The Role of Science and Technology Parks as Firm Growth Boosters: an Empirical Analysis in Catalonia

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Abstract:

This paper aims to contribute to understanding the role played by Science and Technology Parks (STPs) in fostering the growth of firms. Applying a matching procedure, we obtain a database of 170 in-park firms, together with 7,190 out-park firms. After applying a fixed-effects quantile regression, our results show that being located in a STP has a dual effect on firm performance. Although location in a STP has a positive effect for high-growth firms, it has a negative effect for low-growth firms. Furthermore, among all STPs, the effect for science parks is stronger than that for technological parks.

Keywords: science and technology parks, firm location, firm growth

JEL codes: L25, O30, R11, R58

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1. Introduction

The role of Science and Technology Parks (henceforth STPs) as policy tools for promoting innovation and firm growth has generated an intense debate between academics and policy makers. Despite the high number of STPs worldwide, their number keeps on growing. USA continues to head this list, but in developing regions such as Catalonia the number of parks has been growing since the mid-1980s. In general, the literature highlights the effects of STPs on the promotion of new-high-tech firms, the growth of in-park firms, and the creation of an environment which facilitates cooperation and knowledge transfer between firms and institutions such as universities, research centres or technological centres. Empirical studies mostly analyse the effect of location in a STP on firm performance and behaviour (Dettwiler *et al*., 2006; Vásquez-Urriago *et al*., 2016a).

Despite a recent growth in the literature, empirical results are often mixed. For instance, Quintas *et al.* (1992) argue that STPs are not a major source of technological development, and that geographical proximity between a university and a park was unlikely to have much effect in promoting technology transfer. In this context, some authors talk about 'high tech fantasies' (Phillimore, 1999), while others find that in-park firms are no more innovative than out-park firms (Radosevic and Myrzakhmet, 2009).

Although policy makers tend to believe that there is a positive and direct link between the services provided by a park and firms' growth, this linkage is not simple and there is still a lack of knowledge on how one affects the other. STPs are often interpreted as drivers of regional development (Cooke and Imrie, 1989) because they foster innovative activities and regional growth (Yang *et al.*, 2009a), with effects that may be not confined inside an STP's border.

Overall, the implications of STPs are very much larger and include changes in the spatial distribution of economic activities and in the skill composition of the labour force, as well as gains in productivity. Although most of the economic literature is quite optimistic about the positive role of parks, especially Science Parks, it is important to note that some of the claimed effects may hardly have existed, or may apply only for some types of firms or parks. In consequence, to more precisely identify the effects of STPs, we take into account the heterogeneity of in-park firms and the geographical areas where the STPs of our sample are located.

To investigate the relationship between a firm's performance and its location inside / outside an STP, we use data for 170 firms located inside 12 Catalan parks (in-park firms) and 7,190 firms located outside these parks (out-park firms). We test whether in-park firms had the same performance in the period 2006–2013 as did out-park firms located in the same geographical area and having similar internal characteristics.

The aim of this paper is twofold. Firstly, to study the way in which being located in a Catalan park influences firm growth (as measured both in terms of sales and employees). Secondly, to introduce an econometric strategy capable of dealing with the specificities of firms' growth. Using Quantile regressions and controlling for fixed effects has not been fully considered in most of the previous empirical work of firms' growth. We consider that this is a relevant approach as the empirical evidence regarding the role played by STPs on firm performance is quite inconclusive (Colombo and Delmastro, 2002) and most of previous techniques used are far from appropriate. To sum up, the novelties of this paper come from *i)* the extensive set of in-park firms used endures data quality for STPs and the firms located in them, *ii)* the use of alternative measures of firms' growth (both in terms of sales and employees), *iii)* the distinction between Science Parks and Technology Parks and, finally and most importantly, i*v)* the inclusion of firms' heterogeneity in terms of the effects of parks on their performance.

This paper is organized as follows. The second section offers an overview of the main literature on STPs and presents the hypotheses of the empirical analysis. The third section shows the main characteristics of Catalan parks. The fourth and fifth sections present our dataset and econometric methodology, respectively. The sixth section discusses the main empirical results. The final section highlights the main conclusions and suggests further research.

2. Literature review

Analyses of the determinants of firm growth tend to focus on observable variables (Audretsch *et al.*, 2014) such as age, size or industry, while less attention is paid to the non-specific characteristics shared by a group of firms operating in a geographical area. Traditionally, researchers relied almost entirely on a firm's specific characteristics to explain its growth capabilities but, increasingly, the regional dimension of economic activity has attracted attention. Among such external determinants, growing empirical evidence demonstrates that the geographical area in which a firm locates helps to shape its competitiveness and growth capacity.

