



# Science and technology parks and their effects on the quality of tenants' patents

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## Abstract

Science and technology parks (STPs) have proliferated in many countries as an innovation policy tool. Several studies have used patent counts to assess their impact on innovation performance rather than the quality of patents, leading to mixed results. The aim of this paper is to explore whether STPs contribute to increasing the quality of patents filed by tenants since patent counts alone do not capture the technological or economic value of the patented inventions. Using a novel database of Spanish patents generated on- and off-park together with firms' characteristics, we compare the quality of patents filed by firms located inside and outside STPs and find that STPs have a positive effect on the quality of the tenants' innovative performance. We apply a novel econometric technique to confirm that our results are robust to omitted variable bias and explore possible channels through which STPs produce an effect on patent quality, such as by facilitating collaboration, increasing collaboration with universities, and fostering the internationalisation of inventions.

**Keywords** Science and technology parks · Innovation performance · Patent quality · Innovation · Innovation policy

**JEL Classification** O31 · R11

## 1 Introduction

Interest in the effects of business agglomerations on firm innovation has grown rapidly in recent years (Carlino & Kerr, 2015) as innovation activities tend to be geographically clustered (Feldman & Kogler, 2010). The advantages for innovative firms to be co-located are related to Marshallian externalities, driven by specialisation, and to Jacobs externalities,

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driven by diversification (see, for instance, Beaudry & Schiffauerova, 2009). Science and technology parks (STPs) are a special type of agglomeration. In particular, STPs<sup>1</sup> are non-spontaneous clusters, often the result of political decisions, aimed at promoting the creation and growth of knowledge and technology-based firms with a management team that pursues the objectives of the park.

STPs are a widespread innovation policy tool that can play a central role in shaping and developing the entrepreneurial ecosystem (Germain et al., 2022). The interest in this type of cluster has grown steadily in both developing (Rodríguez-Pose & Hardy, 2014) and developed countries (Hobbs et al., 2017). There are more than 360 STPs in Europe (Rowe, 2014) and over 300 in North America (Battelle Technology Partnership Practice, 2013).

Public investment involved in the creation and development of STPs also reflects the importance of STPs in science, technology, and innovation policies, with an estimated 85% of STPs in the EU publicly funded between 2000 and 2012 with around €4.8 billion (Rowe, 2014). STPs are considered important vehicles of innovation policies in many countries, such as Spain (Vásquez-Urriago et al., 2014), where the Science, Technology and Innovation Law of the government states that<sup>2</sup> “[...STPs are] strategic places for the transfer of research results to the productive sectors”.

The academic literature on STPs has paid particular attention to the assessment of on-park effects on the innovation performance of firms. Among the several indicators used to estimate the effect, patent count is one of the most common.

Patents are an indicator of the inventiveness of firms, which is considered a precursor of innovation (Roberts, 1988). One of the key advantages of using patent statistics is their availability, together with the richness of information they provide and their accessibility (Higham et al., 2021; van Zeebroeck & van Pottelsberghe de la Potterie, 2011b). Despite their well-known limitations (Griliches, 1990; Griliches et al., 1987), patent counts are commonly used as an indicator of innovation in economic studies. Nonetheless, measuring the innovativeness of companies based only on patent count disregards the highly skewed nature of their value distribution (Archibugi, 1992; Cohen & Levin, 1989; Griliches, 1990). Survey data show that there are only a small number of highly valuable patents and a large number of patents with little value. Scherer and Harhoff (2000) showed that about 10% of patents account for more than 80% of the value of all the patents, based on a survey of German patents. This conclusion was supported by other authors, such as Gambardella et al. (2008) on their European survey (PatVal-EU). The increasing number of patent applications (Kortum & Lerner, 1999; van Zeebroeck et al., 2009) and new patenting strategies (Guellec & van Pottelsberghe de la Potterie, 2007; Guellec et al., 2012) exacerbate this issue.

The importance of taking into consideration the heterogeneity of innovations has been pointed out in a recent study (Higham et al., 2021). Patent quality is a multidimensional concept which encompasses diverse dimensions of patents such as technological importance and economic value. Using patent quality allows us to take into account the heterogeneity of patents, which may be one of the reasons why studies on STPs using patent count as an indicator of tenants' innovation performance have led to contrasting evidence, with some showing positive effects of STPs on the number of

<sup>1</sup> In its definition of STPs, the International Association of Science Parks (IASP) states “a science park is an organisation managed by specialised professionals whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions”.

<sup>2</sup> Available at <https://www.boe.es/buscar/pdf/2011/BOE-A-2011-9617-consolidado.pdf>.

patent applications (e.g. Hu, 2008; Squicciarini, 2008) and others showing no effect (e.g. Chan et al., 2010; Lindelöf & Löfsten, 2002a; Squicciarini, 2009). In fact, this idea is supported by Ünlü et al. (2022) in their study suggested that patent count might not be the adequate indicator to estimate STP performance. Considering patent count or patent quality as dependent variables may lead to different results as argued by Dang and Motohashi (2015).

To deepen our understanding of the effects of STPs on the innovation performance of tenants, we use patent quality to estimate the effect of STPs on firm innovation performance, considering that it measures the relevance of the inventive activity of companies better than patent count (Dang & Motohashi, 2015). We estimate patent quality using forward citations as a proxy for the technological importance of patents and renewals as a proxy of their economic value. To our knowledge, patent quality has not been used in previous studies of the effect of STPs on tenants' innovation performance.

On a methodological level, we use the patent as the unit of analysis and control for a rich set of patent and firm characteristics. We rely on the 'ignorability assumption' (that is, STP location is not driven by unobserved firm characteristics that also affect patent quality) to identify the STP effect. Nonetheless, to alleviate the concern that our estimates may suffer from omitted variable bias, we apply a novel econometric technique (Cinelli & Hazlett, 2020) to show that our results are robust to strong unobservable confounders. In addition, we perform a set of robustness checks to ensure that our estimates of the STP effect on patent quality are actually conservative.

Finally, we also explore the possible channels through which STPs can influence the quality of tenants' patents. Former scholars have discussed the role of STPs as a booster of cooperation, finding that being located in an STP enhances the likelihood of cooperating for innovation (Vásquez-Urriago et al., 2016), especially with universities (Colombo & Delmastro, 2002; Díez-Vial & Fernández-Olmos, 2015). Furthermore, the role of STPs as a facilitator to foster internationalisation of tenants has been pointed out by the International Association of Science Parks (IASP). Accordingly, we consider three possible channels through which STPs affect the quality of patents obtained by tenants: collaboration to achieve the invention, cooperation with universities and internationalisation.

The remainder of the paper is organised as follows: Sect. 2 presents a review of the literature and describes our analytical framework; Sect. 3 presents the data and methodology and describes the variables used; Sect. 4 presents the empirical results and robustness checks; Sect. 5 reports the results related to the STP channels explored; and Sect. 6 concludes, suggesting implications of the study and lines for further research.

## 2 Literature review

In this section, first, we review the literature on STPs, focusing on the effects they have on the innovation performance of their tenants. Second, we provide an overview of the concept of patent quality, explain how we measure it and provide a general description of the most used indicators in patent literature.

## 2.1 Science and technology parks and their effect on the innovation performance of tenants

The literature on STPs is rich and continues to grow, keeping pace with the growth of STPs worldwide (Hobbs et al., 2017), especially with regard to the effects of STPs on their tenants (for a review, see Albahari et al., 2022). The effect of STPs on tenants is a question of great interest to policy makers given the large amount of public funds invested. The literature on STPs is concerned mainly with estimating the impact on several dimensions of firms' results, such as their economic performance, their relationship with other entities and innovation performance (Lecluyse et al., 2019).

STPs are seen as tools to create certain conditions to facilitate innovation, acting as intermediary organisations (Siegel et al., 2003) or as a link between industry and science through the relation between tenant firms and academic researchers (Colombo & Delmastro, 2002; Fukugawa, 2006). The development and management of connections between diverse entities and the transfer of knowledge amongst them is another expected feature of STPs (Löfsten & Lindelöf, 2002; Squicciarini, 2008).

Even though a positive effect of STPs on the innovation performance of firms located within their boundaries may be expected (Lecluyse et al., 2019), and in spite of the attention paid to STPs by policy makers, scholars find varying results with respect to the effects of STPs. These inconclusive results are found in all the dimensions explored in the literature related to the influence of STPs on economic, cooperative and innovative aspects.

Several studies use patenting activity to estimate the innovation performance of tenants as shown in Table 1. We observe that previous studies use patent count as an indicator. Some of them find no significant effect on firms (Chan et al., 2010; Liberati et al., 2016; Lindelöf & Löfsten, 2002b, 2003; Squicciarini, 2009; Westhead, 1997), while others show that STPs have a positive impact on the number of patents obtained by tenants (Corrocher et al., 2019; Huang et al., 2012; Lamperti et al., 2017; Siegel et al., 2003; Squicciarini, 2008; Yang et al., 2009).

## 2.2 Patent quality

The notion of patent quality has a broad and multidimensional nature which encompasses diverse concepts such as economic value and technological importance (Higham et al., 2021; Nagaoka et al., 2010; Squicciarini et al., 2013) and depends on the viewpoint of the analysis (Guerrini, 2014). A patent may be valuable from an economic perspective, but its technological importance may not show the same trend and vice versa. As such, using diverse indicators to estimate patent quality makes sense as it allows us to consider the different dimensions of patent quality (Higham et al., 2021) and obtain more accurate results.

Earlier studies referred to patent quality by considering the technological importance and economic value of patented inventions and also their possible impact on subsequent innovations (van Zeebroeck, 2011; van Zeebroeck & van Pottelsberghe de la Potterie, 2011b; Squicciarini et al., 2013; Higham et al., 2021).

Forward citations are perhaps the most widespread indicator among scholars as they are closely related to technological importance (Carpenter et al., 1981; Griliches, 1990; Trajtenberg, 1990; Albert et al., 1991; Harhoff et al., 2003; Sapsalis & van Pottelsberghe de la Potterie, 2007). This is because we may interpret a patent with many citations as having a

**Table 1** Studies on the effect of STPs on the patenting activity of tenants

Paper	Country	Sample (firms)	Period	Dep_Var	Methods	Effect
Yang et al., (2009)	Taiwan	57 on-park 190 off-park	1998–2003	Patents granted	Mean comparison	+
Chan et al. (2011)	South Africa	24 on-park 28 off-park	2007	Patent applications	Binomial Logistic Regressions	NS
Corrocher et al. (2019)	Italy	470 on-park 511 off-park	2006–2013	Patent applications	OLS	+
Huang et al. (2012)	Taiwan	55 on-park 51 on-cluster 59 off-park	2003–2008	Patent applications	Negative Binomial	+
Liberati et al. (2016)	Italy	65 on-park 63 off-park	2012	Patent applications	Diff-in-diff estimations	NS
Lindelöf and Löfsten (2002a, 2002b)	Sweden	163 on-park 100 off-park	1996–1998	Patents	Mean comparison	NS
Lindelöf and Löfsten (2003)	Sweden	134 on-park 139 off-park	1996–1998	Patents	Mean comparison	NS
Lamperti et al. (2017)	Italy	147 on-park 146 off-park	2004–2012	Patent applications	Mean comparison/ OLS/ Negative Binomial	+
Siegel et al. (2003)	UK	89 on-park 88 off-park	1992	Patent applications or granted	Negative Binomial/Two-Step Negative Binomial	+
Squicciarini (2008)	Finland	252 on-park	1970–2002	Patent applications	Diff-in-diff estimations	+
Squicciarini (2009)	Finland	48 on-park 72 off-park	1970–2002	Patent applications	Duration model	NS
Westhead (1997)	UK	183 on-park /101 off-park and 47 on-park /48 off-park	1992	Patent applications or granted	Mean comparison	NS

+ positive significant effect at 10%, NS no significant effect.

greater impact on the technology fields in which it is developed. Because of its availability and informative richness, this indicator is firmly rooted in the literature.

