthur, 1990). For example, as the

number of on-park firms increases, the stock of available knowledge (Beaudry and Breschi, 2003) producing externalities also increases, which has positive repercussion for firms' performance. However, some maintain that the positive effects occur only above a minimum critical size (Bakouros et al., 2002).

On the other hand, firms located in large sized STPs can suffer the diseconomies of agglomeration (Arthur, 1990). Congestion costs may be generated by competition in both input and output markets (Prevezer, 1997) and firms may compete over the limited space available in an STP (Chen and Huang, 2004), over specialized workforce (Zucker et al., 1998) and utility services (Folta et al., 2006). Shaver and Flyer (2000) suggest another possible explanation for performance declining with dimension: that is, that larger agglomerations are less attractive to the most innovative firms because of the risk of outgoing spillovers.

Again, empirical work is scarce.[3] Some studies of agglomerations find a positive association between agglomeration size and certain performance measures such as the probability of patenting (McCann and Folta, 2011), or firm growth (Beaudry and Swann, 2009). Folta et al. (2006), however, conclude that there is a non-linear effect between agglomeration size and firm performance: economies of agglomeration benefit firms in relation to their ability to patent and to attract partners, but these effects decline and may even become negative as the agglomeration gets larger. In addition, firms are more likely to fail as clusters grow, suggesting the existence of diseconomies of agglomeration (Folta et al., 2006). Finally, Squicciarini (2009) uses the STP size as a control variable and finds that size positively affects tenant's patenting activity.

Similar to the question of STP age, neither the theoretical nor the empirical literature provides a clear view on the effect of an STP's dimension on tenants' innovation performance. The discussion is focused mostly on the existence or not of a negative effect after a certain critical dimension, and there is some consensus on a positive effect of increasing STP size for initially small parks.

2.3 Effects of park location

Location has traditionally been considered an important factor for the success of firms' innovation activities (McCann and Folta, 2008; Feldman and Kogler, 2010). The advantages for technology-based firms of being located in technologically developed regions were identified

[3] Some authors (Quintas et al., 1992; Lee and Yang, 2000; Colombo and Delmastro, 2002; Kihlgren, 2003; Chen and Huang, 2004; Chan and Lau, 2005; Hu, 2007) proxy STP dimension by number of firms, but these data are used only for descriptive purposes.

by Marshall (1920) almost a century ago and can be resumed in three points: specialized labour; specialized inputs; and knowledge spillovers (Prevezer, 1997). Although geographical proximity *per se* is neither a necessary nor a sufficient condition for knowledge spillovers (Boschma, 2005), its importance is widely recognized in the literature (see e.g. Czarnitzki and Hottenrott, 2009), and a large body of work claims that spatially close agents benefit from knowledge externalities (Boschma, 2005). It has been found also that firms located in more advanced regions are more likely to be innovative (Johansson and Lööf, 2008).

These arguments can be extended to STPs. Parks established in technologically developed regions may benefit from location advantages provided by extra-park relationships and spillovers. They may build on these advantages to become poles of excellence (Chorda, 1996), which attract innovative firms from other areas (Mello and Rocha, 2004).

On the other hand, STPs that are located in less developed regions (Siegel et al., 2003a) can help to compensate for the lack of valuable inputs in these regions and become innovation enclaves (Felsenstein, 1994), which improve the overall image of the region (Sternberg, 2004; Del Castillo Hermosa and Barroeta, 1998). They may constitute a technologically developed space in a lagging region. Also, in a lagging region, if competition is mainly local, on-park firms may have advantages over their competitors. This would not apply in more advanced areas; STP effects would be limited because firms are able to find favourable framework conditions elsewhere (Sternberg, 2004).

The regional context has been accounted for explicitly in a few empirical studies. Link and Scott (2005, 2006) use macroregional dummies and find no significant effect of STP location on performance. Fukugawa (2006) uses number of universities and public research institutes in the region to control for interregional variation in technological opportunities: his findings are somewhat contradictory.[4]

So, there is no clear indication of the influence of the regional context on STP results in the existing studies. Debate continues over whether STPs are more effective as innovation enclaves in less developed regions, or centres of excellence in advanced areas.

2.4 Effects of management's characteristics

[4] Fukugawa found that firms located in STPs in regions with more universities and public research institutes were less likely to develop regional links with these organizations, but were more likely to develop joint research with universities and public research institutes outside the region. The author offers no explanation for this finding.