Most of these external determinants are closely related with agglomeration economies, as the proximate location of firms and institutions fosters interactions and increases their individual efficiency (Puga, 2010) and firm growth. Additionally, STPs may act as incubators for firms (Phan *et al.*, 2005; Colombo and Delmastro, 2002). Among such agglomeration economies there are those generated at STPs, where high-tech firms interact with their counterparts, as well with research centres and public agencies, generating knowledge spillovers that increase their competitiveness and foster growth.

Although much empirical evidence shows that in-park firms have higher growth rates (Lindelöf and Löfsten, 2003; Monck *et al.*, 1988) than their out-park counterparts, it is important to be cautious because some analyses may suffer from technical limitations such as potential selection bias (Dettwiler *et al.*, 2006) arising from factors like in-park firms belonging to high-knowledge industries for which growth rates are high regardless the location, or because public policies fostering NTBFs have allocated more resources for in-park programs than for out-park firms (Löfsten and Lindelöf, 2002). There are many arguments supporting the existence of agglomeration economies fostering in-park firms' performance[1] and most of them can be grouped under traditional Marshallian externalities in terms of *i)* specialised labour markets, *ii)* subsidiary firms and *iii)* technological spillovers.

Firstly, in terms of specialised labour markets, the geographical concentration, inside an STP, of firms having related activities helps to generate a specialised workforce with similar skills that may be easily transferred between firms (Baptista and Swann, 1998). Secondly, in terms of the existence of subsidiary firms, there is a similar mechanism generating economies of scale for the supply of specialised inputs and services (Baptista and Swann, 1998). Thirdly, in terms of technological spillovers, these may arise intra-firm or between them and research centres / universities (Díez-Vial and Fernández-Olmos, 2015). Additionally, some authors (Ferguson and Olofsson, 2004) focus on intangibles such as an STPs' capacity to attract additional customers and to create tighter network relationships. Additionally, spillovers captured from STPs may differ over time, as young firms and those industries in earlier stages of the industry life cycle may benefit more intensively (Díez-Vial and Fernández-Olmos, 2017). These effects may be direct or indirect, as suggested by Salter and Martin (2001) who found

[1] Apart from reported effects in terms of higher growth rates, STPs are argued to favour innovation activities (Vásquez-Urriago *et al*., 2016b; Yang *et al.*, 2009b; Siegel *et al.*, 2003a), to increase R&D intensity (Westhead, 1997), to strength firms' absorptive capacity (Cohen and Levinthal, 1990), to foster productivity (Liberati *et al.*, 2016; Vásquez-Urriago *et al.*, 2014; Dettwiler et al., 2006; Siegel *et al.*, 2003a) and research productivity (Siegel *et al.*, 2003a), to drive firms to R&D cooperation with external partners (Vásquez-Urriago *et al.*, 2016a; Fukugawa, 2006) and to cooperate with local universities (Löfsten and Lindelöf, 2002; Segarra-Blasco and Arauzo-Carod, 2008).

that, although the direct impacts of in-park location on firm growth were small and somewhat random, there were other indirect impacts such as the provision of skilled workers, the R&D facilities and the ability to solve complex problems.

In view of expected positive effects of STPs, during last decades policy makers commonly consider STPs as potential drivers of regional economic development (Durão *et al.*, 2005) and, therefore, encourage universities to cooperate with them (Dettwiler *et al.*, 2006), and try to implement policies that promote new technology-based firms (henceforth NTBFs) inside their borders (Yang *et al.*, 2009b).

Nevertheless, other scholars argue against the existence of "real" positive STP effects (e.g., Colombo and Delmastro, 2002; Löfsten and Lindelöf, 2002; Westhead, 1997). As the results are often inconclusive, the empirical literature has highlighted potential issues such as the selection bias (e.g., Lindelöf and Löfsten, 2003; Lindström and Olofsson, 2002) that need to be taken into account. Additionally, we may find other causes due to the characteristics of STPs and regions where they are located.