Patent renewal is another commonly used indicator in turn related to the economic value of the patent (Bessen, 2008; Pakes & Schankerman, 1984). The fact that a patent is active for more years suggests that its patent holder expects a higher return than the money invested in keeping it alive (Pakes & Schankerman, 1984). Griliches et al. (1987) showed that patent renewal is positively related to the economic value of the patent. Patent renewals may be understood as a private economic value indicator (Pakes & Schankerman, 1984; Squicciarini et al., 2013), i.e. they reflect the economic value of the patent for their owner (Lanjouw et al., 1998).<sup>3</sup>

### 3 Empirical specification and data

In this section, we first present the main characteristics of the dataset used and, subsequently, introduce the empirical specification used in the estimations.

#### 3.1 Data

We build a database including information on all EPO patent applications filed by Spanish firms between 2004 and 2012, which amounts to 6,885 company patents for which we can retrieve firms' and patent quality information, 1,102 (16.0%) of which are from companies located in an STP.<sup>4</sup> The sample is limited to patents with an application date between 2004 and 2012 to allow a 7-year time window for properly observing the forward citations indicator.

The database has been built from different sources, as specified in what follows.

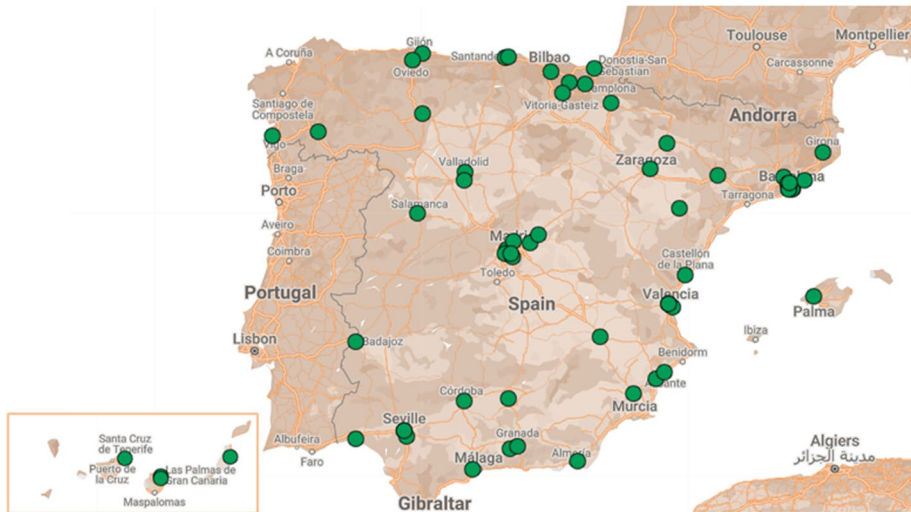
First, the January 2020 version of the REGPAT database from the OECD (Organisation for Economic Co-operation and Development) is the main source of patent information for our dataset as it provides information on patents since 1977 (priority date). The information contained in REGPAT, including the full addresses of applicants and inventors of patents, allows us to geographically locate the patents (Maraud et al., 2008) based on a methodology described below. REGPAT contains information on patent applications from the EPO (European Patent Office).

Second, the July 2021 version of the OECD Patent Quality Indicators Database provides several indicators related to the importance and value of EPO patents.

Third, the Iberian Balance Sheet Analysis System (SABI) database, a product of Bureau Van Dijk, accessed in August 2020, gives information on the balance sheets and other financial information on more than 2.7 million Spanish companies. The database provides

<sup>3</sup> Family size has sometimes also been used as an indirect proxy of patent value (Lanjouw et al., 1998) since the higher the number of countries where protection is sought, the larger the perceived quality of the patent, but we follow Higham et al. (2021) in considering that family size is an indicator of the internationalisation of the patented invention and, as such, we include it in our analysis of channels in Sect. 5.

<sup>4</sup> In a recent study, Albahari et al. (2022) show that sample size is one main driver of mixed evidence STP literature. They review 86 quantitative studies that analyse STP effect and find that it is more likely to achieve a positive and significant STP effect as the sample size increases. For example, if the sample size is larger than 800 on-park firms, the probability of obtaining a positive and significant STP effect is above 80%. Our research relies on a large sample, which is in line with this recent finding.



**Fig. 1** STPs included in the sample

historical information on the accounts of each company since 1990 and allows searches by company name and fiscal ID.

Fourth, the annual APTE directories of companies from 2004 to 2012 provide information on the firms located in the STPs of the APTE. They allow us to identify whether a patent applicant is located in an STP based on the methodology described below. The 2012 annual directory<sup>5</sup> of the APTE (Association of Science and Technology Parks in Spain) shows that 47 STPs belonged to the association (Fig. 1) and hosted more than 6,200 firms with almost 144,000 employees, 29,000 of whom were involved in R&D activities (APTE, 2013).

Bearing in mind that our unit of analysis is the patent, our database includes information related to the patent application (year of application, number of applicants, technological field of the patent), the company applicant (identification, applicant's address, postal code, province in which the applicant's address is located), the characteristics of the company (number of employees in the year of application, sales of the company in the year of application, age of the company in the year of application) and, finally, the patent quality indicators used as a proxy to estimate the innovation performance of tenants (forward citations and renewals).

<sup>5</sup> Currently, 54 STPs belong to the association, hosting more than 7,900 firms with more than 184,000 employees, 38,000 of whom are involved in R&D activities (APTE, 2021).

**Table 2** Description of variables

Characteristics	Label	Description	Mean	Std. Dev
<i>Dependent variables</i>				
Forward citations	<i>Fwd_cits7</i>	Number of patent citations received up to seven years after publication	0.99	2.08
	<i>IFwd_cits7</i>		0.45	0.61
Renewal	<i>Renewal</i>	Life duration of the patent application in number of years	6.74	3.86
	<i>IRenewal</i>		1.91	0.55
<i>Independent variables</i>				
Patent generated in STP	<i>Patpark</i>	1 if the patent is filed by a tenant, 0 otherwise	0.16	0.37
<i>Control variables</i>				
Firm age	<i>Firm_age<sup>a</sup></i>	Firm age in patent application year	26.42	24.24
	<i>IFirm_age</i>		2.85	1.06
Firm size	<i>Firm_emp</i>	Number of employees of the firm in patent application year	731.6	1743.0
	<i>IFirm_emp</i>		4.73	2.15
	<i>Firm_sales</i>	Firm sales in patent application year	518,804	1,504,968
	<i>IFirm_sales</i>		10.03	3.07
Firm sector	<i>NACE_code</i>	Numerical code that refers to the National Classification of Economic Activities (NACE)	1–22 NACE codes	
Firm location	<i>Reg_code</i>	Indicates the region in which the applicant's address is located	1–10 regions	
Patent application year	<i>App_year</i>	Indicates the year in which the EPO patent application is made	1–9 years	
Patent technology field	<i>Tech_field</i>	Indicates the technological field of the patent	1–30 technology fields	

The minimum value of *firm\_age* is 0 as there are cases in which patents are applied for before the creation of the company itself. These are mainly startups whose promoters apply for the patent before founding the organisation. Therefore, the application is considered to be made in year 0 of the company



## 3.2 Variables and descriptive statistics

### 3.2.1 Dependent variables

We use two quantitative indicators (in logs<sup>6</sup>) of patent quality, namely, forward citations (*lfwd\_cits7*) and patent renewal (*lrenewal*), as our dependent variables (Table 2).

First, forward citations are citations received by a patent application from subsequently filed patents. We use forward citations made within seven years after the publication of the cited patent to provide enough time for a patent to be cited, given the existence of different citation patterns across fields, and given that most of the citations received by a patent are made within its first seven years (Squicciarini et al., 2013).<sup>7</sup>

Second, patent renewals refer to the number of years a patent is kept in force. It should be noted that European Patent Office patents must be renewed annually starting from the third year after filing, first at the EPO while pending and, once granted, at all the national patent offices of member states of the European Patent Organisation, where the patent is validated. The renewal fee increases until the tenth year, after which it remains constant.

### 3.2.2 Independent variable

We build a dummy variable (*Patpark*) that takes the value 1 if the patent is generated in an STP and 0 otherwise. We determine whether a firm belongs to an STP based on the annual directories of companies maintained by the APTE. The criteria for defining a patent as on-park or off-park relies on a comparison of the addresses of APTE firms with the addresses of the applicants and inventors of that patent.

There are two pieces of information that can be used to classify a patent as on-park or off-park: the address of the applicant (the firm) and the address of the inventors.<sup>8</sup> In order to determine whether a patent application may be defined as either an on-park or an off-park patent, we use both applicant and inventor addresses (see Fig. 2, Appendix 4).

First, if the address of at least one of the applicants is on-park and the address of at least one of the inventors<sup>9</sup> is on-park or nearby, i.e. located in the same region as the applicant, the patent is considered on-park (899 patent applications).

Second, if the address of at least one of the applicants is on-park but no inventor has an address in the STP's region, the patent is considered an off-park patent despite having at least one on-park applicant. This is because the headquarters of a company may be located on-park and may be in charge of the administrative tasks related to patent filing, but if the

<sup>6</sup> We use the transformation  $\log(x+1)$ . We are aware that applying logs to a variable with zeros could affect the interpretation of the results, (Chen & Roth, 2022). Different to other variables, like money (which can be written in different units, such as dollars or miles of dollars) the citations and the renewals are a count variable so that it would be expected to be less sensible to this transformation. We checked that the results are similar when the number of patents (without logs) is used. These results are available upon request from the authors.

<sup>7</sup> We have also used citations received within five years after the publication of the patent application. Results, available upon request, are robust to the consideration of this alternative indicator.

<sup>8</sup> Each patent application has, on average, three inventors with an associated postal address for each.

<sup>9</sup> When there is no information on the address of the inventors but at least one applicant is on-park, we define that patent application as on-park.

**Table 3** Number of on-park patents and off-park patents and descriptive statistics of patent quality indicators by firm characteristics

	On-park patents		Off-park patents	
	Number patents	Percent (%)	Number patents	Percent (%)
<i>By firm age</i>				
0–5	296	26.9	712	12.3
6–14	493	44.7	1334	23.1
15–24	113	10.3	1201	20.8
25–49	101	9.2	1472	25.5
50+	99	9.0	1064	18.4
<i>By employment size</i>				
1–9	156	14.2	961	16.6
10–49	214	19.4	1184	20.5
50–249	170	15.4	1589	27.5
250+	562	51.0	2049	35.4
<i>By firm sales (euros)</i>				
< 2,000,000	270	24.5	1153	19.9
2,000,001–10,000,000	127	11.5	1029	17.8
10,000,001–50,000,000	121	11.0	1220	21.1
> 50,000,000	584	53.0	2381	41.2
	1102		5783	

research team that generated that patent is located off-park, the patent would be considered off-park according to our definition<sup>10</sup> (14 patent applications).