The official definition of STPs, from the International Association of Science Parks (IASP, 2002), makes reference to the management function of STPs. This feature is one of the main differences between STPs and other types of agglomeration. It has been argued that the existence of a formal integrated management structure provides a more secure basis for firms' long-term development (Westhead and Batstone, 1999). Cabral (1998) suggests that a characteristic of all successful parks is a strong park managerial team, with established or recognized expertise, and Colombo and Delmastro (2002) acknowledge the importance of the internal organization and that it should be lean and agile. Very young firms, in particular, can suffer from several constraints that make it difficult for them to achieve their economic potential (Monck et al., 1988). These constraints include reduced management capacity, paucity of finance, and lack of sales and marketing expertise (Storey and Tether, 1998a). There is a common view that STPs' on-site management can be a determinant of a supportive environment that helps firms to overcome these constraints (Löfsten and Lindelöf, 2002) through the provision of business advice and services related to financial and marketing support (Storey and Tether, 1998b; Heydebreck et al., 2000) from the management team (Westhead and Batstone, 1998). Some authors are critical of those STPs not providing these services, referring to them as 'firm hotels' (Löfsten and Lindelöf, 2002).

However, there is a view also that the added value of on-park location does not come from the active hands-on support from the park's management. According to some studies based on surveys of tenant firms, firms choose an on-park location for the prestige that this location endows, and for easier access to university/research centre facilities and the prestige from links with them (Monck et al., 1988; Westhead and Batstone, 1998). These features do not require particularly active park management. Also, since tenant organizations to an extent can be considered captive customers of the services provided by the STP management, these can be of lower quality (Rienzner and Testa, 2003).

In this paper, we analyse how two main characteristics of the STP management - dimension of the management team, and provision of internationalization and consultancy services to firms - influence innovation performance.

3. Data, methodology and variables definition

3.1. Data

To conduct our analysis we combine firm level data from the 2009 Spanish CIS, published in 2011, with data on STP characteristics from the 2009 Survey of the Characteristics and Results of Science and Technology Parks administered to Spanish STPs.[5]

The CIS for Spain is managed by the Spanish National Statistics Institute (INE) and is mandatory. It collects very detailed information on the characteristics of firms' innovation processes and since 2007 it includes a question on possible on-park location. The 2009 survey covered 37,201 firms, representative of the Spanish business structure, of which 849 were located on an STP[6] (across 25 in 12 different Spanish regions).

While existing work has focused mainly on a few parks (e.g. Yang et al., 2009; Malairaja and Zawdie, 2008; Chan et al., 2010; Bakouros et al., 2002; Felsenstein, 1994), or a large number of parks, but small sample of firms (e.g. Squicciarini, 2008, 2009; Fukugawa, 2006; Colombo and Delmastro 2002; Westhead, 1997; Westhead and Storey, 1995; Siegel et al., 2003b; Löfsten and Lindelöf, 2002), we combine large firm and park samples, which allows us to observe greater parks heterogeneity and to control properly for firm characteristics using a large set of covariates.

Another advantage offered by CIS is that, because it is modelled on the European CIS, it uses already tested indicators and enables comparison with the results of other studies using CIS data for other countries.

3.2. Methodology

The model we use to assess the effect of STP characteristics on the innovation performance of firms can be synthesized in the equation:

$$Y = \alpha + \beta\, STP's_{Characteristics} + \gamma\, Controls + \varepsilon \qquad (1)$$

The model is estimated using ordinary least squares (OLS) regression[7] with controls and standard errors clustered by park. We test the robustness of results to different definitions of the dependent and some of the independent variables. We estimate this model for the sample

[5] Although central government is not directly involved in any STP initiatives, responding to the survey is mandatory for STPs to obtain government funding. In a very few cases, data were supplemented by phone surveys with park managers.

[6] The STP sample includes only those STPs that were *full members* of the Association of Science and Technology Parks of Spain (APTE) for at least two years.

[7] We also estimate Tobit models; the results (presented in the appendix) were very similar. We chose to present the OLS estimations because they provide direct and constant marginal effects, allowing easier comparison across models.

of firms located in STPs since the population of interest is STP tenants and STP characteristics do not apply to off-park firms.

3.3 Variables definition

Each component of equation (1) is explained below.

3.3.1 Dependent variable - lnewmerl

We measure the innovation performance of on-park firms using volume of sales per employee registered in 2009 of new-to-the-market products (i.e. products introduced to the market in the two years previous to the survey - 2007-2009). These data are available for every firm because they correspond to a question in the survey. This indicator is used frequently in studies of innovation (for a review see e.g. Vásquez-Urriago et al., 2011) and is argued to overcome the problems typical of other indicators such as patents, R&D expenses and number of innovations (Smith, 2006).

