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Science Parks, Knowledge Spillovers, and Firms' Innovative Performance. Evidence from Finland

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Abstract

The paper focuses on the role of Science Parks (SPs) as seedbeds of innovation. It investigates whether and to what extent locating inside a science park relates to the innovative output of tenant firms. The simple assessment methodology proposed relies on count data models, uses patents as innovation performance indicators, and exploits original data regarding the Finnish science parks, their main characteristics, and the data of 252 SP tenant firms, including their patenting activity over the period 1970–2002. Among other results, the study suggests that both within and among SPs interaction and spillover effects exist, and points out the way in which they relate to firms' innovative output. Results are robust to controlling for the existence of innovation lags. Parks' first mover disadvantages also emerge, as well as non-negligible matching phenomena whereby firms' and parks' characteristics matter jointly.

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1 Introduction

Science parks (SPs) are organisations intended to promote the innovativeness and competitiveness of the firms and knowledge-based institutions located on their premises. They constitute physical loci where the co-location of industry and research should facilitate knowledge flows and innovation (IASP, 2002; OECD 1997). Science parks' mission should be to: strengthen (local) industry's competitiveness through spreading innovation; transfer technology and knowhow, and enhance the synergy between universities and companies; foster entrepreneurship and help high-tech start-up firms; generate employment, especially knowledge-based jobs; train in new or needed skills; benchmark experiences, and select and exchange best practices and results (IASP, 2009).

The diffusion and growing importance of science parks over the last four decades has motivated many studies to try and empirically assess the effectiveness of these innovation policy tools. The present paper contributes to this SP performance assessment literature by focusing on the role of science parks as seedbeds of innovation. It investigates whether SPs facilitate the innovativeness of their tenant firms by means of stimulating and channelling the knowledge and knowledge spillovers generated within their premises. To this end, it analyses if and to what extent firms' innovative output, measured in terms of patent applications, relates to the presence of Higher Education Institutes (HEIs), incubators and very big companies inside the parks.

The study builds on the science parks' literature, as well as on additional insights offered by the literature on innovation, knowledge and knowledge spillovers, firms' characteristics and innovativeness, and patents. The very simple estimation strategy followed relies on count data models and uses an original cross-section dataset regarding the Finnish science parks, their features, and the main characteristics and patenting activity of 252 tenants located on the SPs' premises. Both park and tenant characteristics' data mainly reflect the year 2002 situation, whereas the innovative activity of firms is recorded throughout the period 1970–2002. The analysis proposed is not to be considered a clean test of causation, as data availability impinges upon the possibility to fully address possible selection and endogeneity problems. Nonetheless, it has the advantage that it can be easily replicated, in terms of performance indicator used and country studied; allows for cross-country comparisons; and helps uncovering interesting relationships between science parks' features, companies' characteristics, and tenants' innovative performance.

The analysis suggests that co-location inside SPs indeed matters for firms' innovative output performance, and that within-parks knowledge spillovers exist. It points out the way they relate to the innovativeness of the tenants and highlights that the successfulness of science parks as seedbeds of innovation is linked to particular combinations of park features and firm characteristics. Results prove robust to accounting for the existence of innovation lags, i.e. the time elapsing between the conception of innovative ideas and their implementation into marketable products and processes. The empirical focus of the paper on Finnish SPs and their tenants aims to fill a gap existing in the literature, and to contribute to a better understanding of part of the very successful albeit little known Finnish system of innovation.

The structure of the paper is as follows. Section 2 draws the framework on which the study relies, and briefly surveys the relevant science parks' literature and the other

contributions considered. It then describes the dataset used in the empirical analysis, and explains the way data have been collected (§ 3). Section 4 illustrates the simple performance assessment model carried out, its econometrics, as well as the variables used in the empirical analysis and their expected behaviour (Section 4.1). Section 5 presents the estimates and comments on the results, whereas Section 6 shows some robustness checks. Section 7 concludes and points out the possible innovation policy implications of the analysis.

2 Science Parks, Location, Knowledge Spillovers and Innovation

According to the International Association of Science Parks (IASP), science parks are organisations managed by specialised professionals whose main aim is to increase the wealth of their communities. They should promote the culture of innovation and the competitiveness of their associated businesses and knowledge-based institutions by means of stimulating and managing the flow of knowledge and technology amongst universities, R&D institutions, companies and markets. To this end, science parks facilitate the creation, growth and internationalisation of skills-intensive businesses and innovation-based companies, also through incubation and spin-off processes, and provide other value-added services as well as high quality space and facilities (IASP, 2002). As for the Finnish SPs in particular, they offer their customers [business development services](#), [programme and project co-operation](#), and [key contacts and networks](#). Co-operation with Higher Education Institutions (HEIs) translates in the creation and development of business development services, pre-incubator and incubator services, as well as co-operative projects and co-operation facilities (Tekel, 2009). Generally firms have to apply to join a science park, and their candidature is evaluated on the basis of their 'potential' and objectives (Tekel, 2009), vis-à-vis the broad mission and objectives of the park. However, being SPs rent-seeking organisations (OECD, 1997), SPs' scouts also search for and invite firms to become tenants, thus avoiding that empty premises may jeopardise their rent income.

Historically, the linear model of innovation (Bush, 1945), the "National System of Innovation" (Lundvall, 1988, 1992), and the "Triple helix" (Etzkowitz and Leydesdorff, 1997)¹ models have all offered arguments supporting of the creation of science parks. Innovation, it has been argued, is a complex process that can be facilitated by organisations like SPs able to foster the interaction of the various actors involved, and to strengthen and suitably channel the knowledge flows thus generated. Complex in theory and broad in scope, the science park concept has followed a variety of approaches when put into practice. Starting from the 60ies, a heterogeneous group of initiatives has

¹ In a nutshell, the linear model of innovation depicts innovation as a process sequentially articulated into basic research, applied research and development, and finally production and diffusion (see Godin, 2006, for a survey). By "National Innovation System" (NIS) it is intended the flow of technology and information among people, enterprises and institutions. This - it is maintained - is key to the innovative process, since innovation and technology development results from a complex set of relationships among the actors in the system, including enterprises, universities and government research institutes. Finally, the triple helix is a spiral model of innovation capturing the multiple reciprocal relationships existing between university, industry, and government, which are considered as relatively equal, yet interdependent, institutional spheres.

spread all over the world using variants of the SP name but claiming common sets of objectives.

The heterogeneous nature of these innovation policy tools is mirrored by the many varieties of analyses aiming to assess science parks' value-added and effectiveness. Similarly broad is the range of performance indicators used. Among these, the survival and growth of New Technology Based Firms (NTBFs); the establishment of links with Higher Education Institutions (HEIs); R&D, innovation input and innovation output; agglomeration effects and regional growth. Of the many assessments that exist, particularly relevant to our purposes are those Hodgson (1996) terms 'relative performance' and 'impact evaluation' analyses, i.e. studies that quantitatively investigate the links between SPs' features, activities, and outcomes.² These assessments exercises generally rely on cross sections, follow simple estimation strategies, and aim to uncover relationships rather than assessing causes, as data quality and availability often constrain the possibility to fully address selection, self-selection and endogeneity concerns.