Third, if none of the addresses of the applicants belong to an STP but at least one address of the inventors belongs to a STP, the patent would be considered on-park. This is done to take into account cases in which a patent is generated on-park but the company files it from an off-park office (154 patent applications).

Fourth, if none of the addresses of the applicants belong to any STP and none of the inventors' addresses are on-park, the patent would be considered off-park except in one situation: if the applicant has their headquarters located in an STP in the same province reported in the patent application. If so, the patent is considered on-park. This would correspond to a case where a company has offices in the same province on- and off-park, and even though the patent is filed from the off-park office, it is very likely that the STP played a role in achieving the patent (61 patent applications).

### 3.2.3 Control variables

The role of control variables is key for estimating the STP effect on tenants' innovation performance (Table 2).

<sup>10</sup> In Appendix 3, we perform a robustness check in which we expand our definition to consider a patent application with these characteristics to be an on-park patent.

We include the age of the firm in logs (*lfirm\_age*), firm size using two variables as proxies<sup>11</sup> (in logs) (*lfirm\_emp*, *lfirm\_sales*) and dummies for each industrial sector (*NACE\_code*) and for each technology field (*tech\_field*). Table 3 shows the different distributions on these characteristics between on-park and off-park patents.

Regarding firm age, Table 3 shows that on-park patents tend to be filed by younger firms than off-park patents: 71.6% of on-park patents are from firms less than 15 years old compared to only 35.4% of off-park patents. Previous studies have found that the older the applicant, the lower the patent quality (Balasubramanian & Lee, 2008). We control for firm age in our models to avoid this potential source of bias.

As regards the number of employees, following the EU recommendation 2003/361, we break down the sample into four subgroups: micro-firms (0–9 employees), small firms (10–49), medium-sized firms (50–249) and large firms (over 250). As shown in Table 3, on-park patents are relatively more concentrated in large firms than off-park patents (51.0% vs. 35.4%) and less concentrated in medium-sized firms (15.4% vs. 27.5%). If we look at the distribution of the sample according to the sales of the applicant companies, we again observe that on-park patents are relatively more concentrated in the largest firms (sales > 50 million euros) as these firms account for 53.0% of on-park patents and only for 41% of off-park patents.

In addition, firm size is also likely to affect patent quality, although the direction of the influence is not clear (Gambardella et al., 2008; Lanjouw & Schankerman, 1997). On the one hand, larger firms may generate higher-quality innovation because of greater capability to bear fixed costs and funds for innovations activities and to access a higher-skilled workforce (Rogers, 2004). On the other hand, they may also show a less demanding selective criterion when applying for a patent (van Zeebroeck & van Pottelsberghe de la Potterie, 2011a) or greater flexibility to recognise opportunities of innovating (Rogers, 2004). As a result, firm size is a potential confounding factor when estimating the effect of STP location on patent quality, so we will control for it in our models.

Patent quality is also affected by differences across technological fields or sectors.<sup>12</sup> On the one hand, there are sectors whose patents have a higher propensity to be cited (van Zeebroeck & van Pottelsberghe de la Potterie, 2011b) and sectors with higher profitability, such as the pharmaceutical sector, where patents may be kept in force for longer as potential profits may outweigh the cost of renewal fees (van Zeebroeck, 2011). On the other hand, patents that belong to more general technological fields may receive a higher number of citations because of their influence on a wider range of patents (Youtie et al., 2008).

<sup>11</sup> We include firm employees and firm sales since both reflect to some extent different dimensions of size and show different correlation patterns with R&D, which is our main unobserved confounder. If we use the dataset PITEC, the Spanish innovation panel, which provides information from the Spanish Innovation Survey and the Spanish R&D Survey on a yearly basis and we include both in a regression in which total R&D is the dependent variable, firm sales show a negative and significant coefficient and firm employees shows a positive and significant coefficient. Unfortunately, PITEC cannot be merged with our dataset because it is anonymized. Results, available upon request, are very similar when we do not use either firm sales or firm employees.

<sup>12</sup> The three main sectors involved in on-park patents are *Manufacturing of other transport equipment* (NACE 30) with 24.4%, *Research and development* (NACE 72) with 22.5% and *Electrical manufacturing* (NACE 27) with 12.4%. The three main sectors involved in off-park patents are *Pharmaceutical manufacturing* (NACE 21) with 14.4%, *Wholesale and commission trade, except of motor vehicles and motorbikes* (NACE 46) with 8.0% and *Research and development* (NACE 72) with 7.7%. On-park patents are more concentrated in the technology fields of *Transport* (15.3%), *Engines, pumps, turbines* (12.6%) and *Pharmaceuticals* (8.8%), whereas the three main off-park patents technology fields are *Pharmaceuticals* (13.8%), *Civil engineering* (8.1%) and *Transport* (7.5%).

Furthermore, the economic value of patents varies across technological fields (Schankerman, 1998).

Finally, we control for the province (location of the patent applicant, NUTS3 level) and time fixed effects (filing year of the patent).

A correlation matrix is shown in Appendix 1.

### 3.3 Empirical specification

To measure the effect of STPs on tenants' innovation performance, we estimate the following equation:

$$PatentQualityIndicator = \alpha + \beta Patpark + \gamma FirmControls + \delta PatentControls + \varepsilon \quad (1)$$

where *PatentQualityIndicator* is the dependent variable and *Patpark* is a dummy variable which equals 1 if the patent was generated in an STP. This is the main explanatory variable, whose effect we want to measure. We have two different sets of control variables: *FirmControls*, which includes *firm\_age*, *firm\_emp*, *firm\_sales* and *NACE\_code*, and *PatentControls*, which includes *reg\_code*, *tech\_field* and *app\_year*;  $\varepsilon$  is the error term.

First, we estimate the effect using ordinary least squares (OLS) for both forward citations and renewals. Second, as these are count variables, we use a Poisson model to estimate the STP effect.

Both models rely on the 'ignorability assumption' (that is, STP location is not driven by unobserved firm characteristics that also affect patent quality). After introducing our set of firm and patent controls, we believe that the main potential confounding factor is firms' R&D investment. Unfortunately, we do not have information about it, because this information is not publicly available.<sup>13</sup> To analyse the amount of bias that we could expect by omitting a firm's R&D investment, we conduct two analyses based on Cinelli and Hazlett (2020) (see Sect. 4.2).

## 4 Results

### 4.1 Main results

Table 4 presents the main results from our baseline regressions. Columns (1) and (3) show results from the OLS model, whereas Columns (2) and (4) show Poisson results.

First, as shown in Columns (1) and (2), we find a positive relationship between location in an STP and the number of forward citations. Being located in an STP produces an increase of around 27% (Column 1) in the number of citations received according to the OLS estimation, and around 21% according to the Poisson regression model.<sup>14</sup>

<sup>13</sup> To our knowledge, the only datasets that provide it are anonymised datasets from innovation surveys in Spain like the Technological Innovation Panel (PITEC) or the *Encuesta sobre Estrategias Empresariales* (ESEE), which cannot be merged with the REGPAT or SABI data because we need the company name.

<sup>14</sup> This percentage has been calculated using the following procedure. Fitted values of *Fwd\_cits7* are calculated for each patent in the observed and the counterfactual situations. That is, we undo the two transformations in  $\log(Fwd\_cits7 + 1)$ . We compute the average citations in the two situations, and the result is that the average citations for patents located in STPs are 27% larger than the average citations for patents outside STPs.

**Table 4** Effect of STPs on patent quality indicators

	Forward citations			
	Renewal		Renewal	
	OLS regression model (1)	Poisson regression model (2)	OLS regression model (3)	Poisson regression model (4)
	log(Fwd_cits7 + 1)	Fwd_cits7	log(Renewal + 1)	Renewal
Patpark	0.093*** [0.025]	0.207*** [0.067]	0.066*** [0.022]	0.066*** [0.022]
log(Firm_age)	-0.053*** [0.010]	-0.151*** [0.028]	-0.044*** [0.009]	-0.041*** [0.009]
log(Firm_emp)	0.006 [0.009]	0.003 [0.029]	0.010 [0.008]	0.011 [0.008]
log(Firm_sales)	0.018*** [0.006]	0.066*** [0.020]	0.008 [0.005]	0.009* [0.006]
Year dummies	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Constant	0.130** [0.065]	-1.204*** [0.274]	1.822*** [0.069]	1.816*** [0.074]
N	6885	6885	6885	6885

Marginal effects; Standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Columns (1) and (3) show the results of the OLS regression model, and Columns (2) and (4) show the results of the Poisson regression model detailed in Sect. 3.2

Second, Columns (3) and (4) show a similar result for patent renewals; i.e. patent applications generated on-park remain in force for a longer period of time. In this case, being located in an STP is related to an increase around 7% in the number of years in which the patent application remains in effect.

These results on two of the main indicators of patent quality show that patents generated on-park are of a higher quality than patents generated off-park.<sup>15</sup>

This finding is in line with several studies which use patent count as a proxy and find evidence of a positive STP effect on the innovation performance of their tenants (Corrocher et al., 2019; Huang et al., 2012; Lamperti et al., 2017; Siegel et al., 2003; Squicciarini, 2008).

### 4.2 Sensitivity analysis

Previous results rely on a strong identification assumption that STP location is not driven by unobserved factors that also affect patent quality.

More precisely, we are concerned with the sensibility of our results to the inclusion of firms' R&D investment. If more R&D-intensive firms are more likely to locate in STPs (conditional on patenting and on the other firm characteristics we control for) and also achieve patents of better quality, then it could be that our estimated STP effect is capturing this R&D effect. In this section, we want to analyse the degree of sensibility of the previous results to the existence of this (and any other unobserved) factor that may influence both STP location and patent quality.

Cinelli and Hazlett (2020) provide the formula for the relative bias<sup>16</sup>:

$$\left| \frac{\widehat{bias}}{\widehat{\beta}_{res}} \right| = \frac{|R_{Y \sim W|D,X} * f_{D \sim W|X}|}{|f_{Y \sim D|X}|}$$

where:

$\left| \frac{\widehat{bias}}{\widehat{\beta}_{res}} \right|$  is the relative bias of the estimated STP effect ( $\widehat{\beta}_{res}$  is the estimated coefficient from our restricted model),

$R_{Y \sim W|D,X} = \sqrt{\frac{R^2_{Y \sim D+X+W} - R^2_{Y \sim D+X}}{1 - R^2_{D \sim X}}}$ , that is, an indicator of the added explanatory power of R&D (W) on patent quality (Y) after accounting for *Patpark*(D) and the control variables (X),

$f_{D \sim W|X} = \sqrt{\frac{R^2_{D \sim W|X}}{1 - R^2_{D \sim X}}}$  with  $R^2_{D \sim W|X} = \sqrt{\frac{R^2_{D \sim X+W} - R^2_{D \sim X}}{1 - R^2_{D \sim X}}}$ , that is, an indicator of the added explanatory power of R&D (W) on *Patpark*(D) after accounting for the control variables (X), an added explanatory power that enters the bias equation via the partial Cohen's *f* rather than via the partial  $R^2$ ,

<sup>15</sup> We explored the hypothesis that firms located close to the STPs might benefit more from the activity of the STPs than companies located further away. We defined a set of 'near-park' postcodes, and we follow the same procedure explained in Sect. 3.2.2 and Appendix 4. Finally, we identify 1171 patents as 'near-park'. The results show that 'near-park' patent do not show any significant difference in comparison to the patents from firms located far away from the STPs. In addition, STP effect remains positive and statistically significant for both indicators of patent quality. Results are available upon request.