Concerning the characteristics of STPs, there are arguments that rely on mismatches between the expectations and the real capabilities of STPs, as well as on a lack of agreement on characteristics needed to be considered as an STP. Recently, policy makers in several countries have increased their expectations of the capacity of STPs to drive growth[2] and, consequently, public support to STPs has expanded considerably. Unfortunately, some of these new parks do not really correspond to the definition of an STP, a business park managed by professionals that fosters knowledge generation and diffusion inside its borders. Some authors also argue that the real effects of STPs are much smaller than expected (Díez-Vial and Fernández-Olmos, 2015). This is a critical point that suggests that being in an STP is not enough *per se* and must be accompanied by other measures taken by a firm in order to ensure that it benefits from the decision to locate inside a park, as suggested by Vásquez-Urriago *et al*. (2016b) when highlighting the importance of interaction between parks' opportunities and firms' internal innovation efforts. Furthermore, the heterogeneous characteristics of STPs may have heterogeneous impacts; Liberati *et al.* (2016) and Albahari *et al.* (2017), for example, find that STP characteristics affect the innovation performance of in-park firms.

Concerning the development level of countries where these parks are located, some of the previous concerns relate to whether STPs may carry out the same role and obtain the same effectiveness, no matter what the institutional environment in which they are located. At this point, it seems that the answer is clearly "No"—geography and institutions matter. In view of the success achieved by some STPs in developed countries, the policy makers of less developed countries have considered STPs to be potentially successful tools, but some case studies (e.g., Rodríguez-Pose and Hardy, 2014) suggest that what is appropriate for a developed country is not necessary appropriate for a less developed one. In a similar way,

[2] There are also some endogeneity issues to be considered (see Appold, 2004).

additional empirical evidence is needed in case of very different institutional settings, as Cheng *et al*. (2014) suggest for the case of Chinese Science Parks.

These requirements apply not only in terms of developed vs. developing countries but also for some developed countries[3] where STPs may have neither the functions, not the results, of a successful park. Among potential explanations for such failures, one may highlight that some parks are not capable of generating sufficient linkages with the local economic environment. Furthermore, in view of the empirical evidence showing that there is not always a direct link between location in a STP and achievement of higher innovation performance (Siegel *et al*., 2003b), there are important uncertainties for STPs located in core countries— a central location is a necessary, but not sufficient, condition, for instance, an in-park firm's relationships may expand beyond the local borders of its STP (Minguillo *et al*., 2015).

In order to properly account for STPs influences on firm growth, it is necessary to isolate all factors other than mere membership. Unfortunately, most of current empirical evidence does not take these factors into account and, consequently, the role played by these institutions over a firm's performance is neither clear nor evident. In our attempt to shed some light over the relationship between STPs and firm growth, the main hypothesis tested in this paper is the following:

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[3] See Liberati *et al.* (2016) and Díez-Vial and Fernández-Olmos (2017) for the Italian and Spanish case, respectively.

"In-park firms have, on average, higher growth rates (as measured in terms of employment and sales) than out-park firms."

This hypothesis assumes that STPs provide in-park firms with a business environment that enhances their growth capabilities (Dettwiler *et al.*, 2006). This expected growth dynamism could be partially explained in terms of selection bias in order to become an in-park firm (Ferguson and Olofsson, 2004). Biases arise because in some countries there are public policies promoting science parks that include financial support to in-park firms (Liberati *et al.*, 2016; Siegel *et al.*, 2003b), or because there is better (Phan *et al.*, 2005), and more diversified (Monck *et al.*, 1988) accessibility to external funding for in-park firms. However, in our empirical application we control for all these potential biases by applying a matching procedure that ensures that in/out-park firms have a similar profile (see Section 4.2).

In line with recent empirical research literature (Vásquez-Urriago *et al*., 2016a; Diez-Vial and Fernández-Olmos, 2015, 2016; Liberati *et al.*, 2016; Lamperti *et al.*, 2017), this paper differs from earlier research that predominantly considered park location effects on firm growth patterns as direct and stable relationships. Previous empirical studies estimate the effects of park location over firm growth with OLS, probit, or tobit econometric estimations.[4] We however apply a quantile

[4] A quantitative review of the existing literature on parks can be found in Diez-Vial and Montoro-Sanchez (2017).

regression methodology in order to capture the heterogeneous effect of locating in an STP on firms' growth.