SP performance assessment and impact evaluation was pioneered by Monck et al (1986) and their analysis of the way SPs may add value to businesses. They gathered empirical evidence by constructing first-hand survey-based data of high-technology firms located in and out the science parks. Doing so, they initiated a whole SP assessment tradition typically comparing the performance of park tenants with that of similar firms located outside the SP premises. Monck et al's (1986) database was later updated and exploited in many UK studies. The use of matched samples also got widely adopted by a variety of studies relying on different yet simple econometric models and constructing wide sets of indicators. To this part of the SP assessment literature pertain, for instance, Westhead and Storey's (1994, 1995) and Westhead's (1997) analyses of the UK science parks, as well as Löfsten and Lindelöf's (2001, 2002, 2003, 2005) and Ferguson and Olofsson (2004) studies of the Swedish SP experience. The aspects investigated include: SPs firms' R&D intensity, their tendency to patent, the launch of new products and services, the growth in terms of sales and unemployment, firms' profitability, survival/closure rates, the links with Universities and HEIs, and SPs' ability to constitute seedbed areas for NTBFs.

Both the UK and the Swedish studies offer mixed evidence about the effectiveness of science parks as innovation policy tools, and do not corroborate or reject such hypothesis. A positive stand is instead taken by Colombo and Delmastro (2002) in their analysis of the Italian NTBFs located in and out the SPs. They find in-SP NTBFs to perform comparatively better in terms of adoption of new technologies and links with HEIs, to show comparatively higher growth rates, and to more successfully get access to public subsidies. Similarly positive conclusions are also offered by Fugukawa's (2006) assessment of the ability of in- and out-Japanese parks' NTBFs to establish links with HEIs.

A completely different way of addressing SPs' effectiveness was instead pursued in some of the US Science Parks' assessment exercises. Examples are Luger and Goldstein (1991), who propose a success/failure classification based on a cross sectional analysis of the rate at which parks foster the creation of new jobs at the regional level; and Link and Scott (2003, 2006) who focus on the diffusion and growth of the US science parks

² We overlook the many case studies that exist, due to their being mainly descriptive and qualitative in nature.

themselves. Among other results, the latter find that SPs located closer to universities, operated by private organisations and with specific technological foci grow faster than the average.

The present paper follows the path initiated by Felsenstein (1994) and investigates the role of science parks as seedbeds of innovation. Felsenstein (1994) studies the interaction effects between SP firms and their neighbouring park firms, local universities and off-park firms to verify whether SPs function as enclaves of innovation rather than seedbeds. He studies two sets of relationships: (1) the relationship between the innovation level of the firm (coded as either significant or incremental), the interaction with a university, and the educational background of the entrepreneur/manager; and (2) the relationship between the innovation level of the firm, SP location and prior work position of the entrepreneur/manager. He tests these hypotheses on 160 surveyed high-technology firms in Israel, located both on and off-park. He finds that seedbed effects, as proxied by the level of interaction with local HEIs and by the entrepreneurs' educational background, are not necessarily related to the firms' innovative level. He also sees SP location to have only a weak and indirect relationship with innovation level, and concludes that the role of the science park is innovation-entrenching rather than innovation-inducing.

We depart from Felsenstein's (1994) empirical strategy and take a mixed approach whereby both parks' and firms' characteristics are at the centre of the analysis.³ The performance indicator we use is patent applications rather than the firms' subjective statements about their own innovation levels. Moreover, we do not have data about the number or quality of the relationships of SP firms with other firms or HEIs, but put forward and test a simple co-location hypothesis. We believe that locating inside science parks may affect the innovative performance of the tenants in two ways: directly, thanks to the interactions among firms and between firms and HEIs; and indirectly, due to the within-park and between-SPs knowledge spillovers.

Our co-location hypothesis is motivated by the very rationale of science parks' creation, a concept where location, innovation, and knowledge spillovers recur as a leitmotiv. As knowledge and knowledge spillovers are amongst the determinants of innovative activities, SPs should fulfil their policy mission by facilitating the interaction of the tenants, and by opportunely managing the knowledge and knowledge spillovers generated by the firms located within SP premises. Evidence suggests that knowledge spillovers positively contribute to innovation when knowledge diffusion outweighs lack of appropriability.⁴ As a matter of fact, both 'incoming' and 'outgoing' spillovers exist (Cassiman and Veugelers, 2002), and firms need to build their absorptive capacity (Cohen and Levinthal, 1989) in order to be able to capture the knowledge that is freely available or that leaks out of their competitors. To understand whether diffusion or lack of appropriability prevails, Audretsch and Feldman (1996), David et al (1996), Feldman and Audretsch (1999), and Saxenian (1994), among others, have investigated the channels through which spillovers work, in particular location and geographical

³ Felsenstein (1994) uses a log-linear modelling to predict the number of cases in a cell of a multi-dimensional contingency table. See § 4 about the simple modelling strategy used in the present paper.

⁴ Knowledge spillovers may foster or hinder innovation and firms' incentives to invest in innovative activities. On the one hand, spillovers enable the diffusion of knowledge, but, on the other hand, such diffusion effect can be counterbalanced by lack of appropriability. This is why the literature (see, for instance, Katz, 1986; Aghion and Tirole, 1994; Klette, 1996; Sena, 2004) offers different answers to this question, depending upon which of the two effects is predominant.

proximity. They all conclude that knowledge spillovers and co-location are very important for innovation, and thus indirectly support the rationale behind the creation of science parks.

The reasoning above contributes to explain both SPs' policy mission and their widespread diffusion, but leaves still open the question of whether science parks succeed in constituting seedbeds of innovation. To address this question we rely on patent counts as innovation output measures. We do so since patents constitute an objective and fairly standardised, abundant and detailed source of data (Griliches, 1990), and the problems associated with their use can be easily dealt with by looking at the correlations between patent counts and other relevant variables (see Scherer, 1984; Schankerman and Pakes, 1986; Trajtenberg, 1990, 1996; Jaffe and Trajtenberg, 2002). In this respect, we rely on two strands of the literature on firms' characteristics and innovativeness. The first is the one investigating the Schumpeterian hypothesis concerning firm size and innovation (e.g. Cohen et al, 1987; Scherer, 1984; Acs and Audretsch, 1988, 1991; Cohen and Klepper, 1992, 1996). The second is the literature focusing on the relationship between firm size and firm growth and the evolution of industry (e.g. Jovanovic, 1982; Jovanovic and MacDonald, 1994; Evans, 1987; Klette & Griliches, 2000; Klepper, 1996). The analytical elements suggested by these literatures help us formalising the hypotheses made in model and predicting the way we expect variables to behave, and will become clear in § 4.1.

3 The Data

The study relies on first-hand data regarding the Finnish science parks, their main features, and the data of 252 firms located within the park premises, these firms' characteristics, and their patenting activity over the period 1970–2002. All science parks located in Finland at the time of the survey (year 2002) were listed for the purpose.⁵ Data were also obtained about the parks' tenants for 15 out of the existing 21 SPs (71.43%). Of the remaining 6 parks, 3 expressly stated not to host any firm, whereas no information could be gathered about the other 3 SPs.

Per each science park it was recorded: its name and location; the year when it was established; whether or not it had a specific sector focus;⁶ if there were (technical) universities/research centres located on the Park's premises; and if it hosted incubators. Incubators are organisations aiming at making financially viable young and innovative businesses able to 'stand on their own feet' when ending the incubation period (usually lasting two to three years). According to the USA National Business Incubation Association (NBIA) business incubators should nurture young firms, and help them surviving and growing during the start-up period, when they are most vulnerable. To this end, incubators should provide hands-on management assistance, access to financing, exposure to critical business or technical support services, as well as shared office services, access to equipment, flexible leases and expandable space (NBIA, 2004).

⁵ Thanks to their affiliation to either the International Association of Science Parks (IASP) or the Finnish Science Parks Association (Tekel) or both.

⁶ We also checked the type of support services offered by the Park.