<sup>16</sup> They also provide the proof for this formula.

**Table 5** Results of analysis for citations

Bound	R2dz.x	R2yz.dx	Coef	S.E	t(H0)	Lower CI	Upper CI
1.00×lfirm_sales	0.0022	0.0011	0.0894	0.0251	3.5638	0.0402	0.1386
2.00×lfirm_sales	0.0044	0.0023	0.0862	0.0251	3.4315	0.0369	0.1354
3.00×lfirm_sales	0.0066	0.0034	0.0829	0.0251	3.2991	0.0336	0.1321

$|f_{Y \sim D|X}| = \sqrt{\frac{R_{Y \sim D|X}^2}{1 - R_{Y \sim D|X}^2}}$  with  $R_{Y \sim Y|X}^2 = \sqrt{\frac{R_{Y \sim X+D}^2 - R_{Y \sim X}^2}{1 - R_{Y \sim X}^2}}$ , that is, an indicator of the added explanatory power of *Patpark*(D) on patent quality (Y) after accounting for the control variables (X), an added explanatory power that enters the bias equation via the partial Cohen’s *f* rather than via the partial  $R^2$ . Note that this last indicator can be estimated for our data and, actually,  $|f_{Y \sim D|X}| = \frac{t_{\hat{\beta}_{res}}}{\sqrt{df_{res}}}$ , where  $t_{\hat{\beta}_{res}}$  is the t-ratio for *Patpark* in our model and  $df_{res}$  are the degrees of freedom in our model.

Departing from this formula, we could try to estimate the indicators  $R_{Y \sim W|D,X}$  and  $f_{D \sim W|X}$  from other datasets or from previous empirical studies. In addition, Cinelli and Hazlett (2020) provide a strategy for bounding the strength of the confounder (R&D) by using the information on some observed covariates. We will show the results following both of these two strategies.

#### 4.2.1 Estimation of $R_{Y \sim W|D,X}$ and $f_{D \sim W|X}$

We have reviewed the literature on patent quality to find empirical papers that provide an estimation of the effect of firm R&D, holding constant the set of control variables we are using. We have found three papers that address this issue. Liu et al. (2008) find that firm R&D intensity is non-significant in explaining patent renewal. Wadhwa et al. (2016) also find that firm R&D intensity is not significant in explaining patent citations once selection is taken into account. Unfortunately, these two papers do not provide OLS estimations, so we cannot use them to estimate  $R_{Y \sim W|D,X}$  (they estimate count data models using maximum likelihood estimation). However, Balasubramanian and Lee (2008) provide an OLS estimation that includes the partial effect of firm R&D on patent citations. Thus, this study offers an estimation for  $R_{Y \sim W|D,X}$ , which would be equal to 0.0123.

$f_{D \sim W|X}$  is the added explanatory power of R&D on STP location once we control for the other firm characteristics. We can estimate this indicator by using PITEC, the Spanish innovation panel, which provides information from the Spanish Innovation Survey and the Spanish R&D Survey on a yearly basis. This dataset includes detailed information on innovation inputs and outputs for all firms that perform internal R&D in Spain, so it is a census of these firms for Spain. In addition, since 2007, it has included information on STP location. We estimate the added explanatory power of firms’ R&D intensity on patenting, controlling for firm employment, firm sales, firm age, firm sector, firm region and year dummies.<sup>17</sup> The value of  $f_{D \sim W|X}$  according to this analysis is equal to 0.103.

<sup>17</sup> The technological field of the patent is not available in PITEC. Note that if we were able to include it, the added explanatory power of R&D would be lower. This means that the actual bias caused by R&D will in practice be slightly lower than the one reported in this analysis.

**Table 6** Results of analysis for patent renewal

Bound	R2dz.x	R2yz.dx	Coef	S.E	t(H0)	Lower CI	Upper CI
1.00×lfirm_sales	0.0022	0.0003	0.0643	0.0229	2.8059	0.0194	0.1092
2.00×lfirm_sales	0.0044	0.0005	0.0628	0.0229	2.7394	0.0179	0.1078
3.00×lfirm_sales	0.0066	0.0008	0.0614	0.0230	2.6730	0.0164	0.1063

Finally, according to the results from Column 1 in Table 4,  $|f_{Y \sim D|X}|$  can be computed and is equal to 0.045 for citations.

With these three indicators, we can compute the relative bias suffered in estimating the STP effects in Column 1, Table 5. This is equal to 2.83%, meaning that if we were able to include firm R&D, the coefficient would be equal to 0.090. That is, the bias caused by omitting firm R&D is estimated to be very small in magnitude, which is coherent with the non-significant effect of R&D intensity on patent citations found by Wadhwa et al. (2016).

#### 4.2.2 Bounding the strength of the confounder by using observed covariates

In this analysis, we use observed covariates to bound the strength of the confounder, following the procedure proposed by Cinelli and Hazlett (2020). More precisely, we use firm sales as the benchmark as firm sales are an important determinant of both patent quality and STP location.

To be able to conduct this analysis, we define.

$$k_D = \frac{R^2_{D \sim W|X_{-j}}}{R^2_{D \sim X_j|X_{-j}}} \text{ and } k_Y = \frac{R^2_{Y \sim W|D,X_{-j}}}{R^2_{Y \sim X_j|D,X_{-j}}}$$

where:

$R^2_{D \sim W|X_{-j}}$  is the added explanatory power of R&D (via  $R^2$ ) on *Patpark* if *firm\_sales* is excluded from the set of controls;

$R^2_{D \sim X_j|X_{-j}}$  is the added explanatory power of *firm\_sales* (via  $R^2$ ) on *Patpark*, controlling for the rest of the covariates used in the analysis;

$R^2_{Y \sim W|D,X_{-j}}$  is the added explanatory power of R&D (via  $R^2$ ) on patent quality if *firm\_sales* is excluded from the set of controls; and.

$R^2_{Y \sim X_j|D,X_{-j}}$  is the added explanatory power of *firm\_sales* (via  $R^2$ ) on patent quality, controlling for the rest of the covariates used in the analysis.

Given  $k_D$  and  $k_Y$ , we can rewrite the strength of the confounders as:

$$R^2_{D \sim W|X} = k_D f^2_{D \sim X_j|X_{-j}}$$

$$R^2_{Y \sim W|D,X} \leq \eta^2 f^2_{Y \sim X_j|D,X_{-j}}$$

where  $\eta$  is a scalar that depends on  $k_D$ ,  $k_Y$  and  $R^2_{D \sim X_j|X_{-j}}$ . These equations enable us to investigate the maximum effect that a confounder at most 'k times' as strong as *firm\_sales* would have on the coefficient estimate for *Patpark*.



**Table 7** STP effect on forward citations by time period included in the sample

	OLS regression model: log(Fwd_cits7 + 1)			
	(1)	(2)	(3)	(4)
	Until 2012	Until 2011	Until 2010	Until 2009
Patpark	0.093 <sup>***</sup> [0.025]	0.105 <sup>***</sup> [0.027]	0.126 <sup>***</sup> [0.029]	0.130 <sup>***</sup> [0.033]
log(Firm_age)	-0.053 <sup>***</sup> [0.010]	-0.052 <sup>***</sup> [0.011]	-0.058 <sup>***</sup> [0.011]	-0.072 <sup>***</sup> [0.013]
log(Fir_emp)	0.006 [0.009]	0.010 [0.010]	0.006 [0.010]	0.021* [0.012]
log(Firm_sales)	0.018 <sup>***</sup> [0.006]	0.017 <sup>**</sup> [0.007]	0.021 <sup>***</sup> [0.008]	0.011 [0.009]
Year dummies	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Constant	0.130 <sup>**</sup> [0.065]	0.162 <sup>**</sup> [0.071]	0.136 <sup>*</sup> [0.074]	0.161 <sup>*</sup> [0.089]
<i>N</i>	6885	6035	5235	4320

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Column (1) shows the results of the OLS regression model with our current sample (until 2012). Column (2) shows the results of OLS regression with the restricted sample until 2011. Column (3) shows the results of the OLS regression model with the restricted sample until 2010, and Column (4) shows the results of the OLS regression model for the sample until 2009

The results for such an analysis in the case of citations are reported in Table 5.

If firm R&D were a confounder as strong as firm sales, the coefficient would be 0.0894. That is, the bias would be 3.55%, a bit higher than the one found using the first strategy, which suggests that R&D is a confounder that is a bit less strong than sales.

The robustness of the results to the confounder is clear from the other rows in the table. Even if firms' R&D (or any other confounder, or all of them together) were two or three times stronger than firm sales, the coefficient of STP location on patent citations would still be over 0.08 and very significant from a statistical point of view.

One advantage of this strategy is that it also allows us to examine the effect of confounding on the estimation of the economic value of the patent. If we conduct the same analysis for renewals, we find (Table 6) that if firm R&D were a confounder as strong as firm sales, the coefficient would be 0.0643 (that is, the bias would be only 2.19%).

Again, the robustness of these results to the confounder is clear from the other rows in the table. Even if firms' R&D (or any other confounder, or all of them together) were two or three times stronger than firm sales, the effects of STP location on patent renewals would still be above 0.036 and very significant from a statistical point of view.

All in all, these analyses show that the effects found are robust to the presence of potential confounders, such as firms' R&D investment. In what follows, we conduct some additional robustness checks.

### 4.3 Robustness checks

Just as we addressed the possibility of being able to overestimate the effect of STPs because of the lack of data on firm R&D expenditure, in order to show the reliability and

**Table 8** STP effect on renewal by time period included in the sample

	OLS regression model		
	App_year(2012)	App_year (2010)	App_year (2008)
	(1)	(2)	(3)
	log (Renewal)	log (Renewal)	log (Renewal)
Patpark	0.066*** [0.022]	0.065** [0.027]	0.102*** [0.035]
log(Firm_age)	-0.044*** [0.009]	-0.055*** [0.011]	-0.067*** [0.014]
log(Fir_emp)	0.010 [0.008]	0.014 [0.009]	-0.005 [0.014]
log(Firm_sales)	0.008 [0.005]	0.008 [0.007]	0.025** [0.011]
Year dummies	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes
Constant	1.822*** [0.069]	1.827*** [0.081]	1.890*** [0.106]
<i>N</i>	6885	5235	3496

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Column (1) shows the results of the OLS regression model which involves the selected sample until 2012, Column (2) shows the results of the OLS regression model which involves the sample until 2010, and Column (3) shows the results of the OLS regression model which involves the sample until 2008

consistency of the STP effect found, we conduct two additional robustness checks on alternative patent quality indicators.

#### 4.3.1 Forward citations

We used the version of the OECD Patent Quality Indicators database from June 2021 and consider patents filed until 2012, so we would expect to observe all the citations received in the first seven years of all the patents included in the sample. However, we have reasons to think that this may not be the case when comparing the January 2020 version of the same database. In Appendix 5, we can see that the average number of 7-year citations for each cohort increases in the latter version of the dataset. This is especially important for applications in 2011 (10% increase) and 2012 (30.7% increase), which suggests that the citations indicator is updated with some lag and, accordingly, our indicator suffers from measurement error which may lead to underestimation of the STP effect.