Operationally, the dependent variable *lnewmerl* is the logarithm of the sales from new-to-the-market products/services per employee.

3.3.2 Independent variables (STP characteristics)

The STP characteristics considered in our model are summarized in Table 1 and discussed below.

TABLE 1 APPROXIMATELY HERE

STP age (*age*) is number of years since establishment of the park and is used together with its quadratic form (*ageq*) to explore the existence of non linear effects.

lnfirms is the log of the number of park tenants at the end of the previous year (2008) and proxies for the size of the park. We also test the robustness of our results to the utilization of the geographical area of the park, measured in squared metres (*lsqmetres*, log) as an alternative indicator of park size. We investigate the existence also of non-linear effects.

To measure the level of technological development in the park's surrounding environment, we need an indicator for innovation or R&D, with high level of geographical disaggregation. One such would be provincial R&D expenditure over GDP. However, since these data are not

available, we use the log of patent applications per million inhabitants[8] in the province where the park is located (*lpatinhabprov*), drawn from the official statistics of the Spanish Office of Patents and Trademarks for 2009.[9] We acknowledge the problems related to using patents as indicators of innovation activity (Griliches, 1998) and we conducted robustness checks using different variables as proxies for the area's level of technological development, and different levels of aggregation. At province level, we use the log of GDP per capita for the province in which the park is located (*provGDPpp*). In order to exploit R&D activity we need to employ a higher level of aggregation and use the log of the regional R&D effort (*reg_r&d*), measured by total regional internal R&D expenditure[10] over GDP. We check the influence of changing the aggregation level by using the log of the number of patent applications per million inhabitants at regional level (*lpatinhabregion*).

The independent variables related to the characteristics of park management are: a) *lstaffr*, which is the log of the number of full-time equivalent employees in the park's management company per 100 tenants; b) *international*, a dummy variable that takes the value 1 if the park's management provides services to foster internationalization activities among its tenants and 0 otherwise; c) *consult*, a dummy variable that takes the value 1 if the park management provides general consulting services such as legal, commercial and/or on fiscal advice to its tenants, and 0 otherwise.

3.3.3 Definition of the covariates

For effective multiple regression analyses, it is essential to have appropriate covariates that allow explicit control for those factors that affect the dependent variable and the variables of interest simultaneously, so that their effect can be interpreted as *ceteris paribus*.

Following previous studies that use CIS data (for a review see Vásquez-Urriago et al., 2011), we employ two groups of covariates as determinants of innovation: firms' general characteristics (i.e. total turnover, exports, industrial sector, firm age), and some innovation-specific firm characteristics (i.e. innovation effort, perceived obstacles to innovation).

Table 2 lists the covariates used in this paper.

TABLE 2 APPROXIMATELY HERE

[8] Number of inhabitants in the province is from the official INE population census.
[9] The Spanish Office of Patents and Trademarks is the public body responsible for issuing and registering patents and trademarks in Spain.
[10] Regional R&D internal expenditure is from INE's 2008 R&D Statistics.

We use lags for turnover, exports and innovation effort (2007 figures) to avoid simultaneity problems between the covariates and the dependent variable.

Table 3 presents the descriptive statistics of the variables used in our models for the 849 on-park firms in our sample.

TABLE 3 APPROXIMATELY HERE

4. Results

4.1 Main results

Table 4 presents the main results. The results in Column 1 do not take account of STP's characteristics as a baseline for comparison. Our results are in line with studies in the literature on the huge importance of firms' innovation efforts (e.g. Czarnitzki and Hottenrott, 2009; Frenz and Ietto-Gillies, 2009; Tsai, 2009) and firm age (e.g. Czarnitzki and Hottenrott, 2009), and also the insignificant influence of industry when other factors are taken into account (e.g. Frenz and Ietto-Gillies, 2009; Faems et al., 2005). We find no significant effect for size or exporting and obstacles to innovation.

TABLE 4 APPROXIMATELY HERE

Column 2 shows the results including STP characteristics, which are very important for explaining firm sales from new products. The main results are discussed below.