In addition to the SP specific features above, it was also recorded the list of names and coordinates of the on-SP firms in the year 2002. Of these firms, we gathered data about: the firm's degree of independence, i.e. whether the firm belonged to a holding/group or not; its sector of activity and, where appropriate, its position within the company's value-added structure (e.g. producer, seller, R&D unit, etc.); the size of the firm, in terms of number of employees in Finland in 2002; whether the firm had two or more units/branches/etc. on the premises of one or more SPs; the firm's year of foundation and year when it moved inside the SP(s). Furthermore, it was recorded each tenant's innovative activity, measured in terms of patents and utility models⁷ applied for at both the Finnish and the European level. To this end, data were gathered from the National Board of Patents and Registration of Finland (PRH) and the European Patent Office (EPO).

Table 1 and Figure 1 offer some descriptive statistics about the number of SP tenants and the presence of HEIs, big companies (i.e. firms with more than 4000 employees in Finland)⁸ and incubators inside the parks.

The information collected was double-checked through a questionnaire, whose respondents were included in the database used for the present study. The questionnaire also aimed at acquiring qualitative data, e.g. the reason why the firms decided to join the science parks (Squicciarini, 2005). It however did not include any question related to firms' innovative performance or output, in order to avoid triggering self-selection of the respondents. Overall, 1089 firms were contacted, 345 of which responded (33.06% response rate).⁹ From the respondents we pulled out all but one of the branches/units belonging to the same firm. Likewise, 'big' outlying companies, i.e.

Table 1: Overall Number of SP Firms*

| Number of Parks Tenants | |
|-------------------------|-------|
| Σ | 1225 |
| μ | 81,67 |
| σ | 55,62 |
| min | 2 |
| max | 186 |

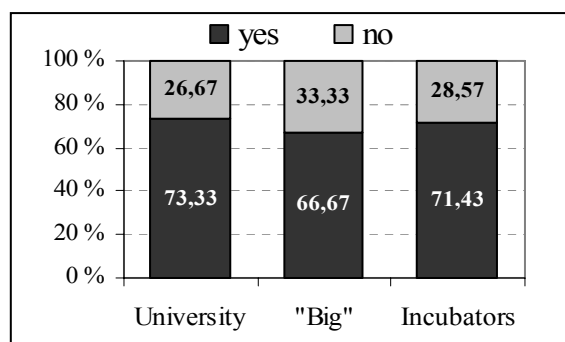
* Data about 18 Science Parks

⁷ Utility models constitute legal devices used in order to protect inventions having a lower innovative capacity or 'rank' than patents do. These 'minor' inventions, although useful, would fail to meet either patent's novelty or non-obviousness criteria, or both. The technical solutions protected by means of utility model rights normally consist in a configuration or a structure from which it is possible to get some utility or practical advantage. See Squicciarini (2005) for more details.

⁸ See the description of the variable *big* in this respect (§ 4.1)

⁹ Sheenan (2001) finds response rates to generally oscillate between 21.6% and 36% and Jobber and Saunders (1993) indicate that the rate of response in business-oriented studies is more sensitive than consumers' ones to characteristics as the number of questions, the length of the survey, etc..

Figure 1: Presence of Universities, 'Big' Companies and Incubators in the SPs*



* Data about 18 Science Parks

those companies having more than 4000 employees in Finland, were pulled out of the database and their presence inside the SP accounted for through a dummy variable called *big* (see § 4.1).

After cleaning the data, the sample included 252 SP tenant firms, whose distribution and characteristics seem to pretty well mirror the universe of Finnish science parks' tenants in the year 2002 (Squicciarini, 2005). Figure 2 and Table 2 show some statistics regarding the composition of the sample by industry, and the size of the tenants.

Figure 2: SP Tenants per Sector (as % of Company and as % of Number of Employees)

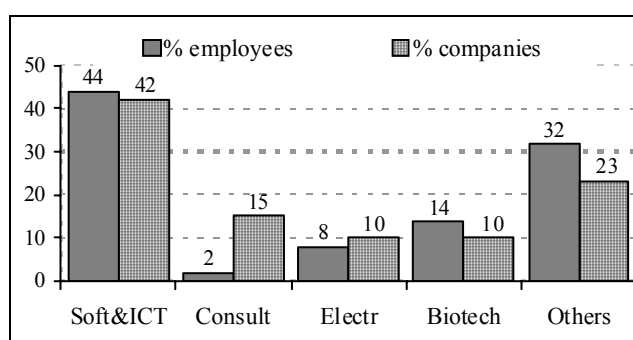


Table 2: Size of the Firms Located Inside the SPs

| Sector | Number of employees | | | |
|---------------------|---------------------|----------|---------------|---------------|
| | max | min | μ | σ |
| Soft&ICT | 2200 | 1 | 170.51 | 470.28 |
| Consult | 150 | 1 | 26.19 | 32.82 |
| Electr | 1000 | 1 | 130.24 | 282.96 |
| Biotech | 3400 | 1 | 224.14 | 754.92 |
| Others | 4000 | 1 | 224.36 | 663.44 |
| Overall | 4000 | 1 | 162.82 | 508.97 |

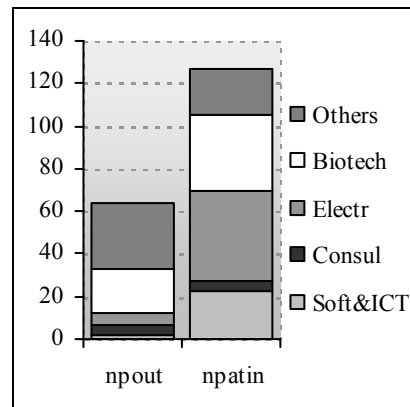
As can be seen, the firms in the software and Information and Communication Technologies (*Soft&ICT*) constitute the most numerous group of the sample, followed

by biotechnology, medical devices and pharmaceuticals (*biotech*), and electrics and electronics (*electr*) companies. Many consultancies, in different fields, also populate the SPs. The residual category *others* groups firms belonging to sectors like energy, pulp and paper, environment, food, construction, etc..

Figure 3 summarises the patenting activity of the firms, per sector and time, whereas Table 3 shows some descriptive statistics mirroring the years the firms spent inside (*yyin*) and outside (*yyout*) the parks, and the firms' innovative output (i.e. the number of patent applications and utility models) generated during their in- (*npatin*) and out- SP (*npout*) periods.

Yyout mirrors the period elapsed from the firm's year of foundation until it moved inside the science park.¹⁰ *Yyin* instead reflects the year(s) the firm has been on park, from the moment it became a tenant until the end of observation date (Dec 2002).

Figure 3: Number of Patent Applications per Sector and Time



Note: Data about 191 applications out of 206

Legend: npout: patents applied for during the out-of-Park period
npatin: patents applied for during the SP tenancy period

Overall, only the 20.24% of the companies in the sample were found to have applied for patenting at least once, whereas the vast majority of them (79.76%) showed no patenting activity during the period considered. Furthermore, at a first glance, firms look to have been more prone to patenting after becoming SP tenants, as suggested by the overall number of patents applied for after joining the parks. However, this apparently improved innovative output performance needs to be econometrically verified before relating it in any way to locating inside a science park, and all that being SP tenants may imply for firms.

¹⁰ The founding date of those companies that already existed in 1970 was censored (i.e. the companies were reported as having been established in the 1970), because the PRH only offers data from the year 1970 onward. Would we not censor the data, it might appear (possibly erroneously), that many years passed before the tenants began to patent.