3. The Catalan park network

In 2002, the International Association of Science Parks defined a Science Park as an organization managed by skilled professionals, whose main aim is to increase the wealth of its territory by promoting the innovation, the R&D cooperation and the competitiveness of its associated businesses and knowledge-based institutions. In view of this generic definition, it should not be surprising to find a wide range of identifiers for STPs (Fukugawa, 2006). For instance, "Science Park" is used in the United Kingdom; "Technopole" or "Technopolis" in France; "Technology Centre" or "Technology Park" in Germany; "Science and Technology Park" in Spain; and "Research Park" is mainly used in the U.S.A. (Bellavista and Sanz, 2009).

According to the managerial institutions of the Catalan park network, there are two kinds of parks, Science Parks and Technology Parks. On the one hand, a Science Park is the result of an initiative from one or several universities and the Catalan government. Its main purposes are to facilitate the creation of spin-offs and NTBFs and to promote the link between high-tech firms and research university groups. On the other hand, Technology Parks are created through common efforts by local public agents, the Catalan government, and clusters of innovative firms. In these initiatives, technological centres and universities ensure technology transfer between research institutions and local firms. During the current economic crisis, European regions such as Catalonia have changed their STPs' orientation from technology transfer mechanisms and towards institutions that aim at boosting entrepreneurship initiatives (Areti *et al.*, 2016).

Catalonia has a network integrating the 17 STPs, known as *Xarxa de Parcs Científics i Tecnològics de Catalunya* (henceforth XPCAT). In this paper, we focus on the twelve of these parks that have offered us information about resident firms (see Table 1).

[Insert Table 1 about here]

4. Database and descriptive statistics

4.1. Database and selection procedure

The following econometric analysis uses data collected from two sources. First, we use information offered by the XPCAT and complemented by data from the Spanish STPs network (*Asociación de Parques Científicos y Tecnológicos de España*, henceforth APTE) in order to identify the Catalan firms located inside the parks. Second, we compile financial and budgetary information of Catalan companies using data from the Spanish Mercantile Register (*Sistema de Análisis de Balances Ibéricos*, henceforth SABI) compiled by Bureau van Dijk. This database contains exhaustive information on balance sheets at the firm level.

We collected detailed information for firms covering the period 2006–2013. This period represents the consolidation of the Catalan policy to create new Science and Technology parks. Before 2008, Catalan policy was more oriented to locate the facilities in order to reinforce the Catalan Innovation System. The main objective was to foster the generation of innovations and increase competitiveness. Once the main infrastructures had been designed, in 2008 the Catalan government created a policy package that was more specialized and oriented towards the consolidation of its science and innovation system. Consequently, the period between 2006 and 2013 allows the comparison of the period after the creation of the main Science and Technology Parks in Catalonia.

In order to obtain our final database, we applied the following filtering process. Firstly, from the SABI database we selected firms located in those municipalities where there is an STP. Secondly, in order to get a comparable group of out-park firms, we selected firms that were operating in the same industry as those in-park firms. Thirdly, we considered only in-park firms located in Catalonia. Furthermore, using information obtained from the Spanish Statistics Institute, we deflated monetary variables to control for the effect of prices.

The Mercantile Register provides data on firms belonging to the STPs 1 to 9 listed in Table 1. Hence, our initial list of 1,103 participants shrank to 287 firms. In these parks there are 910 firms and our final sample rises to include 31.53% of the Catalan in-parks firms. In addition, the matching procedure ensures that the firms' size and age distributions are similar between out-park and in-park firms and that there are no selection bias problems between the two groups of firms. We should point out that a selection bias might occur if the observed in-park firms were not representative of all in-park firms. However, we consider our sample to be sufficiently representative of firms located in Catalan STPs.

4.2. The matching procedure

Mainly due to a potential selection bias, the empirical literature has raised a certain scepticism about STPs capacity to foster firm growth. There are several reasons for this. Firstly, because in-park firms are younger and smaller than out-park firms (Lindström and Olofsson, 2002; Ferguson, 1999). Also, differences in firm size may result in higher growth rates in order to overcome the "liability of newness" and to achieve a minimum efficient size (Coad *et al.*, 2013). Additionally, bias may also be caused by the skill composition of in-park firms. In this sense, Lindelöf and Löfsten (2003) point out that in-park firms are mainly founded by academics, which implies that these firms are biased towards a skilled workforce and may result in these firms underperforming in terms of employment growth. Therefore, a higher performance of firms in STPs may be the consequence of a spurious relationship arising from a selection bias problem. Thus, we consider that the probability of a firm located in an STP is not a random process, and that one must control for the factors that make firms more likely to be recruited by a park manager. These factors also affect potential firm growth and thus require an appropriate control mechanism.