First, STP age shows a U-shaped relationship with firm performance. Firms in younger and older STPs perform better than firms in middle-aged STPs, with the minimum point found at around 18 years. We interpret this result as follows. It is in line with those who argue that older STPs perform better due to their accumulation of knowledge and experience of interaction. Accumulation of such knowledge and experience takes time and accounts for the upward slope of the U-curve. However, the downward slope as STPs become middle-aged can be hypothesized as reflecting the existence of a short term impact of location in a STP. The reasons for this short term impact are probably more marketing than innovation related. For example, firms are able to win new customers just because they are located in a park. This

effect vanishes over time and takes several years for it to be replaced by the longer term effects of knowledge accumulation and trust.

Second, firms in larger STPs perform better. When the squared terms are included,[11] we find no evidence of congestion effects, although it should be noted that the STPs in our sample are not of a size that would induce congestion (the largest STP has 1,436 firms). We find that a 1% increase in the number of firms is related to a 0.45% increase in the sales of new products per employee. A different, related indicator of dimension is geographical size of the STP; several arguments in the literature are related to geographical space. The result for this indicator are reported in Column 3 and although not statistically significant, the effects remain positive and there is no evidence of congestion effects.

Third, we analyse STP management. We find that the larger the management structure, the better the results of the firms located in the STP. We find no evidence of non linear elasticity. More precisely, a 1% increase in the management staff is related to a 0.43% increase in the sales of new products per employee. The management services provided to tenants offers a different picture. Internationalization services do not have an effect, while the effect of general consultancy services is negative. These results might be explained as lower quality services provided by park management compared to the services available on the market. Thus, the positive influence of a strong management structure is not driven by the provision of direct services to firms, but by other reasons such as contributing to the creation of an environment conducive to innovation, increasing entrepreneurs' networks, facilitating technology transfer and enhancing firms' reputation.

Fourth, we examine the influence of STP location. Table 4, Column 2 uses the indicator of number of patent applications per million inhabitants in the province where the STP is located. We find a negative effect on firm performance, suggesting that STPs perform better in less developed provinces. Note that this effect is quite large (a 1% increase in patent applications per million inhabitants is related to a 0.665% decrease in the dependent variable), but only marginally significant. This might be because this variable varies only at province level so that estimation of the effect is less precise (standard errors quite high). Since the variability in this variable is low the estimation is somewhat imprecise.[12] We test the robustness of this result using different indicators for development: provincial GDP per capita (Table 4, Column 4); regional patents (Column 5); and regional R&D effort (Column 6). Regional patents and R&D

[11] Available upon request.

[12] In Table 4, column 3, the size of the coefficient is very similar to that in column 2, but not statistically significant at the conventional statistical levels.

effort show negative and significant effects; GDP shows negative, non significant effects which still are of large magnitude. These results suggest that STPs are instruments of innovation-policy for less developed regions (Siegel et al., 2003a) by compensating for a lack of inputs in these regions and constituting innovation enclaves. In more advanced regions, the STP effect is more limited because there are other favourable framework conditions available to firms (Felsenstein, 1994; Sternberg, 2004).

4.2 Robustness checks and further results

The dependent variable aims to demonstrate firm innovativeness. Previous studies use various definitions of the dependent variable such as (i) percentage of sales from products new to the market (Laursen and Salter, 2006; Falk, 2007), (ii) transformations of this indicator[13] (Klomp and van Leuween, 2001, Mohnen et al., 2006; Raymond et al., 2006), and (iii) total sales from products new to the market. In this subsection we explore whether our results are robust to these different definitions of the dependent variable (*lnnewmer*, *ltnewmer* and *linnovsales* -all in logs).

Table 5 presents the results. We observe that all the main results hold. The influence of age follows an inverted U-shape, size of STP and its management structure both show a positive influence, while provision of consultancy services is negative. Finally, degree of development of the province shows a negative effect.[14]

TABLE 5 APPROXIMATELY HERE

5. Discussion and conclusions

The aim of this paper was to shed light on the contribution of STPs to firm innovation, by empirically assessing the influence of STP characteristics on tenant firms' innovation. We were particularly interested in the effects of park age, dimension, management and location in a more or a less developed environment on the innovativeness of tenants.

[13] This variables is obtained using the formula: $\log\left(\frac{newmer1}{1-newmwer1}\right)$, where *newmer1*=*newmer*/100, and *newmer* is the share of sales obtained from new to the market products over total turnover.

[14] This negative influence emerges also using the different indicators for province/regional development.