Table 3: SPs Tenants' Patenting Activity per Sector and Time

| | | yyout | yyin | npout | npat |
|------------------------------|----------|--------------|-------------|--------------|-------------|
| soft&ICT ware | Σ | 362.92 | 538.08 | 2 | 23 |
| | μ | 3.67 | 5.38 | 0.02 | 0.22 |
| | σ | 6.06 | 4.82 | 0.14 | 0.73 |
| consult | Σ | 144.00 | 186.00 | 5 | 4 |
| | μ | 4.36 | 5.64 | 0.14 | 0.11 |
| | σ | 9.30 | 4.41 | 0.83 | 0.46 |
| electr | Σ | 152.00 | 176.00 | 5 | 43 |
| | μ | 6.61 | 7.65 | 0.21 | 1.79 |
| | σ | 9.39 | 6.23 | 0.83 | 4.64 |
| biotech | Σ | 242.00 | 147.00 | 21 | 35 |
| | μ | 10.08 | 6.13 | 0.84 | 1.40 |
| | σ | 9.50 | 4.53 | 2.25 | 3.28 |
| others | Σ | 312.00 | 322.00 | 31 | 22 |
| | μ | 0.97 | 5.67 | 0.53 | 0.38 |
| | σ | 9.92 | 4.19 | 1.67 | 1.28 |
| overall | Σ | 1212.9 2 | 1369.0 8 | 64 | 127 |
| | μ | 5.18 | 5.78 | 0.26 | 0.51 |
| | σ | 8.44 | 4.76 | 1.18 | 2.00 |

4 The Model

We investigate the role of science parks as seedbeds of innovation by means of analysing whether and to what extent being SP tenants relates to the innovative output performance of the firms, measured in terms of patent and utility model applications. As anticipated, the hypothesis we test here is a co-location one, i.e. whether being located inside a SP, and the on-park presence of outlying firms, HEIs departments, and incubators, relate to the innovative output of the tenant firms. The co-location effects we aim to uncover may result both from the direct interaction of firms with other SP tenants – being these HEIs or else -, or from the knowledge spilling over within and across parks. We cannot fully disentangle the results of direct interactions from the effect of knowledge spillovers as we do not have data about patent citations, nor about the number, type or quality of the intra-park relationships that occur. Nevertheless, we try to address how the presence of different types of actors, whether outlying firms, HEIs or incubators, and the park's potential repository of knowledge (proxied by the number of firms located inside the SP) relate to firms' innovativeness.

The very simple model and estimation strategy proposed are not to be considered a clean test of causation, as the data allows us to only partially address selection, self-selection and endogeneity concerns. With respect to selection, it is possible that parks would select and accept tenants on the basis of the firms' previous innovative activity. Hence, *ceteris paribus*, firms' having patents in their portfolio would be preferred as tenants. As for self-selection, its existence would imply that innovation-oriented firms

would be comparatively more willing to locate inside science parks. If selection and self-selection mechanisms occur we would have endogeneity problems. However, we can be positive that endogeneity should not jeopardise our estimates thanks to both the science park literature (e.g. Felsenstein, 1994; Westhead and Storey, 1994) and the qualitative data gathered through our questionnaire.¹¹ On the one hand, science parks are also lucrative property-based ventures and rent-seeking organisations (OECD, 1997). They prefer not to select firms when lacking of tenants, or may lower their selection standards in order to secure rent income, as it seems to happen in our case as well. Moreover, selection—if and when it happens—normally operates with respect to characteristics that are not related to the patenting activity of the firm (e.g. financial viability).¹² On the other hand, our qualitative data (see Squicciarini, 2005) support the view that firms choose to locate inside science parks simply because they find SP premises particularly suitable, or because they deem that becoming a tenant enhances their image or prestige. We can thus be confident that selection or self-selection should not be determined by the variable of interest, i.e. firms' patenting activity, and that endogeneity problems should not impinge upon the results of the study.¹³

In our model the dependent variable y_{ij} is the number of patents and utility models¹⁴ applied for by company i located inside the science park j during its tenancy period (we call it $npatin_{ij}$). It relates to the firm's own characteristics, \mathbf{X}_i , and to the science park's main features, \mathbf{Z}_j .

$$y_{ij} = f(\mathbf{X}_i, \mathbf{Z}_j)$$

We estimate the likelihood that y_{ij} relates to \mathbf{X}_i and \mathbf{Z}_j to uncover if, how and how much SPs and their characteristics relate to the patenting activity of their tenants, and if co-location and knowledge spillover effects exist. The estimates rely on patent applications rather than on patent granted to try and encompass all the possible degrees of novelty of firms' innovative output, whether “new to the market” or “new to the firm” (OECD, 2005). “New to the firm” innovations involve (minor) modifications of existing products or processes, whereas “new to the market” innovations are radical innovations. If the object of a patent application, it is likely that new-to-the-firm innovations would not be granted IPR protection, whereas new-to-the-market innovations should.

Before illustrating the specification of the model proposed, it is worth addressing some issues deserving attention: sample characteristics, innovation lags, and possible matching phenomena. Firstly, our sample is small and usual precaution should be used

¹¹ See Squicciarini 2005.

¹² Direct discussion with Tekel allowed us to rule out that the selection of tenants might happen solely or partially on the basis of their patenting activity. We unfortunately did not succeed to obtain further info about the specific SP admission procedure and (when applicable) selection criteria.

¹³ Even supposing that the firms locating inside the SPs are a selected and self-selected group of innovators would not impinge upon the analysis carried out here. Our aim is to investigate whether and to what extent the innovativeness of the firms that (at a certain moment in their lifetime) become tenants relates to being located in a SP exhibiting certain characteristics. We control for the before-joining-the-park innovative performance of the firms and by no means aim at generalising our results to the universe of Finnish firms, since we somehow agree with Massey et al. (1992) about SPs being geographical entities that are expression of a hierarchical social structure, and that are built around the notions of difference and status.

¹⁴ Both types of intellectual property rights are envisaged by the Finnish legislation. For more details see the Finnish Patents Act No. 550 of December 15, 1967 as lately amended by No. 650/00 of 30 June 2000 and No. 990/04 of 19 November 2004.

when analysing results. Moreover, the picture we draw of the Finnish science parks' reality is mainly based on their 2002 situation, as we could not fully track firms' and parks' characteristics over time. Furthermore—as it normally happens when relying on patents—the data are count and truncated, as we observe firms' patenting behaviour only from the 1970 until the end of the year 2002.

Secondly, innovations are not instantaneous phenomena: time and effort are needed to transform an idea into an invention, and to make that invention industrially viable, i.e. the object of a patent. Hence, the patents applied for during the tenancy period might represent the outcome of innovative activities carried out over past periods. To check for such a possibility we at a later stage recur to the use lagged variables, in order to avoid either under- or over-estimating SP tenancy's effects. In this way, we also control for the possible endogeneity that may arise from simultaneity, i.e. from observing the change in both the tenancy status and the firms' patenting activity during the very same period. Thirdly, matching phenomena may exist, in the sense that we cannot exclude that parks' and firms' characteristics matter jointly. To investigate such a possibility we check for some of the interactions that may exist between the X_i and the Z_j . Given the size of our sample, we focus only on some of the many interaction terms that can be generated.

4.1 The Regressors and their Expected Behaviour

As mentioned, we use two sets of regressors: the first mirrors the main features of the science parks (Z_j), the second accounts for the main characteristics of the firms (X_i). The Z_j we have are: $ncom_j$, un_{ij} , big_j , $incub_j$, $area_j$, $spold_j$.

4.1.1 Science Parks' Main Features

$Ncom_j$ is a discrete variable reflecting the overall number of tenants the j th SP had in the year 2002.¹⁵ As all parks have different numbers of tenants and the $ncom_j$ value is unique for all firms located in the same SP, the variable also captures park-specific effects. $Ncom_j$ belongs to a set of three variables ($ncom_j$, un_{ij} and big_j) that aim to uncover possible interaction and spillover effects. Given the geographic component of spillovers (among others, Jaffe et al. 1993), we expect $ncom_j$ to take a positive sign. Our hypothesis is that the higher the number of firms located inside the same park, the higher the possibility of interacting, and the more likely that spillovers occur. Two types of mechanisms might be at work in this case. On the one hand, following Klette's (1996) finding about spillovers emerging among lines of business carried out by different firms in the same interlocking group, more firms might mean more spillovers. On the other hand, Audretsch and Feldman's (1996) result about the greater propensity to cluster of industries where knowledge spillovers are prevalent suggests that parks generating more spillovers may attract more firms. Hence, the more the firms in the park, the more the interaction and possible spillovers, the more attractive the park, i.e.