Following the existing literature (Liberati *et al.*, 2016; Lamperti *et al.*, 2017), we control for selection bias by matching treated (i.e. in-park) and untreated firms (i.e. out-park). The matching procedure leads us to control for these individual characteristics that in-park firms may have and which may result in a different propensity to be in an STP, and so to find a homogenous comparison group between in-park and out-park firms. Matching techniques allow the comparison of two potential results, W1 for those firms receiving the treatment (D=1), and W0 for those firms not receiving any treatment (D=0). Matching is based on the conditional independence assumption, which states that, conditional on a vector of covariates, the potential outcomes W1 and W0 are independent of D. In order to ensure that this assumption is fulfilled, it is necessary to observe those variables that simultaneously affect the firm growth and the selection of being located in a STP.

Following Lamperti *et al.* (2017), here we apply coarsened exact matching (CEM) as described in Iacus *et al.* (2008) and Blackwell *et al.* (2009). This is a non-parametric technique that establishes a covariate balance between treated and control units, but offering some advantages. First, CEM does not require assumptions about the data generation process. Hence, users can make robust inferences without any such assumptions. Second, CEM allows establishing, ex ante, the bounds within which matched comparisons are to be made. This procedure may reduce the statistical bias associated with their estimates. Therefore, CEM meets the congruence principle and it restricts the matched data to areas of common empirical support (Iacus *et al.*, 2011).

CEM temporarily coarsens each variable by recoding so that substantively indistinguishable values are grouped and assigned the same numerical values. In other words, CEM temporarily coarsens each "*k*" treatment-related variable into "*m*" substantively meaningful categories and assigns units into one of $k_{m1} \times k_{m2} \times$ …. k_{mm} strata. Observations within strata without at least one treated and control unit are zero-weighted, while observations within "matched" strata are weighted according to the number of treated and control units contained.

The covariates used to determine the strata are grouped in three different characteristics. First, we include the firm age and firm size. Firm size distribution is highly skewed and this must be taken into account. CEM allows us to create intervals of matching and we have created four categories of firm sizes which group firms from 0 to 10 employees, from 11 to 50 employees, from 51 to 250 employees and larger than 250 employees. The matching procedure considers these four different group sizes. Secondly, we introduce the sector in which the firm operates (by considering a two-digit level) and a dummy that identifies firms located in Barcelona. We assume that firms located in Barcelona city enjoy larger agglomeration economies (hence, controlling for their location is also necessary). Finally, we capture a firm's technological capacity by creating the ratio of a firm's productivity (as calculated as sales per worker) to the sectoral average productivity. This variable allows us to control firms which are above or under the sectoral productivity level and to proxy for technological or knowledge intensity at firm level[5].

From the total number of 69,553 observations of out-park firms, 24,037 observations belonged to the matched sample and from the 1,803 observations of in-park firms we obtained 654 matched observations. Afterwards, CEM removes unmatched observations and a ''matched'' sample is subsequently refined for post-matching analysis. The CEM controls for the selection bias between in-park and out-park firms by generating homogenous groups of firms. Hence, the sample is capable of estimating the differences between a group of homogenous firms inside STPs and those outside.

[Insert Table 2 about here]

Table 2 shows the multivariate distance with CEM for our main variables indicating the imbalance of the variable between the distribution of all respondents and the matched sample. Furthermore, the remaining columns report the different value of the quantile distribution in order to compare the values of

[5] Other variables measuring a firm's technological capacity might have been the R&D investment or the percentage of skilled workers. However, the SABI database does not provide information of these parameters. Our normalized indicator of the labour productivity might be considered as a proxy that compares the performance of a firm with their competitors in the same sector. We assume that a larger productivity implies firms with larger capacity to be more competitive in the market.

the initial sample and the matched sample. The information shows that the distribution of every variable is balanced.

Once we have identified the sample of treated and control firms, we apply a quantile regression in order to analyse the impact of belonging to a STP on firm growth. The output of the CEM methodology estimates the representation weights of the firm. These weights are included in the corresponding estimations (Table 4 and Table A-4). Here we adopt a double measure of the firm growth: sales and employment firm growth.

Finally, we should mention that there is a potential under-estimation of indirect impacts due to the existence of indirect impact on out-park firms. Out-park firms located close to the STPs, or with close relationships with agents inside the STPs, may benefit from the growth. However, although our data does not allow us to disentangle these indirect impacts, we should note that such was not the purpose of the paper, but rather to report the different trend that in-park firms may have in comparison with out-park firms and to capture the heterogeneous impact that location in a STP may have on a firm's growth. Finally, as stated previously, a selection bias may arise if the observed in-park firms are not representative of all in-park firms.