The first important conclusion that can be drawn from our study is that STP characteristics, often disregarded in previous studies, affect the innovative results of firms. More precisely, we find that park age has a non-linear effect on sales of innovative products. Firms in younger and older parks outperform those in middle-aged parks. This finding can be explained by a twofold impact of being located on-park: an initial short-term positive impact for the firm generated by the visibility and prestige of a park location, and reasons related mainly to marketing; and a long-term positive effect likely due to the accumulation of knowledge, organizational learning, better understanding of tenants' needs and more effective business support. This result reconciles the contrasting views in the literature: the short-term effect supports the arguments of those who think STPs are prestigious locations for innovative firms, while the existence of a long-term positive effect supports the view that STPs are instruments of innovation policy.

Regarding STP size, we found that firms in larger parks outperform those in smaller parks. This points to the existence of economies of agglomeration, due probably to a greater knowledge stock within larger parks which facilitates knowledge spillovers. We found no evidence of congestion effects, although it is possible that the largest STP in our sample is not large enough for these to be an issue.

The size of the STP management team positively affects the innovation performance of tenants. However, this positive impact is not explained by the services provided by management: general consultancy services have a negative impact, and services aimed at fostering internationalization have no significant effects on firms' innovation. It is possible that a larger management team helps firms to achieve better results by augmenting the entrepreneur's network and facilitating technology transfer, but that tenancies should avail themselves of the best services provided in the market.

Finally, we found that STPs perform better in less technologically developed areas, that is, that STPs have a higher impact on tenants' performance if the level of technological development in the area surrounding the park is located is lower. This finding supports the role of STPs as instruments of innovation policy in less developed regions, where parks can constitute enclaves of innovation. The competitive advantage of an on-park location is smaller in more advanced regions where firms can find favourable framework conditions elsewhere.

This paper has implications for policy and managers. First, for policy, our findings on the existence of long-term effects of parks on firms' innovation performance and an on-park

location being more beneficial for firms in less developed regions, supports the idea of STPs being instruments of technology and innovation policy that should be protected from the effects of political cycles. In addition, the heterogeneous effects identified suggest that policy-makers should avoid indiscriminate financial support for STPs. More precisely, this study suggests that efforts to increase the size of STPs would benefit their firms, but that the provision of services has not been helpful.

Second, the implications for managers are two-fold. We show that STPs vary in the benefits that a park location provides, so it is important to identify the most appropriate type of STP. We show also, that the services provided by the park's management may not be the best available.

Although the literature on STPs has grown it focuses mainly on estimation of the average effects on firm innovation, which has led to contrasting results. The present study allows for the existence of heterogeneous effects and shows that they are systematically related to certain STP characteristics. We believe deeper investigation of their heterogeneity would contribute to the knowledge in this area. For example, STPs' demographics and the roles played by universities and research institutes might be interesting lines of research. Also, despite heavy data requirement, it would be interesting to analyse firms' and parks' heterogeneity jointly so to enable the development of more context-specific strategies.

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TABLES

Table 1. STPs' characteristics

Characteristic	Label	Description
Age	age	Age of the STP (years)
	ageq	Age of the STP (quadratic)
Size	lnfirms	Number of tenant organizations in 2008 (log)
	lsqmetres	Geographical extension of the park (squared meters) (log)
Location	lpatinhabprov	Number of patent applications per million inhabitants in the province (log)
	lpatinhabreg	Number of patent applications per million inhabitants in the region (log)
	provGDPpp	Provincial Gross Domestic Product per capita (log)
	reg_r&d	Regional R&D effort (regional R&D expense over regional GDP)
Management	lstaffr	Number of full-time equivalent employees in the Park's management company per 100 tenants (log)
	international	1 if the Park provides services to foster internationalization of firm, 0 otherwise
	consult	1 if the Park provides advice on legal, commercial and fiscal issues, 0 otherwise

Table 2. Covariates

Characteristic	Label	Description
Size	lsales07 lsales07_2	Turnover in 2007 (log) Turnover in 2007 (log, quadratic)
Exports	x_s07	Exports over turnover in 2007
Industrial sector	high mediumhigh mediumlow low kis nkis restact	Technological level of industrial sector (0,1) (following OECD Science, Technology and Industry Scoreboard) 7 dummies: high-tech manufacturing, medium-high-tech manufacturing, medium-low-tech manufacturing, low-tech manufacturing, knowledge intensity service, no-knowledge intensity service, other sectors
Age	lfirmage	Firm age (years, log)
Innovation effort	lrdexpen_emp	Expenditure on innovation activities in 2007 per employee (thousand euros)
Cost obstacles to innovation	costobst	Perceived average importance of the following factors as a barrier to innovation during 2007-2009: - lack of internal funds - lack external funds - high costs of innovating - risk costs due to uncertain demand of innovative products and services (scale: 1 – 4; 1 very important; 4 unimportant)
Information obstacles to innovation	infobst	Perceived average importance of the following factors as barriers to innovation during 2007-2009: - lack of qualified personnel - lack of information on technology - lack of information on the markets - difficulty to find cooperation partners (scale: 1 – 4; 1 very important; 4 unimportant)