¹⁵ The 2002 $ncom_j$ figure is very likely to differ from that of the number of tenants in the SP at the time of entry, i.e. when the firm joined the Park. Could we get that figure, we might be able to see if, for instance, spillover effects require a 'minimum' number of tenants to be triggered; or if any relationship links the number of tenants to the spillovers generated within and among the SPs.

the bigger the prospect benefit to join for the out-of-park firms. Again, the more the firms joining the SP, the higher the prospect of benefitting from interactions and spillovers, etc., in a sort of circular causation pattern.¹⁶

Uni_j is a dummy variable taking value 1 if there is at least one technical HEI's office / department / laboratory located inside the science park. Backed by Löfsten and Lindelöf's (2002) findings we expect tenants to establish a comparative higher number of links with HEIs than outside-the-park firms. We reckon that these links, however, should emerge through a negative coefficient of the *uni_j* variable. Following Hall et al. (2003) we in fact believe that projects with universities, being in areas of new sciences, may experience more difficulties and delays, even if they are less likely to be aborted prematurely. Collaborations with HEIs would hence delay the moment in which the results of the innovative activities might be harvested. This fact, paired with truncation, may lead to observe a negative coefficient of the *uni_j* variable. Nevertheless, we do not ignore the general belief (among others, OECD, 1997; Zucker et al, 1988; Westhead, 1997) that being close to basic science institutions is good for firms. Strengthening the links with HEIs and research centres should make firms better off in terms of, e.g., improved access to well-trained human resources and to new scientific knowledge. This in turn should augment firms' innovative capacity. Still, we are especially aware of the delays that the relationship with HEIs might cause over firms' innovative activities.

The dummy variable *big_j* denotes the presence of outlying firms in the park. By outlying we mean companies with more than 4.000 employees in Finland in the 2002 as, for instance, Nokia, Sonera and Orion. These firms are pulled from the sample and their presence accounted for through a dummy variable because of their being somewhat ubiquitous and extremely prolific patenting-wise. Not only they would dwarf the other tenants' innovative performance, but it would be impossible to understand if their patenting activity is (at all) related to their being SP tenants. We expect the dummy *big_j* to take a significant and positive coefficient since we believe that the presence of big firms would positively influence the other firms' innovative activity, thanks to the information possibly spilling over and the know-how transmitted through formal and informal contacts. In this respect, Acs and Audretsch (1988) underline that small firms are more competitive and generate more innovations in sectors prevalently made up of large firms. They also hold the total number of innovations to be positively related to the extent to which an industry is made up of large firms. Both hypotheses seem extremely plausible in the case of Finland and the industries considered here.

Incub_j is a dummy variable accounting for the presence of incubators inside the science park. Unfortunately we do not have information about which companies were incubated and how long for. We only know whether incubators exist in the park, and may only speculate about how their presence may affect tenant firms in general, and young companies in particular. As for the 'average' firm located inside SPs, we would expect it not to be affected by the presence of incubators. Conversely two opposite effects might be expected with respect to those firms that joined SPs at very early stages of their lifetime (and that, therefore, might have got incubated). On the one hand, we could expect the *incub_j* dummy to take up a negative sign due to the type of companies incubators normally host. 'Market rookies', i.e. early stage firms, might need time to get

¹⁶ Of course, space constraints exist. We envisage such a phenomenon to occur only until exhausting the available SP facility. From that moment on, if not even earlier, selection processes might take place. About the possible existence of selection and self-selection mechanisms see §4.

settled. Therefore, their patenting activity might not be particularly prolific in the first phase of their life. On the other hand, if selection occurs, those young firms allowed to enter the SPs' incubators should show above-the-average potential to innovate and grow. *Ceteris paribus*, this should lead them to somehow over-perform non-incubated firms, and to behave as 'gazelles' (see, among others, Sims and O'Regan, 2006, and Acs and Muller, 2008). The possible existence of selection mechanisms would thus lead to expect a positive sign. If incubators even moderately succeed in constituting seed-bed areas for new firms, as Massey et al (1992) find, the negative effect determined by the firms being very young should be counterbalanced by their better than average innovative performance.

Area_j is a dummy variable capturing the presence of two or more science parks in the same geographic area, i.e. the same city. We expect (Henderson et al, 1995; Belleflamme et al, 2000, David et al, 1996; Feldman and Audretsch, 1999) *area_j*'s coefficient to take up a positive sign. We reckon that the existence of more science parks in the same city area may lead to more efficient matches SP-firms. Having the possibility to choose which park to locate in, firms might select the SP that better suit their needs or, conversely, parks may allow in as tenants those companies that they know they would be able to help best.

Spold_j tells how old park *j* was at the end of the year 2002.¹⁷ We use it as a proxy for the experience and expertise cumulated by the SP, as well as an indicator of the networking ability of the parks (Saxenian, 1994). Holding knowledge to be cumulative leads us to expect this variable's coefficient to be positive. However, first-movers disadvantages may exist (Rauch, 1993), whereby older parks may bear the cost of being pioneers and of learning by themselves how to best support their tenants. This being the case, *spold_j*'s coefficient should be significant and negative.

4.1.2 Firms' Characteristics

As for firms' main characteristics, the X_i , the variables included in the model are: *howm_i*, *fiem_i*, *group_i*, *yyout_i*, *npout_i*, *yyin_{ij}*, *soft&ICT_i*, *electr_i* and *biot_i*.

Howm_i is a count variable mirroring the total number of branches or units firm *i* has on the premises of one or several Finnish science parks. Through *howm_i* we try to understand whether having multiple locations inside the SPs confers any competitive advantage to the tenants. We believe that, in presence of multiple locations, each firm's unit might benefit in two ways: directly, thanks to the direct support each park provides; indirectly, i.e. from the knowledge spilling over within the park (Cassiman and Veugelers, 2002) where the firm is located. In addition to benefiting from this 'inter-park effect', firms may also benefit from 'intra-parks' externalities, whereby the interactions built and the knowledge spilling over and absorbed within a certain SP can serve the purpose of units or branches located elsewhere. Would such mechanisms take place, we should expect that the more the on-park units the better off the tenant. Hence, would *howm_i*'s coefficient be significant, we would also expect it to show a positive sign.

Fiem_i reflects the number of employees firm *i* had in Finland in the year 2002. Similarly to Acs and Audretsch (1988) we classify innovators according to the size of

¹⁷ We assume that Parks opened their doors on the very first day of the year when they were founded.

the entire firm and not only of the on-park subsidiary/unit. *Ceteris paribus*, we expect f_{iem_i} to be significant and to take up a positive sign. Our hypothesis is backed by Scherer's (1984) results that patenting rises (less than proportionally) with firm size, by Pavitt et al's (1987) finding that the number of innovations per employee is above average in both firms with less than 1,000 and more than 10,000 employees, and by the analyses about firm size and innovation carried out by Acs and Audtretsch (1990, 1991). One remark is needed with respect to f_{iem_i} . We are aware that the number of employees is likely to change periodically, but we do not have panel data and rely on cross sectional estimates. Referring to the 2002 year figure may thus mistakenly lead to attribute the patents obtained in earlier periods to a number of employees differing from the real size of the firm at that time. However such a modelling choice would bias the estimates if we presuppose the existence of a systematic measurement error linked to the way in which companies grow. We may for instance believe that firms' growth would depend on their overall performance—and innovative activity in particular. Hence we might hypothesise that better performing firms should grow and possibly grow faster (as in Jovanovic, 1982; Evans, 1987; Hall 1987). Conversely those performing badly would 'shrink' and ultimately exit the market. However, it is not at all clear that firms grow only or principally as a consequence of their patenting activity. Actually, if the different patterns happen randomly, our estimates would not be off the mark.