In Table 7, we explore this issue by conducting a robustness check using only the older cohorts of patents. As expected, we find that the STP effect increases considerably (up to a 39.8% increase if only applications until 2009 are included<sup>18</sup>), which suggests that our main analysis is a conservative estimation of the STP effect.

<sup>18</sup> We follow the same method explained above to calculate this percentage.

### 4.3.2 Renewals

The maximum renewal period is 20 years. However, the maximum period we observe (for the first cohort of applications) is only 16 years. If most of the applications are renewed several times, it would mean that the differences in economic value are revealed only after many renewals. Again, this could be a source of measurement error which leads to underestimation in our results. In Table 8, we explore this issue by conducting a robustness check using only the older cohorts of patents. As we expected, we find that the STP effect increases considerably when only the older cohorts of patents are used (up to a 54.6% increase if only applications until 2008 are included), which suggests that our main analysis is again a conservative estimation of the STP effect.

## 5 Channels through which the effect takes place

The second part of our work aims to identify the channels through which STPs affect the quality of patents. It should be noted that one of the objectives of STPs is to facilitate a network that brings together different agents with the aim of promoting the internationalisation of their tenants, facilitating communication between companies, entrepreneurs and technicians. STPs aim to create environments that foster innovative, creative and quality development, stimulating and managing the relationship between universities and companies (IASP, 2021).

Economic geography theory shows that geographical proximity fosters the development of links between different organisations (Baptista & Swann, 1998; Hervas-Oliver & Albors-Garrigos, 2009). Agglomeration facilitates contacts between different agents (Gilly & Torre, 2000), reduces search costs (Feldman, 1999) and increases the probability of actively searching for innovative partners (MacPherson, 1997), creating more stable and long-lasting relationships (Love & Roper, 2001). For their own idiosyncrasy, STPs provide such geographical proximity, thereby facilitating collaboration between tenants. Ng et al. (2020) point out that proximity with other firms is a relevant factor for firms located in STPs. Additionally, STPs facilitate other types of proximity, such as cognitive, organisational, social and institutional proximity (Albahari, 2021). Furthermore, fostering collaboration between companies and other entities is a specific objective of STPs, and there is empirical evidence that confirms this phenomenon. For example, Vásquez-Urriago et al. (2016) show that being located in an STP increases the likelihood of establishing cooperative links.

Collaboration with universities and other HEIs is particularly important for STPs. Closeness to universities increases the attractiveness and growth of STPs (Ng et al., 2020; Theeranattapong et al., 2021). Strengthening university-industry relations by facilitating the flow of knowledge and technology is a declared objective of STPs. The study of the effects of STPs on the relationship between tenants and universities has been widely discussed in the literature, taking into account that one of the main objectives of STPs is to foster collaboration between both types of agents (Albahari et al., 2017; Link & Scott, 2007). However, Theeranattapong et al. (2021) suggested a further research on university role through studies which may compare between STPs with university presence or not. Several studies find a positive effect of STPs on university-tenant relationships (e.g. Díez-Vial & Fernández-Olmos, 2015; Felsenstein, 1994; Löfsten & Lindelöf, 2002, 2003; Vedovello, 1997).

Moreover, STPs also actively seek to foster the internationalisation of their companies (Tomelin et al., 2018) through services provided to tenants (Albahari et al., 2018) and through the integration of STPs in international networks (Cadorin et al., 2017). Some studies have shown that on-park companies have wider international markets (Löfsten & Lindelöf, 2002).

Thus, we may expect that STPs increase the quality of the patent of their tenants through three main channels: by facilitating collaboration between different agents, by increasing the scientific base of tenants' inventions through collaboration with universities and by fostering the internationalisation of those inventions.

The channels above can be proxied using the following variables. *Inv\_number* (number of inventors related to the patent) is used as a proxy for the *collaborative dimension*. This indicator has been acknowledged to be positively correlated with patent quality (Guellec & Van Pottelsberghe De La Potterie, 2000; Guellec & Van Pottelsberghe de la Potterie, 2002; Schettino et al., 2013). *University*<sup>19</sup> (dummy variable that takes the value of 1 if a university is a co-applicant of the patent and zero otherwise) is used as a proxy for the level of the *scientific knowledge base* of a patent. Patents with academic participation have also been found to be of higher quality (Fleming & Sorenson, 2004; Harhoff et al., 1999; Jung & Lee, 2016; Sapsalis et al., 2006). *IFamily\_size* (number of patent offices where an invention is protected) is used as a proxy for the *international dimension* in the commercialisation of inventions and the international strategies of patent applicants to commercialise or exploit inventions, either directly or via licensing agreements (Martínez, 2011). This indicator has also been acknowledged to reflect perceived patent quality (Putnam, 1997; Lanjouw et al., 1998; Harhoff et al., 2003; Gambardella et al., 2008; van Zeebroeck & van Pottelsberghe de la Potterie, 2011a).

In Table 9, we can see that on-park patents tend to be more collaborative (with an average of 3.3 inventors) than off-park patents (average of 2.5 inventors). In addition, they are more likely to include a university as a co-applicant (3.6% of on-park patents and 0.4% of off-park patents). Finally, they are less international, so patent protection is sought in fewer countries for the same invention (average of 5.2 patent family size on-park and 5.7 off-park), although this difference is significant when the variable is without logs and non-significant in logs.

Table 10 shows the results related to forward citation, and Table 11 shows the results related to renewal when the three potential channels are included. In both tables, Column (1) sets out the results of the OLS model detailed in Sect. 4.1; Column (2) presents the estimated results by including in the model the variable used to estimate the collaborative nature of the patent; Column (3) shows the results when we include in the model the variables used to estimate the scientific base of the patent; Column (4) presents the result by including in the model the variable used to estimate the internationalisation of the patent; Column (5) shows the results when we include both collaboration and scientific base of the patent to estimate them; and Column (6) finally presents the results when we include the three potential channels.

Regarding forward citations, we observe that the STP effect decreases by 6.5% in Column (2) and Column (3). This indicates that the number of inventors and the relationship with the university show up as possible channels to partly explain the STP effect found. The opposite happens if we look at Column (4) as the STP effect increases by 7.5%. This finding indicates that internationalisation may not be a channel for explaining STP effect.

<sup>19</sup> NPL\_citations was considered a proxy for estimating the scientific basis of the patent. However, the results did not show significance for any of the patent quality indicators selected in our research.

**Table 9** Description of channels variables

Dimensions	Variable/proxy	Label	Description	Off-park patents		On-park patents		p-values
				Mean	Std. dev	Mean	Std. dev	
Collaboration	Number of inventors	<i>Inv_number</i>	Number of inventors of the patent	2.501	1.802	3.314	2.221	0.000
		<i>Inv_number</i>		1.148	0.441	1.350	0.465	0.000
Scientific base	University role	<i>University</i>	1 if any of the applicants is a university, 0 otherwise	0.004	0.067	0.036	0.187	0.000
Internationalisation	Family size	<i>Family_size</i>	Number of patent offices where a certain invention	5.696	6.124	5.244	4.054	0.019
		<i>IFamily_size</i>	has been protected	1.656	0.685	1.684	0.569	0.209

**Table 10** Relationship of STP channels to forward citations

	(1)	(2)	(3)	(4)	(5)	(6)
	log (Fwd_cits7)	log (Fwd_cits7)	log (Fwd_cits7)	log (Fwd_cits7)	log (Fwd_cits7)	log (Fwd_cits7)
Patpark	0.093 <sup>***</sup> [0.025]	0.087 <sup>***</sup> [0.025]	0.086 <sup>***</sup> [0.025]	0.098 <sup>***</sup> [0.024]	0.082 <sup>***</sup> [0.025]	0.089 <sup>***</sup> [0.024]
log(Firm_age)	-0.053 <sup>***</sup> [0.010]	-0.052 <sup>***</sup> [0.010]	-0.052 <sup>***</sup> [0.010]	-0.048 <sup>***</sup> [0.010]	-0.052 <sup>***</sup> [0.010]	-0.047 <sup>***</sup> [0.010]
log(Firm_emp)	0.006 [0.009]	0.005 [0.009]	0.006 [0.009]	0.010 [0.009]	0.006 [0.009]	0.010 [0.009]
log(Firm_sales)	0.018 <sup>***</sup> [0.006]	0.018 <sup>***</sup> [0.006]	0.017 <sup>***</sup> [0.006]	0.014 <sup>**</sup> [0.006]	0.017 <sup>***</sup> [0.006]	0.014 <sup>**</sup> [0.006]
Inv_number		0.010 <sup>**</sup> [0.004]			0.009 <sup>**</sup> [0.004]	0.007 [0.004]
University			0.191 <sup>**</sup> [0.086]		0.175 <sup>**</sup> [0.087]	0.157 <sup>*</sup> [0.080]
Family_size				0.021 <sup>***</sup> [0.002]		0.021 <sup>***</sup> [0.002]
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.129 <sup>***</sup> [0.065]	0.113 <sup>*</sup> [0.066]	0.124 <sup>*</sup> [0.065]	0.054 [0.065]	0.109 <sup>*</sup> [0.066]	0.039 [0.066]
N	6885	6885	6885	6885	6885	6885

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

**Table 11** Relationship of STP channels to renewals

	(1)	(2)	(3)	(4)	(5)	(6)
	log (Renewal)	log (Renewal)	log (Renewal)	log (Renewal)	log (Renewal)	log (Renewal)
Parpark	0.066 <sup>***</sup> [0.022]	0.056 <sup>***</sup> [0.022]	0.064 <sup>***</sup> [0.022]	0.074 <sup>***</sup> [0.021]	0.056 <sup>**</sup> [0.022]	0.067 <sup>***</sup> [0.021]
log(Firm_age)	-0.044 <sup>***</sup> [0.009]	-0.043 <sup>***</sup> [0.009]	-0.044 <sup>***</sup> [0.009]	-0.036 <sup>***</sup> [0.009]	-0.043 <sup>***</sup> [0.009]	-0.036 <sup>***</sup> [0.009]
log(Firm_emp)	0.010 [0.008]	0.009 [0.008]	0.010 [0.008]	0.016 <sup>**</sup> [0.008]	0.009 [0.008]	0.015 <sup>**</sup> [0.008]
log(Firm_sales)	0.008 [0.005]	0.007 [0.005]	0.008 [0.005]	0.003 [0.005]	0.007 [0.005]	0.002 [0.005]
Inv_number		0.017 <sup>***</sup> [0.004]			0.017 <sup>***</sup> [0.004]	0.013 <sup>***</sup> [0.004]
University			0.043 [0.065]		0.013 [0.066]	-0.015 [0.063]
Family_size				0.032 <sup>***</sup> [0.001]		0.031 <sup>***</sup> [0.001]
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.815 <sup>***</sup> [0.068]	1.795 <sup>***</sup> [0.069]	1.821 <sup>***</sup> [0.069]	1.710 <sup>***</sup> [0.066]	1.794 <sup>***</sup> [0.069]	1.688 <sup>***</sup> [0.067]
N	6885	6885	6885	6885	6885	6885

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Actually, as the relationship between STP location and internationalisation is negative, on-park patents get more citations than similar off-park patents despite being less international and the positive effect of internationalisation on citations. In addition, in Column (5), number of inventors and relationship with university are both included, and together they explain 11.8% of the STP effect. Column (6) shows that both together collaboration and scientific base are the channels with stronger effect. That is, STPs would be facilitating greater collaboration and closer science–industry links, which is in line with the objectives of STPs, and this helps to explain part of their effect on patent forward citations.