Table 3. Descriptive statistics (849 observations)

Variable	Mean	Std.Dev.	Min.	Max.
Dependent variables				
newmerl	14387.06	43567.13	0.00	607684.40
newmer	16.21	29.50	0.00	100
tnewmer	589.12	2354.91	0.0001	9997.34
linnovsales	1347258	1.07e+07	0	2.34e+08
Independent variables – STPs' characteristics				
age	15.59	5.12	6.00	24.00
nfirms	224.40	218.10	2	1436
sqmeters(1)	1145,5	865,5	6,5	2841,0
patinhabprov	82.98	32.46	11.92	131.21
patinhabreg	77.61	28.04	37.00	159.05
provGDPpp	24.79	5.33	17.08	34.49
reg_r&d	1.39	0.47	0.35	2.00
staffr	27.75	68.32	0.00	1550.00
international	0.64	0.48	0	1
consult	0.26	0.44	0	1
Control variables – firms' characteristics				
lsales07	12.11	5.59	0.00	20.74
x_s07	0.03	0.12	0.00	0.95
restact	0.04	0.20	0.00	1.00
low	0.036	0.19	0.00	1.00
mediumlow	0.034	0.18	0.00	1.00
kis	0.64	0.48	0.00	1.00
mediumhigh	0.08	0.27	0.00	1.00
nkis	0.09	0.28	0.00	1.00
rdexpen_emp	32878.32	68140.92	0.00	915000.00
costobst	0.55	0.20	0.25	1.00
infobst	0.39	0.13	0.25	1.00
firmage	12.64	12.00	1.0	152

(1) thousands.

Table 4. Influence of parks' characteristics on innovation. Main specification.

	(1) lnewmerl	(2) lnewmerl	(3) lnewmerl	(4) lnewmerl	(5) lnewmerl	(6) lnewmerl
age		-0.576***	-0.479**	-0.496***	-0.528***	-0.546***
		(0.129)	(0.164)	(0.106)	(0.119)	(0.103)
ageq		0.016***	0.014**	0.015***	0.016***	0.017***
		(0.004)	(0.005)	(0.003)	(0.004)	(0.003)
lnfirms		0.452*		0.366*	0.426*	0.370**
		(0.169)		(0.134)	(0.158)	(0.120)
lpatinhabprov		-0.665**	-0.516			
		(0.219)	(0.268)			
lstaffr		0.427**	0.380**	0.396**	0.336*	0.358**
		(0.122)	(0.126)	(0.134)	(0.136)	(0.123)
international		0.065	0.221	0.167	0.128	0.190
		(0.369)	(0.431)	(0.377)	(0.401)	(0.349)
consult		-1.136*	-1.131*	-0.815	-0.725	-0.861*
		(0.424)	(0.420)	(0.403)	(0.450)	(0.385)
lsales07	0.038	0.035	0.034	0.038	0.036	0.036
	(0.036)	(0.034)	(0.035)	(0.034)	(0.034)	(0.034)
x_v07	1.232	1.320	1.366	1.240	1.266	1.256
	(1.100)	(1.137)	(1.109)	(1.140)	(1.128)	(1.133)
restact	-1.562	-1.706	-1.620	-1.720	-1.731	-1.756
	(1.302)	(1.292)	(1.278)	(1.302)	(1.292)	(1.303)
low	-0.409	-0.483	-0.349	-0.484	-0.441	-0.532
	(1.042)	(1.042)	(1.021)	(1.036)	(1.034)	(1.041)
mediumlow	-0.410	-0.442	-0.582	-0.403	-0.401	-0.486
	(1.428)	(1.381)	(1.407)	(1.380)	(1.381)	(1.387)
mediumhigh	-0.477	-0.505	-0.530	-0.506	-0.467	-0.574
	(0.906)	(0.885)	(0.879)	(0.886)	(0.890)	(0.879)
kis	-0.903	-1.035	-0.924	-1.036	-1.038	-1.091
	(0.812)	(0.784)	(0.796)	(0.780)	(0.785)	(0.780)
nkis	-0.391	-0.562	-0.422	-0.542	-0.518	-0.591
	(0.856)	(0.861)	(0.854)	(0.857)	(0.865)	(0.863)
lrdexpen_emp	0.379***	0.382***	0.378***	0.382***	0.382***	0.389***
	(0.042)	(0.040)	(0.040)	(0.041)	(0.040)	(0.042)
costobst	1.197	1.112	1.107	1.145	1.156	1.088
	(0.847)	(0.851)	(0.853)	(0.874)	(0.851)	(0.852)
infobst	0.864	0.670	0.693	0.765	0.683	0.730
	(1.238)	(1.239)	(1.227)	(1.223)	(1.221)	(1.217)
lfirmage	0.813**	0.833**	0.860**	0.812**	0.809**	0.815**
	(0.256)	(0.240)	(0.243)	(0.245)	(0.243)	(0.245)
provGDPpp				-1.037		
				(0.537)		
lpatinhabreg					-0.599*	
					(0.252)	
reg_r&d						-1.604**
						(0.474)
lsqmetres			0.107			
			(0.106)			
N	849	849	849	849	849	849
r2	0.112	0.124	0.120	0.123	0.123	0.125