$Group_i$ is a dummy variable denoting whether the i th company belongs to a holding/group or not. We hold that being part of a group would make the patenting activity of the tenants seem less 'remarkable', because of corporate patenting rules. Patents' assignment may sometimes go to the mother company to better exploit the potential of innovations at the corporate level, and to avoid ex post licensing problems. We therefore expect the coefficient of the group variable to be negative, also supported by Geroski et al (1997) who find that being independent has a strong positive effect on the innovation spell length.

Y_{yout_i} is a count variable that tells how many years the i th firm has spent outside the science park, before joining it. N_{pout_i} , instead, reflects the number of patents firm i applied for during that very period. We assume that firms are established and move inside the science parks in January of the corresponding year—unless otherwise expressly specified by the firm. Through $npout_i$ and $yyout_i$ we account for the patenting activity the firms exhibited before joining the park, as we expect their prior innovativeness to influence their later performance as SP tenants. *Ceteris paribus*, we expect the coefficients of $npout_i$ and $yyout_i$ to take up, respectively, a positive and a negative sign. On the one hand, if we hold innovative activities to be persistent (Cefis, 2003), having already patented before joining the park should positively influence the probability of patenting again while inside the SP. On the other hand, the longer it took to apply for a number of (off-parks) patents, the worse the company's patenting performance is. Furthermore, if we hypothesise the existence of diminishing returns to R&D, in a similar fashion to Klette & Griliches (2000), then the older the company, the slower the pace at which it would generate new innovations. Last, if locating inside SPs may in any way benefit the firms, the longer the period they did not enjoy the tenancy status, the worse it should be for their innovative performance. Through $yyout_i$ and $npout_i$ we also try to capture and at least partially control for the possible selection and self selection mechanisms that may exist.

$Y_{in_{ij}}$ is a count variable denoting the years firm i has spent inside the science park j , from the moment it became a tenant until December 2002. We expect this variable's coefficient to be significant and positive if firms may, in any way, benefit from locating inside the SPs. If being tenants make firms better off innovation-wise than locating elsewhere, then the longer firms stay inside the park, the better it should be for their innovative output performance.

Finally, three dummies, **soft&ICT** $_i$, **electr** $_i$ and **biot** $_i$ account for the most represented sectors the firms in our sample belong to. If industry specific effects exist these variables should be significant since, as Cohen et al (1987) argue, sector-specific effect can be more important than firm size in determining firms' R&D intensity and—we add—patenting activity.

5 Estimates and Results

The analytical strategy used in the present paper relies on count data models, given the nature of our dependent variable, i.e. the number of patent applications. The estimates are carried out following Poisson (P),¹⁸ Negative Binomial (NB) and Tobit (T) models, both including and excluding sector dummies. This is done to better capture the explanatory power of the variables. We use the Huber-White-sandwich estimator of variance to test for heteroscedasticity and specification bias. The Poisson seems appropriate as we have non-negative count data, where zeros are preponderant, i.e. those firms with no patent applications in portfolio, and the dependent variable has a clear discrete nature and takes on small values. The Negative Binomial gives us the possibility to relax the Poisson assumption that the variance equals the mean value. Arising from a natural formulation of cross-section heterogeneity, it allows for overdispersion. Through the Tobit, instead, we see if we can better address the problem of having a limited dependent variable.¹⁹

The results of the estimates are presented in Table 4, where the top part shows the model's overall fit summary statistics, and the bottom part the estimated coefficients of the model, obtained both including and excluding the sector dummies. Table 1A in Annex A instead shows the corresponding Incidence Rate Ratios (IRR) of the models, obtained by exponentiating the regression coefficients of the Poisson and Negative Binomial estimates. IRR are a relative measure of the effect of a given exposure and are obtained as the ratio of two incidence rates: the incidence rate among the exposed proportion of the population, divided by the incidence rate in the unexposed portion of the population.²⁰ The estimates showed in Table 4 as well as those presented in all the other tables included in the present paper see as dependent variable $npatin_{ij}$, i.e. the

¹⁸ In the Poisson case, our fitting regression is of the form $\Pr(Y_{ij} = y_{ij}) = \frac{e^{-\lambda_{ij}} \lambda_{ij}^{y_{ij}}}{y_{ij}!}$ where $y_{ij} = npatin_{ij}$ and each y_{ij}

is drawn from a Poisson distribution with parameter λ_{ij} , with $\ln \lambda_{ij} = \alpha' \mathbf{X}_i + \beta' \mathbf{Z}_j$ where $\mathbf{X}_i = [howm_i, fiem_i, group_i, yyout_i, npout_i, yyin_{ij}, soft\&ICT_i, electr_i, biot_i]$ and $\mathbf{Z}_j = [ncom_j, uni_j, big_j, incub_j, area_j, spold_j]$ the vectors of regressors and α and β the vectors of coefficients.

¹⁹ See Greene, 2000.

²⁰ For more info about IRR and their interpretation visit www.ats.ucla.edu/stat/stata/output/stata_poisson_output.htm (see references).

number of patents and utility models applied for by firm i while being on park j . To address the possible concerns that might arise about the model identification strategy, and to exclude that the possible positive relationship between $yyin_{ij}$ (i.e. the number of years the firm has been in the science park) and $npatin_{ij}$ could occur just through 'mechanical means',²¹ we also estimated alternative model specifications. These used as dependent variable the patent rate, i.e. the number of patents while being a tenant, and fully confirmed the results discussed in the present paper. The robustness of the results presented here is furthermore supported by additional analyses carried out in Squicciarini (2009).

Since the three model specifications used (P, NB, and T) yield similar estimates, we here focus on and discuss the coefficients of the Poisson estimates only, when analysing our results. Our choice is based on the higher Pseudo R-square exhibited by the Poisson estimates, and is backed by the goodness-of-fit tests and further regressions carried out in a companion study (Squicciarini, 2005). We do so aware that the R-square statistic should be interpreted with caution, since it does not mean the proportion of variance of the response variable explained by the predictors (Greene, 2000), as McFadden's R-square instead does in OLS regression.

As for firms' characteristics, the coefficients of the firm-size related variable are always strongly significant, even if very small. Per each additional employee, firms are only around 0.1% more likely to patent. The regressors accounting for the number of patents applied for and the years spent elsewhere before joining the park also behave as expected. The significance and sign of both the $yyout_i$ and $npout_i$ coefficients confirm the persistence of innovative activities.²² Per each additional patent obtained before-joining-the-SP, firms are 21%–35% more likely to patent while on park. Sector related effects emerge as well, with the tenants in the *electr_i* and *biot_i* industries profiting substantially from their locating on park (compared to the control group *others_i*). We can exclude these results to be due to small degrees of diversity, i.e. that some industries 'coincide' with specific parks, as we checked for such a possibility.²³

Table 4 also points out that belonging to groups/holdings may make firms 63%–68% less likely to patent (see Table 4 in the Appendix). *Howm_i* is never significant but in the with-sector Poisson estimates. Its behaviour, though, seem to suggest that having several units on one or more SPs may relate to better innovative performances. Finally, $yyin_{ij}$, the regressor accounting for the time tenants spend on park, strongly points out that enjoying the science parks' tenancy positively relates to firms' innovative output. Ceteris paribus, per each additional year spent on park, firms seem 13%–20% more likely to patent. This result would argue in favour of science parks being successful in constituting seedbeds of innovation.