4.3. Descriptive statistics

Table 3 shows the mean tests of characteristics between the finally selected in-park and out-park firms (see Table A-1 and A-2 for additional data). Out-park firms show some significant differences in the mean test. In-park firms have a higher propensity to export, and high-tech manufacturing sectors and knowledge intensive services are overrepresented. Regarding those variables related with firm performance, in-park firms show larger growth rates in terms of employees. However, the mean difference is not significant for sales growth rates. One explanation for this behaviour is that firms located in an STP are developing new projects and may have larger growth rates on average. Finally, in-park firms are significantly different in age and size, regardless the measure of size, from their out-park counterparts.

[Insert Table 3 about here]

Table 3 also shows that there are significant differences between firms located in Science Parks and those in Technology Parks. The difference-of-means tests show that firms located in Technology Parks are older and larger than firms located in Science Parks. Furthermore, the results indicate that firms in Science Parks belong to high-tech manufacturing sectors and Knowledge Intensive Services. Hence, it seems that they are more similar to NTBFs, which are characterized by being young and operating in high-tech sectors. Finally, firms in Science Parks show a lower propensity to export, have a lower productivity, and have higher sales growth.

[Insert Figure 1 about here]

The key variable in our analysis is logarithmic firm growth measured in terms of sales and employees. Figure 1 shows firm growth distribution for our matched sample. We observe that there are differences between in-park and out-park firms. In terms of sales and employment growth, the density in the modal growth of in-park firms is smaller, while their density is larger in the right tail. Additionally, Figure 1 highlights the unequal distribution of growth rates and also the fact that the dispersion of the in-park firms is larger than out-park firms. Finally, this figure also reports the Kolmogorov–Smirnov test results, which show that the null hypothesis of equality for the growth distributions is rejected.

5. Econometric methodology

After the matching procedure, we test whether in-park firms perform differently from out-park firms. For this, we estimate the following equations:

$$GrSales_{i,t} = \alpha_{10} + \alpha_{11}Parks_{i,t} + \alpha_{12}\,Controls_{it-1} + \varepsilon_{1it} \quad [1]$$

$$GrEmpl_{i,t} = \alpha_{20} + \alpha_{21}Parks_{i,t} + \alpha_{22}\,Controls_{it-1} + \varepsilon_{2i,t} \quad [2]$$

where α_i are the coefficients to be estimated and ε_{it} is the usual error term for firm *i* at time *t*. Our dependent variables differ depending on our hypothesis. Equations [1] and [2] estimate the determinants of firm growth. Firm growth rates are measured in terms of two growth indicators: sales growth (*GrSales*) in Equation [1] and employment growth in (*GrEmpl*) in Equation [2]. Firm growth rates are calculated by taking log-differences of size between period "t" and period "t-1".

We include two sets of explanatory variables according to the nature of the variable (see Table A-3). Firstly, we include a dummy that identifies firms that are located in STPs (*Parks*). Second, we include some control variables of firms' characteristics such as firm size, measured in log employees (*lnLab*) or log sales (*lnSales*); firm age in log (*lnAge*), and its quadratic value (*lnAgesq*); the ratio of long-term funding to asset ratio (*LTdebtAssets*); the ratio of the profits to assets (*ProfitsAssets*); the productivity ratio measured and the log of the sales to workers ratio (*SalesLab*). All the variables are lagged in order to avoid problems of endogeneity. Finally, we include sector and time dummies to control for specific industrial characteristics and different time periods.

In order to capture the different effects that the determinants may have on firm performance, we estimate Equations (1)-(2) using quantile regressions (Koenker and Bassett, 1978). Quantile regressions are preferable to other techniques for several reasons. First, the standard least-squares assumption of normally distributed errors does not hold for our data, because firms' growth rates follow a Laplace distribution. Second, quantile regressions describe the distribution of the dependent variable. And third, quantile regression is more efficient in treating outliers and heavy-tailed distributions. Furthermore, they allow us capture the heterogeneous impact that STPs have on firm performance (Vásquez-Urriago *et al*., 2016a).