As for the results obtained on the influence that channels have on patent renewals (Table 11), we observe that the results in Column (2) show that the effect decreases about 15.2%. Therefore, a greater collaboration partially explains the STP effect found. However, exploring the relationship with the university, we find that the result in Column (3) does not show any variation in the effect, so it cannot be considered a possible channel of influence of STPs on patent renewal. Renewals follow a pattern similar to that of forward citations: we observe in Column (5) that on-park patents remain in effect more years than similar off-park patents despite being less international. In this sense, Column (6) includes all the three possible channels for the effect of STPs and shows that internationalisation is the channel with lightly stronger effect, above the other two channels.

To sum up, the results obtained for both indicators of patent quality indicate that the effect of STPs on the quality of patents can be partly explained by a greater level of collaboration and, only in the case of forward citations, closer science–industry links for patents obtained by tenants.

Finally, we find that patents generated on-park tend to have smaller patent families than those generated off-park. Hence, the effect occurs even though STPs lead to a slightly lower degree of internationalisation in patents.

## 6 Conclusions

The attention given to STPs as a science, technology and innovation policy tool has been growing over the years, as witnessed by the large number of STPs worldwide and the huge amounts of money invested. However, studies on the effects of STPs on innovation performance tend to use the number of patent applications as an indicator without considering the skewness of the distribution of patent quality and obtain disparate results. This paper estimates the effect of being located in an STP, focusing instead on the patenting quality of tenants, and explores possible channels through which the effect takes place. To this aim, we develop a novel database in which we have identified whether patents are generated on- or off-park in Spain, and we associate firms' characteristics with each record.

Our results show that being located in an STP has a positive effect on patent quality, with an increase of over 20% in the number of citations received and around 7% in the number of years the patent remains in effect. These results support the literature that finds that being located in STPs would lead to a positive effect on firms' innovation performance.

Our identification strategy relies on the 'ignorability assumption'; that is, after introducing our set of firm and patent controls, there are no additional confounding factors. This is a strong assumption and can lead to overestimation of STP effect if some firm characteristics that increase the likelihood of STP location also influence patent quality (e.g. R&D intensity). We address this limitation by using a novel econometric technique to estimate



the possible overestimation of the effect (Cinelli & Hazlett, 2020) and performing some robustness checks to show the consistency of the STP effect found in our study. We show that, actually, our results are a conservative estimation of the STP effect.

We also provide evidence of the channels through which STPs increase the likelihood of obtaining higher-quality patents. Around 12.6% of the STP effect on the number of citations is explained by the fact that patents developed on-park are more collaborative (larger inventor teams) and show greater participation of universities (university co-applicants) than patents developed off-park. Regarding the number of years the patent remains in effect, we find that around 15% of the STP effect is explained by the more collaborative nature of on-park patents, while university involvement does not play a role in explaining the STP effect on renewals. We also find that the internationalisation channel has the greater effect on the patent quality of tenants, compared to the other two channels considered.

Our findings provide useful insights to STP managers. The positive effect of STPs on the quality of tenants' patents that we find, suggests another possible argument in favour of the on-park localisation that park managers can use to promote their organisation. At the same time, our findings also suggest possible issues to tackle in the management of these organisations. We find that, among the channels considered, internationalisation is the one having the greater effect; nonetheless, we also observe that patents of on-park firms tend to be less international than those by off-park firms. This suggests that STPs management teams could still make a stronger effort to encourage and support an international approach of the firms located within their boundaries, acknowledging that the internationalisation of tenants is one of the main objectives of STPs, as recognised by the IASP.

Our results make a relevant contribution to the evaluation of STPs as innovation, science and technology policy. Public policy evaluation should play a very important role in public governance. It contributes to achieving effectiveness and accountability in the decision-making processes of the public sector. Therefore, to analyse the effects of public policies, the design of evaluation mechanisms is necessary. If these policies cannot be evaluated because the mechanisms or instruments have not been designed at the right time, it is essential to at least monitor the results obtained after their implementation, identifying the relevant indicators for each policy. In that context, our paper sheds light on another dimension of the STP effect that has not been taken into account in previous studies, thus contributing to the evaluation of this tool of innovation, science and technology policy.

Finally, our study is not without limitations. We are aware that STPs are essentially heterogeneous (Albahari et al., 2018). STPs differ in terms of maturity (year of creation), available spaces, services provided to tenants, degree of specialisation, and so on, and these different features may have a different impact on tenants. In addition, tenants also have different characteristics, which implies that some may benefit more from locating on-park. The issue of STP and tenant heterogeneity would be an interesting avenue for further research which aims to identify which characteristics of the STPs have a greater influence on the innovation performance of tenants and which firms benefit more from an on-park location. Such research would further contribute to improving our knowledge of STPs as innovation policy instruments.

## Appendix 1—Correlation matrix

See Table 12

**Table 12** Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Fwd_cits7	1.000								
(2) Renewal	0.122	1.000							
(3) Patpark	0.069	0.093	1.000						
(4) Inv_number	0.086	0.004	0.157	1.000					
(5) Family_size	0.272	0.172	-0.028	0.179	1.000				
(6) University	0.038	0.016	0.120	0.151	0.035	1.000			
(7) Firm_age	-0.024	-0.099	-0.177	0.010	0.028	-0.049	1.000		
(8) Firm_emp	-0.006	0.002	0.132	0.037	-0.102	-0.007	0.274	1.000	
(9) Firm_sales	-0.021	-0.061	-0.046	0.076	-0.096	-0.019	0.380	0.581	1.000

## Appendix 2—Regression results on channels

See Table 13

**Table 13** OLS regression model results

	(1) log (inv_number)	(2) log (family_size)	(3) University
Patpark	0.132*** [0.019]	-0.157 [0.025]	0.034*** [0.008]
log(Firm_age)	-0.019*** [0.007]	-0.038*** [0.010]	-0.002 [0.002]
log(Firm_emp)	0.020*** [0.006]	-0.009 [0.010]	-0.002 [0.002]
log(Firm_sales)	0.018*** [0.004]	0.017** [0.008]	0.006 [0.001]
Year dummies	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes
Constant	0.862*** [0.052]	1.454*** [0.069]	0.027* [0.016]
<i>N</i>	6885	6885	6885

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

## Appendix 3—Robustness check of sample selection criteria

We test two possible alternative criteria. The first one considers only the address of the applicants without taking into account the addresses of the inventors to classify the patents. In this way, on-park patents are those which have at least one of the applicants on-park. The second considers on-park patents all those obtained by a company with at least one on-park patent. This extreme assumption allows us to check whether the results hold despite this less conservative approach.

As shown in Table 14, the effect of STPs remains consistently positive for both indicators of patent quality regardless of the selection criteria chosen.

**Table 14** Effect of STPs on patent quality indicators by selection criteria

	OLS regression			
	(1)	(2)	(3)	(4)
	log (Fwd_cits7)	log (Renewal)	log (Fwd_cits7)	log (Renewal)
Patpark_App	0.061 ** [0.026]	0.065 *** [0.022]		
Patpark_All			0.086 *** [0.020]	0.041 ** [0.018]
log(Firm_age)	-0.054 *** [0.010]	-0.043 *** [0.009]	-0.054 *** [0.010]	-0.046 *** [0.009]
log(Firm_emp)	0.008 [0.009]	0.010 [0.008]	0.004 [0.009]	0.010 [0.008]
log(Firm_sales)	0.018 *** [0.006]	0.008 [0.005]	0.017 *** [0.006]	0.007 [0.005]
Year dummies	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Constant	0.132 ** [0.065]	1.821 *** [0.069]	0.145 ** [0.065]	1.833 *** [0.069]
<i>N</i>	6885	6885	6885	6885

Marginal effects; Robust standard errors in brackets; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$

Columns (1) and (2) show the results of the OLS regression model for criteria selection only with applicants' addresses. Columns (3) and (4) show the results of the OLS regression model for criteria selection which considers any patent of firms with on-park patents an on-park patent

## Appendix 4—Flowchart of patent classification

See Fig. 2.

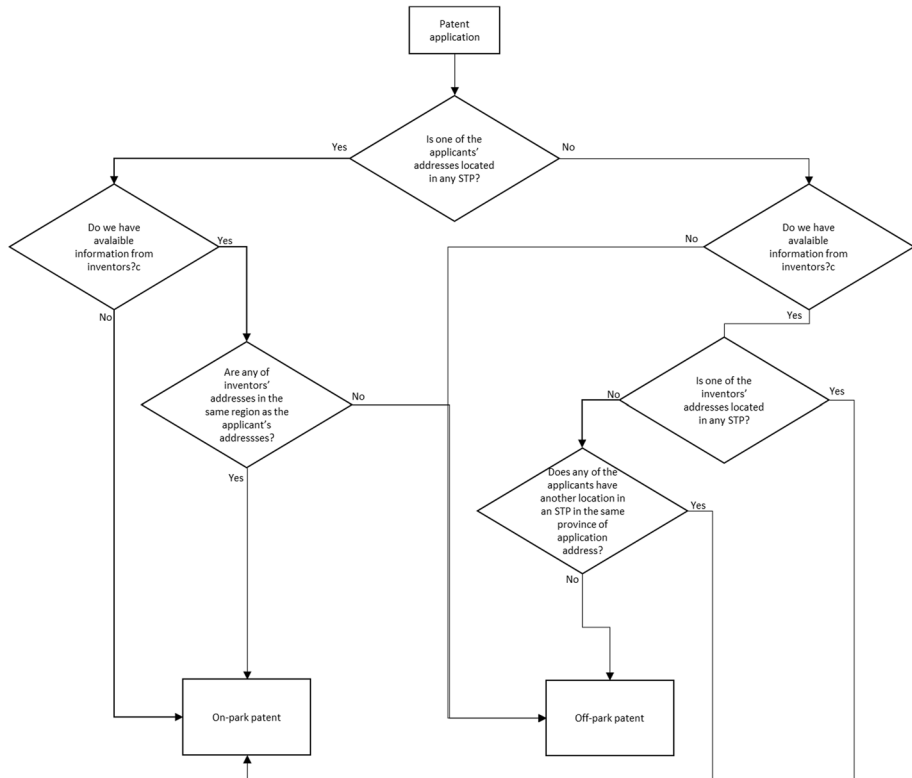


Fig. 2 Flow chart of on-park and off-park patent classification

## Appendix 5—Robustness check of forward citations lag

Table 15 shows that the average number of 7-year citations for each year increases in the July 21 version of the dataset. Mainly, there is a greater difference in 2011 (10% increase) and 2012 (30.7% increase). This indicates that the forward citations indicator is suffering lag.