Marginal effects; Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1;
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5. Different dependent variables.

	(1) lnnewmer	(2) ltnewmer	(3) linnovsales
age	-0.258***	-0.586***	-0.735***
	(0.044)	(0.155)	(0.156)
ageq	0.007***	0.015**	0.021***
	(0.001)	(0.004)	(0.005)
lnfirms	0.163**	0.427*	0.660**
	(0.051)	(0.170)	(0.231)
lpatinhabprov	-0.384***	-0.960***	-0.820**
	(0.067)	(0.227)	(0.286)
lstaffr	0.174***	0.495***	0.543**
	(0.044)	(0.132)	(0.165)
international	0.024	0.064	0.075
	(0.098)	(0.305)	(0.505)
consult	-0.596***	-1.511*	-1.300*
	(0.145)	(0.547)	(0.588)
lsales07	0.003	-0.026	0.067
	(0.014)	(0.042)	(0.042)
x_v07	0.324	0.726	1.577
	(0.372)	(1.134)	(1.591)
restact	-0.494	-1.393	-2.680
	(0.446)	(1.259)	(1.730)
low	0.102	1.047	-1.039
	(0.412)	(1.154)	(1.407)
mediumlow	-0.259	-0.789	-0.440
	(0.478)	(1.287)	(1.998)
mediumhigh	-0.118	-0.401	-0.728
	(0.358)	(0.933)	(1.180)
kis	-0.198	-0.752	-1.387
	(0.304)	(0.802)	(1.035)
nkis	-0.133	-0.060	-1.181
	(0.306)	(0.913)	(1.146)
lrdexpen_emp	0.139***	0.411***	0.510***
	(0.011)	(0.032)	(0.054)
costobst	0.256	0.533	1.014
	(0.321)	(0.998)	(1.075)
infobst	0.365	1.485	1.024
	(0.445)	(1.411)	(1.672)
lfirmage	0.169	0.516	1.460***
	(0.091)	(0.293)	(0.318)
N	849	849	849
r2	0.120	0.107	0.133

Marginal effects; Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix 1. Main specification. Tobit estimations.