Recently, quantile regressions have been applied to panel data (Koenker, 2004; Canay, 2011). In line with previous empirical analysis (Mazzucato and Parris (2015; Coad *et al.* 2016), we apply panel quantile regressions following Canay (2011). Panel quantile regressions allow us to control for time-invariant firm-specific effects in order to better analyse the effect of locating in a science and technology parks on firm growth. We proceed to estimate firm growth in two steps. First, we estimate the unobserved time-invariant effects by least-squares estimation (i.e. using usual fixed-effect regression). Once we obtain the unobserved time-invariant effects, it is assumed that the same value is taken across the quantiles. Second, we apply the quantile regression estimator (Koenker and Bassett, 1978) with a new dependent variable which removes the fixed-effect of our initial dependent variable. This new dependent variable is regressed on our independent variables. Therefore, the quantile regression includes only the time-varying error term once the influence of the time-invariant variable has been controlled for.

In view of the characteristics of firms included in our dataset, fixed-effects quantile regression seems to be the more appropriate methodology as it allows us to explain the influence of the location in STPs on firm performance, both for those firms that are successful and for those that are less successful. To this end, we present results for the quantiles $\theta = 0.10, 0.25, 0.50, 0.75$ and 0.90.

6. Results

Our results (Table 4) suggest that the effects of STPs on firm growth are quite complex, as there is some heterogeneity of firms in terms of their capacity to benefit from being inside an STP. In fact, in-park firms are diverse in terms of, inter alia, size, age, financial condition or technology stream. Furthermore, the nature of the parks is heterogeneous in many ways which include proximity to urban concentrations, capacity to promote creative knowledge, specialisation and governance.

Our results show that i) firms with growth rates over the upper quantile distribution receive a positive impact for being located in an STP and that ii) firms with growth rates over the lower quantile distribution receive a negative impact for being located in an STP. These results are in line with the heterogeneous effect of STPs on firms' innovation outcomes (Vásquez-Urriago *et al*., 2016a).

[Insert Table 4 about here]

These results indicate that the relationship between in-park location and firm growth is neither direct not simple. In this sense, although our results may seem that refuse our initial hypothesis, on closer investigation, this effect exists but not for all firms. Concretely, whilst being located in a park has a positive influence for high-growth firms, the effect is negative for medium-low growth firms. We note that our matching procedure included a proxy for a firm's innovation capacity. Due to lack of information on a firm's innovation behaviour, our STP location results may also be capturing the different innovation nature between in-park and out-park firms. Our results are complementary to previous analyses such as Albahari *et al*. (2017, 2016), Vásquez-Urriago et al. (2016a, 2014) and Díez-Vial *et al*. (2017) which use the Spanish Community Innovation Survey.

This raises questions about the role of STPs in terms of regional development, as our results indicate that STPs accentuate the process of firm selection, facilitate the growth and survival of dynamic firms, and penalize others (according to the positive / negative effects on firm growth). Hence, the role of the STP is not so much as a key driver of the regional development but as a filter of the key factors responsible for capturing the added knowledge value.

[Insert Figure 2 about here]

In terms of the effect of in-park location on firm growth, i) Figure 2 illustrates, in a general way, the marginal effects of location inside an STP on firm growth, measured both in terms of sales and employees, showing that impact of in-park location is slightly higher when measuring growth using sales than when using employees; and ii) Figure 3 and Table A-4 investigate in more detail the specific effects of Science Parks and Technology Parks, showing that firms located in Science Parks have a larger sensitivity across the quantile distribution in comparison with firms located in Technology Parks, for which the in-effect is lower, although the dispersion in the tails is higher for the latter. Additionally, while for Science Parks there is clearly an increasingly positive effect across quantiles, for Technological Parks the effect is not linear. In contrast to our results, Lamperti *et al*. (2017) found that firms located in science parks do not achieve higher growth rates.

[Insert Figure 3 about here]

In Table 4, it is shown that being in an STP enhances employment and sales growth among firms in the upper quantiles, while the impact is negative for firms in the lower quantiles. This is a key point as it indicates that being in an STP may be a necessary condition for growth but it is not sufficient one—no firm will experience growth just because of its location in an STP, but only because of some additional determinants. At this point, we may suggest heterogeneity in terms of absorptive capacity as one potential explanation of these asymmetrical effects, since not all firms have the same capacity to internalize external effects arising from being inside an STP. Nevertheless, although in general terms our results partially corroborate previous evidence supporting STPs as institutions that foster employment and sales growth (Liberati *et al.*, 2016; Dettwiler *et al.*, 2006; Ferguson and Olofsson, 2004) and, therefore, public policies supporting STPs are needed in order to foster the growth of more dynamic firms, this may not be viewed as an optimal strategy for all types of firm. Consequently, the asymmetrical STP effect raises the question of whether it is necessary to have rigorous selection criteria before locating in an STP.