**Table 15** Average number of forward citations of the OECD Patent Quality Indicators database versions per year

app_year	July 21 edition	January 20 edition	(a) – (b)
	fwd_cits7 (a)	fwd_cits7 (b)	
2004	1.089	1.085	0.004
2005	1.499	1.484	0.015
2006	1.169	1.157	0.012
2007	1.082	1.070	0.012
2008	0.962	0.953	0.009
2009	0.905	0.894	0.011
2010	0.814	0.781	0.033
2011	0.890	0.809	0.081
2012	0.694	0.531	0.163

If the dataset shows no lag in updating citations, the fwd\_cits7 indicator should have been identical in the two columns, but we observe that it is systematically larger in the version from June 2021 and that the difference increases for more recent patents

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## Declarations

**Conflict of interest** We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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## References

- Albahari, A. (2021). The logic behind science and technology parks. In *Handbook of research on business and technology incubation and acceleration* (pp. 97–109). Edward Elgar Publishing, Cheltenham. <https://doi.org/10.4337/9781788974783.00012>

- Albahari, A., Barge-Gil, A., Pérez-Canto, S., & Landoni, P. (2022). The effect of science and technology parks on tenant firms: A literature review. *The Journal of Technology Transfer*. <https://doi.org/10.1007/s10961-022-09949-7>
- Albahari, A., Barge-Gil, A., Pérez-Canto, S., & Modrego, A. (2018). The influence of science and technology park characteristics on firms' innovation results. *Papers in Regional Science*, 97, 253–279. <https://doi.org/10.1111/pirs.12253>
- Albahari, A., Pérez-Canto, S., Barge-Gil, A., & Modrego, A. (2017). Technology parks versus science parks: Does the university make the difference? *Technological Forecasting and Social Change*, 116, 13–28. <https://doi.org/10.1016/j.techfore.2016.11.012>
- Albert, M. B., Avery, D., Narin, F., & McAllister, P. (1991). Direct validation of citation counts as indicators of industrially important patents. *Research Policy*, 20, 251–259. [https://doi.org/10.1016/0048-7333\(91\)90055-U](https://doi.org/10.1016/0048-7333(91)90055-U)
- APTE. (2013). Directory 2012.
- APTE. (2021). Directory 2020.
- Archibugi, D. (1992). Patenting as an indicator of technological innovation: A review. *Science and Public Policy*, 19, 357–368. <https://doi.org/10.1093/spp/19.6.357>
- Balasubramanian, N., & Lee, J. (2008). Firm age and innovation. *Industrial and Corporate Change*, 17, 1019–1047. <https://doi.org/10.1093/icc/dtn028>
- Baptista, R., & Swann, P. (1998). Do firms in clusters innovate more? *Research Policy*, 27, 525–540. [https://doi.org/10.1016/S0048-7333\(98\)00065-1](https://doi.org/10.1016/S0048-7333(98)00065-1)
- Beaudry, C., & Schiffrerova, A. (2009). Who's right, Marshall or Jacobs? The localization versus urbanization debate. *Research Policy*, 38, 318–337. <https://doi.org/10.1016/j.respol.2008.11.010>
- Bessen, J. (2008). The value of U.S. patents by owner and patent characteristics. *Research Policy*, 37, 932–945. <https://doi.org/10.1016/j.respol.2008.02.005>
- Cadorin, E., Johansson, S. G., & Klofsten, M. (2017). Future developments for science parks. *Industry and Higher Education*, 31, 156–167. <https://doi.org/10.1177/0950422217700995>
- Carlino, G., Kerr, W. R. (2015). Agglomeration and Innovation, 1st ed. In *Handbook of regional and urban economics*. Elsevier B.V. <https://doi.org/10.1016/B978-0-444-59517-1.00006-4>
- Carpenter, M. P., Narin, F., & Woolf, P. (1981). Citation rates to technologically important patents. *World Patent Information*, 3, 160–163. [https://doi.org/10.1016/0172-2190\(81\)90098-3](https://doi.org/10.1016/0172-2190(81)90098-3)
- Chan, K. Y. A., Oerlemans, L. A. G., & Pretorius, M. W. (2010). Knowledge exchange behaviours of science park firms: The innovation hub case. *Technology Analysis and Strategic Management*, 22, 207–228. <https://doi.org/10.1080/09537320903498546>
- Chan, K. Y. A., Oerlemans, L., & Pretorius, T. (2011). Innovation outcomes of South African new technology-based firms: a contribution to the debate on the performance of science park firms. *South African Journal of Economic and Management Sciences*, 14(4), 361–378. <https://doi.org/10.4102/sajems.v14i4.34>
- Chen, J., Roth, J. (2022). Log-like ? ATEs defined with zero outcomes are (arbitrarily) (pp. 1–18).
- Cinelli, C., & Hazlett, C. (2020). Making sense of sensitivity: Extending omitted variable bias. *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, 82, 39–67. <https://doi.org/10.1111/rssb.12348>
- Cohen, W. M., Levin, R. C. (1989). Chapter 18 Empirical studies of innovation and market structure. In *Handbook of industrial organization* (pp. 1059–1107). Elsevier, Amsterdam. [https://doi.org/10.1016/S1573-448X\(89\)02006-6](https://doi.org/10.1016/S1573-448X(89)02006-6)
- Colombo, M. G., & Delmastro, M. (2002). The determinants of organizational change and structural inertia: technological and organizational factors. *Journal of Economics and Management Strategy*, 11, 595–635. <https://doi.org/10.1111/j.1430-9134.2002.00595.x>
- Corrocher, N., Lamperti, F., & Mavilia, R. (2019). Do science parks sustain or trigger innovation? Empirical evidence from Italy. *Technological Forecasting and Social Change*, 147, 140–151. <https://doi.org/10.1016/j.techfore.2019.07.005>
- Dang, J., & Motohashi, K. (2015). Patent statistics: A good indicator for innovation in China? Patent subsidy program impacts on patent quality. *China Economic Review*, 35, 137–155. <https://doi.org/10.1016/j.chieco.2015.03.012>
- Díez-Vial, I., & Fernández-Olmos, M. (2015). Knowledge spillovers in science and technology parks: How can firms benefit most? *Journal of Technology Transfer*, 40, 70–84. <https://doi.org/10.1007/s10961-013-9329-4>
- Feldman, M.P., Kogler, D.F., 2010. Stylized facts in the geography of innovation. In *Handbook of the economics of innovation* (pp. 381–410). Elsevier, Amsterdam. [https://doi.org/10.1016/S0169-7218\(10\)01008-7](https://doi.org/10.1016/S0169-7218(10)01008-7)

- Feldman, M. P. (1999). The new economics of innovation, spillovers and agglomeration: A review of empirical studies. *Economics of Innovation and New Technology*, 8, 5–25. <https://doi.org/10.1080/10438599900000002>
- Felsenstein, D. (1994). University-related science parks—‘seedbeds’ or ‘enclaves’ of innovation? *Technovation*, 14, 93–110. [https://doi.org/10.1016/0166-4972\(94\)90099-X](https://doi.org/10.1016/0166-4972(94)90099-X)
- Fleming, L., & Sorenson, O. (2004). Science as a map in technological search. *Strategic Management Journal*, 25, 909–928. <https://doi.org/10.1002/smj.384>
- Fukugawa, N. (2006). Science parks in Japan and their value-added contributions to new technology-based firms. *International Journal of Industrial Organization*, 24, 381–400. <https://doi.org/10.1016/j.ijindorg.2005.07.005>
- Gambardella, A., Harhoff, D., & Verspagen, B. (2008). The value of European patents. *European Management Review*, 5, 69–84. <https://doi.org/10.1057/emr.2008.10>
- Germain, E., Klofsten, M., Löfsten, H., & Mian, S. (2022). Science parks as key players in entrepreneurial ecosystems. *R&D Management*. <https://doi.org/10.1111/radm.12536>
- Gilly, J., & Torre, A. (2000). *Proximity relations: Elements for an analytical framework*. Aldershot: Ashgate Publishing Limited.
- Griliches, Z., Pakes, A., Hall, B. H. (1987). The value of patents as indicators of inventive activity. In *Economic policy and technological performance* (pp. 97–124). Cambridge University Press, New York. <https://doi.org/10.1017/cbo9780511559938.006>
- Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, 28, 1661–1707.
- Guellec, D., Martinez, C., & Zuniga, P. (2012). Pre-emptive patenting: Securing market exclusion and freedom of operation. *Economics of Innovation and New Technology*, 21, 1–29. <https://doi.org/10.1080/10438599.2010.536378>
- Guellec, D., Pottelsberghe, V., & de la Potterie, B. (2002). The value of patents and patenting strategies: Countries and technology areas patterns. *Economics of Innovation and New Technology*, 11, 133–148. <https://doi.org/10.1080/10438590210896>
- Guellec, D., & Potterie de la, B. V. (2000). Applications, grants and the value of patent. *Economics Letters*, 69, 109–114. [https://doi.org/10.1016/s0165-1765\(00\)00265-2](https://doi.org/10.1016/s0165-1765(00)00265-2)
- Guellec, D., & van Pottelsberghe de la Potterie, B. (2007). *The economics of the european patent system: IP policy for innovation and competition*. Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780199216987.001.0001>
- Guerrini, C. J. (2014). Defining patent quality. *Fordham Law Review*, 82, 3091–3143.
- Harhoff, D., Narin, F., Scherer, F. M., & Vopel, K. (1999). Citation frequency and the value of patented inventions. *Review of Economics and Statistics*, 81, 511–515. <https://doi.org/10.1162/003465399558265>
- Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy*, 32, 1343–1363. [https://doi.org/10.1016/S0048-7333\(02\)00124-5](https://doi.org/10.1016/S0048-7333(02)00124-5)
- Hervas-Oliver, J. L., & Albors-Garrigos, J. (2009). The role of the firm’s internal and relational capabilities in clusters: When distance and embeddedness are not enough to explain innovation. *Journal of Economic Geography*, 9, 263–283. <https://doi.org/10.1093/jeg/lbn033>
- Higham, K., de Rassenfosse, G., & Jaffe, A. B. (2021). Patent Quality: Towards a systematic framework for analysis and measurement. *Research Policy*, 50, 104215. <https://doi.org/10.1016/j.respol.2021.104215>
- Hobbs, K. G., Link, A. N., & Scott, J. T. (2017). Science and technology parks: An annotated and analytical literature review. *Journal of Technology Transfer*, 42, 957–976. <https://doi.org/10.1007/s10961-016-9522-3>
- Hu, T. S. (2008). Interaction among high-tech talent and its impact on innovation performance: A comparison of Taiwanese science parks at different stages of development. *European Planning Studies*, 16, 163–187. <https://doi.org/10.1080/09654310701814462>
- Huang, K. F., Yu, C. M. J., & Seetoo, D. H. (2012). Firm innovation in policy-driven parks and spontaneous clusters: The smaller firm the better? *Journal of Technology Transfer*, 37, 715–731. <https://doi.org/10.1007/s10961-012-9248-9>
- IASP. (2021). IASP international board.
- Jung, H. J., & Lee, J. J. (2016). The quest for originality: A new typology of knowledge search and breakthrough inventions. *Academy of Management Journal*, 59, 1725–1753. <https://doi.org/10.5465/amj.2014.0756>
- Kortum, S., & Lerner, J. (1999). What is behind the recent surge in patenting? *Research Policy*, 28, 1–22. [https://doi.org/10.1016/S0048-7333\(98\)00082-1](https://doi.org/10.1016/S0048-7333(98)00082-1)