	(1) lnewmerl	(2) lnewmerl	(3) lnewmerl	(4) lnewmerl	(5) lnewmerl	(6) lnewmerl
age		-1.462***	-1.118*	-1.284***	-1.370***	-1.366***
		(0.329)	(0.443)	(0.252)	(0.328)	(0.261)
ageq		0.041***	0.032*	0.038***	0.040***	0.041***
		(0.010)	(0.013)	(0.008)	(0.010)	(0.008)
lnfirms		1.408**		1.204***	1.352***	1.221***
		(0.430)		(0.351)	(0.402)	(0.325)
lpatihabprov		-1.651**	-1.258			
		(0.600)	(0.785)			
lstaffr		1.072*	0.864*	1.008*	0.851	0.906*
		(0.430)	(0.418)	(0.445)	(0.458)	(0.428)
international		0.007	0.471	0.276	0.181	0.313
		(0.923)	(1.207)	(0.966)	(1.021)	(0.908)
consult		-2.409*	-2.595*	-1.733	-1.521	-1.770
		(1.131)	(1.156)	(1.025)	(1.147)	(1.021)
lsales07	0.107	0.106	0.096	0.114	0.108	0.111
	(0.103)	(0.098)	(0.101)	(0.098)	(0.098)	(0.098)
x_v07	3.308	3.550	3.728	3.338	3.409	3.386
	(2.459)	(2.564)	(2.475)	(2.585)	(2.548)	(2.557)
restact	-4.340	-4.624	-4.387	-4.620	-4.731	-4.714
	(3.591)	(3.540)	(3.477)	(3.576)	(3.545)	(3.577)
low	-0.718	-0.898	-0.532	-0.960	-0.864	-1.030
	(2.733)	(2.738)	(2.606)	(2.739)	(2.732)	(2.747)
mediumlow	0.154	0.315	-0.299	0.439	0.403	0.257
	(3.275)	(3.116)	(3.231)	(3.118)	(3.106)	(3.145)
mediumhigh	-0.707	-0.753	-0.871	-0.760	-0.683	-0.919
	(1.931)	(1.842)	(1.835)	(1.839)	(1.851)	(1.828)
kis	-1.683	-1.932	-1.695	-1.935	-1.955	-2.047
	(1.755)	(1.657)	(1.690)	(1.648)	(1.661)	(1.652)
nkis	-0.407	-0.622	-0.383	-0.584	-0.551	-0.686
	(2.017)	(2.011)	(1.989)	(2.001)	(2.013)	(2.008)
lrdexpen_emp	1.211***	1.225***	1.204***	1.220***	1.223***	1.231***
	(0.144)	(0.143)	(0.141)	(0.141)	(0.143)	(0.142)
costobst	3.202	3.237	3.081	3.256	3.292	3.109
	(2.159)	(2.125)	(2.128)	(2.204)	(2.129)	(2.151)
infobst	3.028	2.546	2.593	2.861	2.658	2.809
	(3.307)	(3.289)	(3.269)	(3.246)	(3.235)	(3.236)
lfirmage	2.209***	2.277***	2.346***	2.207***	2.206***	2.198***
	(0.617)	(0.558)	(0.579)	(0.565)	(0.565)	(0.562)
provGDPpp				-2.578		
				(1.329)		
lpatinhabreg					-1.461*	
					(0.704)	
reg_r&d						-3.537**
						(1.225)
lsqmetres			0.188			
			(0.311)			
N	849	849	849	849	849	849
r2						

Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix 2. Different dependent variables. Tobit estimations.

	(1) lnnewmer	(2) ltnewmer	(3) linnovsales
age	-0.595***	-1.179	-1.906***
	(0.113)	(0.784)	(0.427)
ageq	0.016***	0.028	0.053***
	(0.003)	(0.023)	(0.013)
lnfirms	0.505***	0.255	1.962***
	(0.144)	(0.490)	(0.583)
lpatihabprov	-0.817***	-3.223**	-2.101**
	(0.198)	(1.084)	(0.799)
lstaffr	0.428**	0.937*	1.382*
	(0.156)	(0.472)	(0.578)
international	0.031	0.513	-0.008
	(0.294)	(1.335)	(1.237)
consult	-1.165**	-4.604*	-2.900
	(0.400)	(1.854)	(1.545)
lsales07	0.022	-0.199	0.171
	(0.036)	(0.127)	(0.127)
x_v07	1.162	-4.248	4.443
	(0.867)	(5.726)	(3.501)
restact	-1.587	-0.817	-6.746
	(1.261)	(3.820)	(4.763)
low	0.109	7.521*	-1.791
	(1.021)	(3.213)	(3.721)
mediumlow	-0.010	-8.166**	0.607
	(1.117)	(3.151)	(4.311)
mediumhigh	-0.194	-2.614	-1.055
	(0.715)	(2.234)	(2.450)
kis	-0.481	-1.928	-2.539
	(0.636)	(2.262)	(2.192)
nkis	-0.161	2.204	-1.412
	(0.724)	(2.611)	(2.676)
lrdexpen_emp	0.454***	1.631***	1.622***
	(0.048)	(0.211)	(0.190)
costobst	0.990	-2.422	3.689
	(0.778)	(2.710)	(2.749)
infobst	1.098	6.251	3.452
	(1.181)	(4.041)	(4.371)
lfirmage	0.639**	-0.116	3.516***
	(0.208)	(0.995)	(0.724)
N	849	849	849
r2			

Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$