To understand what may make parks able to accomplish their policy mission, we now turn to the analysis of the SP features. The estimates indeed suggest that within-park interactions and knowledge spillovers may exist, with the overall number of

²¹ Since the more time a firm has been inside the park, the longer time it has had to patent while being a tenant. Such a positive relationship could be expected even if science parks had zero effect on innovative activity.

²² These coefficients might also warn about the possible existence of selection and self-selection mechanisms. As already stated, we are inclined to believe that endogeneity should not undermine our results. Still, we agree, science parks' selection and self-selection mechanisms would deserve further investigation.

²³ To this end, we investigated both the existence of thematic SPs and the sector distribution of the firms within each Park, and were able to rule out the existence of small degrees of diversity.

tenants and the presence of outliers and HEIs inside the science parks significantly relating to the patenting activity of the tenants. Per each additional tenant located inside the park, firms look 2.3%–4.4% more likely to patent. Certainly remarkable is the role of outliers: their presence on park multiplies firms' patenting by a factor varying between 6 and 16. Conversely, and in line with our expectations, HEIs relate to 88%–94% lower patenting output of the firms.

Overall, the estimates suggest that the more the firms in the Park the better it is for the tenants' patenting activity, and that tenants likely benefit from interacting and from the knowledge spilling out from the outliers. Outsourcing and subcontracting, together with informal exchanges and social happenings, may very likely be the channels through which knowledge is passed on from the outliers to the other SP firms.

Our results also support the hypothesis that SP tenants have a higher probability of engaging in R&D activities with HEIs (as in Löfsten and Lindelöf, 2002). Such relationships, though, apparently end up being negatively related to firms' patenting activity (see also Dechenaux et al, 2003;²⁴ Thursby et al, 2001).

A feature that the behaviour of the $ncom_j$, big_j and un_{ij} coefficients clearly underlines when coupled with the firm-related variables (in terms of both significance and size) is the existence of non-negligible matching phenomena. The patenting activity of the tenants seems in fact to be strongly related to particular combinations of firms' and parks' characteristics.

Nothing can instead be said about the relationship between the existence of two or more parks in the same city area ($area_j$) and firms' innovative output. Conversely, and with respect to the role of incubators, the non-significance of the incubator variable confirms our expectations, i.e. that the average firm's innovative activity is not related to the existence of incubators inside the SP. Finally, the estimates suggest that science park age ($spold_j$) might negatively relate to the patenting performance of the tenants, and that first mover disadvantages may indeed exist. The older the park is (in years), the 24%–39% less likely to patent its tenants may be.

6 Robustness Checks

Beyond offering many insights, the reference model estimates of Table 4 point out issues worth being further investigated. We here focus, in particular, on two of them: the possible role of innovation lags (Scherer, 1984; Hall et al, 1986) and the possible existence of firm-and-park matching phenomena.

With respect to the existence of innovation lags, we do not ignore the possibility that patents applied for at time t may be the result of innovative efforts realised, say, during time $t-1$, $t-2$, etc.. So far, though, for a patent to be counted among the $npatin_{ij}$ it sufficed that its filing date was posterior to the day in which the firm became a park tenant. This implicitly corresponds to not accounting for possible innovation lags and

²⁴ "Half of University inventions are no more than a proof of concept at the time of license", Dechenaux et al, 2003, p 5.

may bias the analysis, since we might be overestimating the effect of SPs and attribute to the SP tenancy period innovations that have instead been generated before that.²⁵

We consider two main lags: the 'end-of-innovation to application' and the 'research-effort-to-application' lag. By 'end-of-innovation to application' lag we refer to the time elapsing between the finalisation of the innovation process and the moment the patent is applied for. In this respect, Scherer (1984) finds that, on average, nine months elapse between the conception of an industrial invention and the filing of a patent application. By 'research-effort-to-application' lag instead we mean the period covering the entire innovation process as well as the time needed to formulate the patent application. Of these two lags, the former should normally be (much) shorter than the latter.

To account for such dynamics, we lag the time-related firm variables, namely, $npatin_{ij}$, $yyin_{ij}$, $npout_i$ and $yyout_i$. When saying 'lagged' we mean, for instance, that a patent is counted among the k -month-lagged $npatin_{ij}$ if it has been filed at least k months after the date in which the firm became a park tenant. Innovation lags of, respectively, 6, 12, 18 and 24 months are considered. Depending on the length of the lag considered, we should be able to either totally or partially control for the possible effect of both innovation lags mentioned above.

Through lagging the firm and time related variables we also try to account for the time firms might need to profit from their tenancy status. It is in fact reasonable to suppose that firms will likely benefit from locating inside the SPs 'after a while', since time is needed to build relationships and to absorb and suitably exploit incoming knowledge spillovers.

Table 5 shows the results of the robust Poisson estimates carried after lagging the variables (see Table 5 in the Appendix). It confirms our previous analysis and sheds light on two important issues. Firstly, $yyin_{ij}$'s coefficients are always significant and positive. Hence, even after accounting for innovation lags being on park shows to positively relate to the patenting activity of the firms. Secondly, and more importantly, beyond confirming that interactions and within-SP knowledge spillovers may indeed take place, the estimates suggest the existence of intra-parks spillovers. In Table 5 the coefficients of $howm_i$, i.e. the variable mirroring the number of units a firm has inside the Finnish science parks, turn out to be always positive and significant. Overall results seem to support the hypothesis that co-location matters for innovation and that science parks succeed in managing and channelling the knowledge and knowledge spillovers generated within and among their premises.

Finally, we address the possible role of firm- and park- characteristics' matching. This implies verifying if particular combinations of firms' characteristics and parks' features are needed for SPs to (more) effectively constitute seedbeds of innovation. To check for such a possibility we construct some interaction terms. However, to avoid losing too many degrees of freedom, we concentrate on two possible interactions only. The first is the effect that the presence of Universities inside the park might have on biotech firms. The second is that of outliers on electric and electronics firms. To investigate whether these matching issues are at stake, we build $unibio_{ij}=uni_j*biot_i$ and $bigelect_{ij}=big_j*electr_i$. We add such interaction terms to the set of regressors already

²⁵ The parks' effect might conversely be underestimated if, prior to moving inside the SP, the firms' decision to become tenants had been motivated by their having collaborations or else with the SP itself or SP tenants. Such a research path, although interesting, goes beyond the scope of the present analysis.

specified and carry out with and without-lag estimates. The resulting robust Poisson estimates are shown in Table 6 (see Table 6 in the Appendix).

Table 6 confirms, among others, the positive relationship existing between firms' innovative output and the presence of outlying companies and by the years spent on park, as well as the persistence of innovative activities and the existence of sector-specific patterns. It also further backs the hypothesis that intra-SPs spillovers may exist. More interestingly though, the estimates suggest that matching issues do play a role: both $unibio_{ij}$'s and $bigele_{ij}$'s coefficients are significant and positive. Besides, the variable accounting for the presence of HEIs inside the park stops being significant in the lagged and with-interaction-terms estimates. The implication of these results is twofold. On the one hand, it may mean that the negative relationship with HEIs may, in the long term, be reversed, as we find in companion analyses (Squicciarini, 2005). On the other end, there certainly are specific industries—namely biotech—that seem to always benefit from locating close to HEIs.