Finally, our results illustrate some other interesting features. Firm age shows a significant non-linear relationship with firm growth. In particular, this variable shows an inverted U-shaped pattern. So, firms with more experience in the market enjoy larger growth rates, however those firms that have been operating over a long period in the market may have learning diseconomies. In line with the empirical literature, firm size is negatively associated with firm growth; small firms grow more quickly than larger firms. This effect points out that there is a convergence process of firm sizes to a medium efficient size, in which small firms achieve growth rates larger than those of large firms. Regarding the financial variables, the ratio of long-term funding shows, on average, a negative impact (quantile 50%), while the ratio of profits shows a positive effect. On the one hand, access to long-term funds may foster firm growth, but an excessive level may constrain a firm's capacity to decide their investments. On the other hand, a larger profitability generates unused assets that may be devoted to expanding the firm. Finally, the coefficient of the productivity indicates a significant negative impact on the sales growth rate, but a positive one on the employment growth rate. This result may be justified by the fact that high productive firms will have incentives to increase the number of employees in the following period, while the increase in the sales growth rate may not be so immediate.

When discussing empirical evidence about role played by STPs, it is important to properly take into account the institutional settings of the areas where these parks are located as well as the industries in which in-park firms operate. On this subject, firms included in our data set are clearly less knowledge intensive than in some Northern European countries, where STPs have been considered as being important drivers of regional economies. Although this point may explain some of previous differences, using quantile regressions allows us to control for firm heterogeneity in order to precisely identify whether, as seems very likely, parks' effects may differ across firms.

7. Conclusions

Based on a sample of 170 firms located in Catalan Science and Technology Parks, we explore whether location in STPs impacts firm performance. The empirical analysis controls for the potential selection bias applying a matching procedure between in-park firms and an extensive sample of out-park firms according to the industry each firm belongs to, the municipality where the firm is located, the firm size and the firm age. Having controlled for this potential selection bias, we apply a quantile regression estimation in order to obtain the impact of locating in STPs on firm growth, and because we are interested in pointing out that the impact of park location on growth in terms of employees and sales differs according to the firm's level of dynamism.

Our main results may be summarized in three different points. First, being located in a STP has a dual effect on firm performance—for high growth firms an in-park location has a positive effect in terms of growth, while for low growth firms the effect is negative. Accordingly, not all firms may be interested in locating inside an STP nor should public administrations promote parks for any kind of firm. This is an important outcome as a large strand of academic literature has enthusiastically favoured STPs as key drivers of regional development regardless of a firm's profile.

Second, our results are robust to alternative measures of firm growth, as we have calculated growth both in terms of sales and workers, these being broadly similar. Third, when comparing the role of science parks with that of technological parks, our results suggest the former have stronger effects than those of the latter. This is also a key finding, suggesting that the potential utility of Science Parks as a policy instrument is higher than that of Technological Park, although the risks are also greater.

Our results provide some useful insights in terms of policy implications and we explore two of these. The first insight is of the unequal effects of STPs over firms' performance. We have demonstrated how the effects of STPs are not the same across the whole range of in-park firms, suggesting that not all firms benefit in the same way from belonging to an STP. This result implies that public policies supporting STPs should be restrictive in terms of the firms that enter into these parks. The second insight suggests that policy makers should not only control the type of firms inside STPs, but also revise public policies related to the promotion of STPs, noticeably in some Southern European countries where policies have imitated those of Northern European countries. Concretely, STP promotion by policy makers has expanded considerably and this may not be an optimal strategy given that STPs may not be the best choice for some low-performance firms, or some laggard regions.

This research has some potential limitations. First, our matching procedure ensures that in- and out-STP firms are similar, thus reducing selection bias between the two groups of firms, but such a bias might still occur if the observed within-STP firms were not representative of all within-STP firms. Our sample is, however, broadly representative of firms located in Catalan STPs. Second, the matching procedure includes a proxy for a firm's innovation capacity given that we did not have information on R&D and innovation investment. Hence, the matching procedure might not fully capture the innovation capacity of firms. Finally, regarding future research directions, in order to disentangle potential restrictive effects caused by the economic crisis in the period 2006–2013, we intend to explore whether our results hold for different periods.

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