- Lamperti, F., Mavilia, R., & Castellini, S. (2017). The role of science parks: A puzzle of growth, innovation and R&D investments. *Journal of Technology Transfer*, 42, 158–183. <https://doi.org/10.1007/s10961-015-9455-2>
- Lanjouw, J. O., Schankerman, M. (1997). Stylized facts of patent litigation: Value, scope and ownership. National Bureau of Economic Research Working Paper Series No. 6297.
- Lanjouw, J. O., Pakes, A., & Putnam, J. (1998). How to count patents and value intellectual property: The uses of patent renewal and application data. *Journal of Industrial Economics*, 46, 405–432. <https://doi.org/10.1111/1467-6451.00081>
- Lecluyse, L., Knockaert, M., & Spithoven, A. (2019). The contribution of science parks: A literature review and future research agenda. *Journal of Technology Transfer*, 44, 559–595. <https://doi.org/10.1007/s10961-018-09712-x>
- Liberati, D., Marinucci, M., & Tanzi, G. M. (2016). Science and technology parks in Italy: Main features and analysis of their effects on the firms hosted. *Journal of Technology Transfer*, 41, 694–729. <https://doi.org/10.1007/s10961-015-9397-8>
- Lindelöf, P., & Löfsten, H. (2002a). Growth, management and financing of new technology-based firms—assessing value-added contributions of firms located on and off Science Parks. *Omega - the International Journal of Management Science*, 30, 143–154. [https://doi.org/10.1016/S0305-0483\(02\)00023-3](https://doi.org/10.1016/S0305-0483(02)00023-3)
- Lindelöf, P., & Löfsten, H. (2002b). Growth, management and financing of new technology-based firms. Assessing value-added contributions of firms located on and off Science Parks. *Omega*, 30, 143–154. [https://doi.org/10.1016/S0305-0483\(02\)00023-3](https://doi.org/10.1016/S0305-0483(02)00023-3)
- Lindelöf, P., & Löfsten, H. (2003). Science park location and new technology-based firms in Sweden—Implications for strategy and performance. *Small Business Economics*, 20, 245–258. <https://doi.org/10.1023/A:1022861823493>
- Link, A. N., & Scott, J. T. (2007). The economics of university research parks. *Oxford Review of Economic Policy*, 23, 661–674. <https://doi.org/10.1093/oxrep/grm030>
- Liu, K., Arthurs, J., Cullen, J., & Alexander, R. (2008). Internal sequential innovations: How does inter-relatedness affect patent renewal? *Research Policy*, 37, 946–953. <https://doi.org/10.1016/j.respol.2008.03.005>
- Löfsten, H., & Lindelöf, P. (2002). Science Parks and the growth of new technology-based firms—Academic-industry links, innovation and markets. *Research Policy*, 31, 859–876. [https://doi.org/10.1016/S0048-7333\(01\)00153-6](https://doi.org/10.1016/S0048-7333(01)00153-6)
- Löfsten, H., & Lindelöf, P. (2003). Determinants for an entrepreneurial milieu: Science Parks and business policy in growing firms. *Technovation*, 23, 51–64. [https://doi.org/10.1016/S0166-4972\(01\)00086-4](https://doi.org/10.1016/S0166-4972(01)00086-4)
- Love, J. H., & Roper, S. (2001). Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants. *Research Policy*, 30, 643–661. [https://doi.org/10.1016/S0048-7333\(00\)00098-6](https://doi.org/10.1016/S0048-7333(00)00098-6)
- MacPherson, A. (1997). The contribution of external service inputs to the product development efforts of small manufacturing firms. *R&D Management*, 27, 127–144. <https://doi.org/10.1111/1467-9310.00049>
- Maraut, S., Dernis, H., Webb, C., Spiezia, V., Guellec, D. (2008). The OECD REGPAT database: A presentation. OECD Science, Technology and Industry Working Papers No. 2008/2.
- Martínez, C. (2011). Patent families: When do different definitions really matter? *Scientometrics*, 86, 39–63. <https://doi.org/10.1007/s11192-010-0251-3>
- Nagaoka, S., Motohashi, K., Goto, A. (2010). Patent statistics as an innovation indicator. In *Handbook of the economics of innovation*. (pp. 1083–1127). Elsevier, Amsterdam. [https://doi.org/10.1016/S0169-7218\(10\)02009-5](https://doi.org/10.1016/S0169-7218(10)02009-5)
- Ng, W. K. B., Junker, R., Appel-Meulenbroek, R., Clodt, M., & Arentze, T. (2020). Perceived benefits of science park attributes among park tenants in the Netherlands. *Journal of Technology Transfer*, 45, 1196–1227. <https://doi.org/10.1007/s10961-019-09744-x>
- Pakes, A., Schankerman, M. (1984). The Rate of obsolescence of patents, research gestation Lags, and the private rate of return to research resources. In *R&D, patents, and productivity*. (pp. 73–88). University of Chicago Press, Chicago
- Battelle Technology Partnership Practice. (2013). Driving regional innovation and growth: The 2012 survey of North American University Research Parks.
- Putnam, J. D. (1997). The value of international patent rights. *Journal of International Business Studies*. [Doctoral dissertation, Yale University].
- Roberts, E. B. (1988). What we've learned: Managing Invention and Innovation. *Research-Technology Management*, 31, 11–29. <https://doi.org/10.1080/08956308.1988.11670497>
- Rodríguez-Pose, A., & Hardy, D. (2014). *Technology and industrial parks in emerging countries: Panacea or pipedream?* Heidelberg: Springer. <https://doi.org/10.1080/00343404.2015.1053338>



- Rogers, M. (2004). Networks, firm size and innovation. *Small Business Economics*, 22, 141–153. <https://doi.org/10.1023/B:SBEJ.0000014451.99047.69>
- Rowe, D. (2014). Setting up, managing and evaluating EU science and technology parks. European Commission, Directorate-General for Regional and Urban Policy, Brussels.
- Sapsalis, E., & van Pottelsberghe de la Potterie, B. (2007). The institutional sources of knowledge and the value of academic patents. *Economics of Innovation and New Technology*, 16, 139–157. <https://doi.org/10.1080/10438590600982939>
- Sapsalis, E., van Pottelsberghe de la Potterie, B., & Navon, R. (2006). Academic versus industry patenting: An in-depth analysis of what determines patent value. *Research Policy*, 35, 1631–1645. <https://doi.org/10.1016/j.respol.2006.09.014>
- Schankerman, M. (1998). How valuable is patent protection? Estimates by technology field. *The RAND Journal of Economics*, 29, 77. <https://doi.org/10.2307/2555817>
- Scherer, F. M., & Harhoff, D. (2000). Technology policy for a world of skew-distributed outcomes. *Research Policy*, 29, 559–566. [https://doi.org/10.1016/S0048-7333\(99\)00089-X](https://doi.org/10.1016/S0048-7333(99)00089-X)
- Schettino, F., Sterlacchini, A., & Venturini, F. (2013). Inventive productivity and patent quality: Evidence from Italian inventors. *Journal of Policy Modeling*, 35, 1043–1056. <https://doi.org/10.1016/j.jpolmod.2013.02.008>
- Siegel, D. S., Westhead, P., & Wright, M. (2003). Assessing the impact of university science parks on research productivity: Exploratory firm-level evidence from the United Kingdom. *International Journal of Industrial Organization*, 21, 1357–1369. [https://doi.org/10.1016/S0167-7187\(03\)00086-9](https://doi.org/10.1016/S0167-7187(03)00086-9)
- Squicciarini, M., Dernis, H., Criscuolo, C. (2013). Measuring patent quality: Indicators of technological and economic value. OECD Science, Technology and Industry Working Papers No. 2013/3.
- Squicciarini, M. (2008). Science parks' tenants versus out-of-park firms: Who innovates more? A duration model. *Journal of Technology Transfer*, 33, 45–71. <https://doi.org/10.1007/s10961-007-9037-z>
- Squicciarini, M. (2009). Science parks: Seedbeds of innovation? A duration analysis of firms' patenting activity. *Small Business Economics*, 32, 169–190. <https://doi.org/10.1007/s11187-007-9075-9>
- Theeranattapong, T., Pickernell, D., & Simms, C. (2021). Systematic literature review paper: The regional innovation system - university - science park nexus. *The Journal of Technology Transfer*. <https://doi.org/10.1007/s10961-020-09837-y>
- Tomelin, J., Amal, M., Zen, A. C., & Arrabito, P. (2018). Internationalisation of science parks: Experiences of Brazilian innovation environments. In R. van Tulder, A. Verbeke, & L. Piscitello (Eds.), *International business in the information and digital age (Progress in international business research, vol. 13)* (pp. 391–408). Bingley: Emerald Publishing Limited. <https://doi.org/10.1108/S1745-8862201800013017>
- Trajtenberg, M. (1990). A penny for your quotes: Patent citations and the value of innovations. *The RAND Journal of Economics*, 21, 172–187. <https://doi.org/10.2307/2555502>
- Ünlü, H., Temel, S., & Miller, K. (2022). Understanding the drivers of patent performance of University Science Parks in Turkey. *Journal of Technology Transfer*, 48, 842–872. <https://doi.org/10.1007/s10961-022-09929-x>
- van Zeebroeck, N. (2011). The puzzle of patent value indicators. *Economics of Innovation and New Technology*, 20, 33–62. <https://doi.org/10.1080/10438590903038256>
- van Zeebroeck, N., & van van Pottelsberghe de la Potterie, B. (2011a). The vulnerability of patent value determinants. *Economics of Innovation and New Technology*, 20, 283–308. <https://doi.org/10.1080/10438591003668638>
- van Zeebroeck, N., & van van Pottelsberghe de la Potterie, B. (2011b). Filing strategies and patent value. *Economics of Innovation and New Technology*, 20, 539–561. <https://doi.org/10.1080/10438591003668646>
- van Zeebroeck, N., van van Pottelsberghe de la Potterie, B., & Guellec, D. (2009). Claiming more: The increased voluminosity of patent applications and its determinants. *Research Policy*, 38, 1006–1020. <https://doi.org/10.1016/j.respol.2009.02.004>
- Vásquez-Urriago, Á. R., Barge-Gil, A., & Modrego Rico, A. (2016). Science and technology parks and cooperation for innovation: Empirical evidence from Spain. *Research Policy*, 45, 137–147. <https://doi.org/10.1016/j.respol.2015.07.006>
- Vásquez-Urriago, Á. R., Barge-Gil, A., Rico, A. M., & Paraskevopoulou, E. (2014). The impact of science and technology parks on firms' product innovation: Empirical evidence from Spain. *Journal of Evolutionary Economics*, 24, 835–873. <https://doi.org/10.1007/s00191-013-0337-1>
- Vedovello, C. (1997). Science parks and university-industry interaction: Geographical proximity between the agents as a driving force. *Technovation*, 17, 491–531. [https://doi.org/10.1016/S0166-4972\(97\)00027-8](https://doi.org/10.1016/S0166-4972(97)00027-8)

- Wadhwa, A., Phelps, C., & Kotha, S. (2016). Corporate venture capital portfolios and firm innovation. *Journal of Business Venturing*, 31, 95–112. <https://doi.org/10.1016/j.jbusvent.2015.04.006>
- Westhead, P. (1997). R&D “inputs” and “outputs” of technology-based firms located on and off science parks. *R&D Management*, 27, 45–62. <https://doi.org/10.1111/1467-9310.00041>
- Yang, C. H., Motohashi, K., & Chen, J. R. (2009). Are new technology-based firms located on science parks really more innovative? Evidence from Taiwan. *Research Policy*, 38, 77–85. <https://doi.org/10.1016/j.respol.2008.09.001>
- Youtie, J., Iacopetta, M., & Graham, S. (2008). Assessing the nature of nanotechnology: Can we uncover an emerging general purpose technology? *Journal of Technology Transfer*, 33, 315–329. <https://doi.org/10.1007/s10961-007-9030-6>

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