7 Conclusions

The analysis proposed attempts to find evidence about the role of science parks as seedbeds of innovation. In particular, we investigate whether locating inside SPs, and the possible interactions and knowledge spillovers that co-location might trigger, positively relate to the innovative activity of tenant firms. To this end we build a framework for the analysis of SP performance that relies on the SP literature as well as on further insights offered by the literature on R&D and innovation, knowledge and knowledge spillovers, patents, firms' characteristics and innovativeness, and localisation and agglomeration of industries. We also propose an empirical assessment strategy that can be easily replicated in terms of performance indicators used, extended to other countries, and that allows for cross-country comparisons. The analysis presented here exploits an original dataset regarding the Finnish science parks, 252 firms located on their premises, and these firms' patenting activity over a 33 year period (Jan 1970-Dec 2002). The assessment exercise carried out translates into a simple cross-sectional analysis relying on count data models.

Among other findings, our results point out that locating inside the science parks positively relates to the tenants' innovative output performance, fact that we attribute to the interactions and knowledge spillovers that co-location might trigger. This result holds true both in general and with respect to specific industries (e.g. electrics and electronics). Conversely, the co-location of firms and HEIs inside a science park apparently impinges upon the tenants' likelihood to patent. This result, however, does not persist when accounting for innovation lags and shows to be reversed—i.e. the presence of on-park HEIs to positively relate to firms' patenting output—when specific sectors are considered (e.g. biotech). Last, we uncover the possible existence of SP-first-mover disadvantages, whereby older parks prove less able to accomplish their innovation policy mission.

Our analysis, which is not to be considered a clean test of causation, does not say much about the possible selection and self-selection mechanisms that may exist. Backed by the SP literature and by the additional qualitative data we gathered, we exclude that such problems could jeopardise our findings. Moreover, the research question we pose

does not go into the direction of a 'what if' analysis, nor it addresses the comparative performance of in- and out- SP firms (as we instead do in Squicciarini, 2008). What we attempt here is an analysis of the role of science parks as seedbeds of innovation and, in particular, about the way co-location and knowledge spillovers may relate to firms' innovative output. Our results seem very encouraging in this respect and should also hold in case selection and self-selection were at stake. Agreeing with Massey et al (1992) and considering SPs as 'socially elitist' enterprises would in fact change the generality of our results, but not undermine their robustness. Would we do so, we would investigate how best performers, when gathered together, can be helped to further improve their innovative ability.

Carrying out the same analysis on a bigger sample and using panel data would certainly help to verify how general our results really are. It could also be important to complement the present study with a patent-quality analysis, as more is not always better. In any case, though, the simplicity and broad applicability of the analysis carried out in the present paper make our performance assessment exercise easily replicable in other contexts and countries, and allows for cross-country comparisons. Furthermore the results of the study offer insights for the formulation of SP management strategies and for innovation policy. On the one hand, the co-location on park of different innovation agents indeed seems to positively relate to the innovative output of the firms, even if it takes time for SP to learn how to best support the firms they host.²⁶ On the other hand, the existence of matching phenomena calls for the necessity to clarify SPs' identity: whether elitist loci aiming at further strengthening the innovative ability of selected firms; or regional development institutions broadly fostering the innovativeness of local firms.

²⁶ See Malerba, 1992, about the variety of ways in which firms and organisations may learn.

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Appendix

Table 4: Determinants of the Tenants' Patenting Performance while on-Park ($npatin_{ij}$)

| | Model without Sector Dummies | | | | | Model with Sector Dummies | | | | |
|-------------------------------|------------------------------|--------------|-------------------------|-----------------------|------------------|---------------------------|--------------|-------------------------|-----------------------|------------------|
| | (1) Log likel | (2) # obs | (3) Wald/LR χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 | (1) Log likel | (2) # obs | (3) Wald/LR χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 |
| Robust Poisson (P) | -154.41 | 184 | 74.77 | 0.00 | 0.46 | -135.73 | 184 | 203.81 | 0.00 | 0.53 |
| Robust Negative Binomial (NB) | -124.24 | 184 | 70.53 | 0.00 | 0.15 | -120.37 | 184 | 99.02 | 0.00 | 0.17 |
| Tobit (T) | -140.44 | 184 | 36.30 | 0.00 | 0.11 | -136.88 | 184 | 43.41 | 0.00 | 0.14 |

| | ncom | big | uni | incub | area | spage | howm | fitem | group | yyout | npout | yyin | Soft&ICT | electr | biot | cons |
|-----------|-------------------|--------------------|---------------------|-------------------|------------------|--------------------|------------------|-------------------|---------------------|--------------------|-------------------|-------------------|----------------|-------------------|-------------------|---------------------|
| P | .043** (-3.27) | 2.801** (-2.85) | -2.771** (-2.49) | -.512 (-0.44) | -.399 (-0.71) | -.041** (-2.76) | .196 (-1.63) | .001** (-3.00) | -1.154** (-2.16) | -.105** (-2.70) | .268** (-3.57) | .181** (-5.86) | | | | 1.0579 (-.90) |
| NB | .024* (1.67) | 2.382** (2.40) | -2.127* (-1.93) | -.158 (-0.15) | .525 (0.82) | -.023 (-1.62) | .084 (0.63) | .001** (2.40) | -1.138 (-1.58) | -.062* (-1.86) | .300** (2.06) | .150** (5.08) | | | | -.8206 (-0.58) |
| T | .057 (1.44) | 4.225* (1.75) | -4.800* (-1.86) | -2.831 (-0.82) | .2813 (0.13) | -.039 (-0.96) | .102 (0.21) | .003** (2.20) | -1.903 (-0.94) | -.191* (-1.90) | .991** (2.45) | .424** (3.42) | | | | -4.3503 (-0.86) |
| P | 0.023* (1.73) | 1.909* (1.92) | -1.379 (-1.26) | .754 (0.65) | .505 (0.82) | -.023* (-1.65) | .178** (2.14) | .001** (2.53) | -1.006** (-2.02) | -.057* (-1.78) | .192** (2.80) | .148** (5.64) | .431 (0.75) | 1.609** (4.00) | 2.170** (4.04) | -2.670** (-2.14) |
| NB | .012 (1.23) | 1.193 (1.31) | -1.037 (-1.09) | .522 (0.51) | .908 (1.37) | -.011 (-1.29) | .098 (0.79) | .001* (1.96) | -1.107* (-1.69) | -.048 (-1.44) | .299** (2.05) | .120** (4.14) | .527 (0.97) | 1.405** (2.60) | 2.126** (3.54) | -3.268** (-2.59) |
| T | .038 (1.24) | 1.851 (0.78) | -2.645 (-1.08) | -.759 (-0.22) | .820 (0.39) | -.019 (-0.67) | .229 (0.51) | .003* (1.91) | -1.627 (-0.84) | -.154 (-1.61) | .881** (2.34) | .346** (2.86) | .514 (0.32) | 4.056* (2.09) | 4.528* (1.92) | -8.425* (-1.74) |

Legend:

Top part of the table: model overall fit statistics. Bottom part of the table: estimated model coefficients, with and without sector-related variables.

(1) log likelihood of the fitted model; (2) number of observations used in the Poisson regression; (3) LR χ^2 (T) / Wald χ^2 (P and NB) test statistic; (4) probability of getting a test statistic as extreme as, or more so, than the one observed under the null hypothesis; (5) McFadden's pseudo R-square.

** = significant at 5% level; * = significant at 10% level; z (P and NB) and t (T) values in parentheses

Table 5: Robust Poisson Estimates - Determinants of the Tenants' Patenting Performance ($npatin_{ij}$) with Lagged Variables (6–24 months)

| | Model without Sector Dummies | | | | | Model with Sector Dummies | | | | |
|-----------------|------------------------------|--------------|----------------------|-----------------------|---------------------|---------------------------|--------------|-------------------------|-----------------------|---------------------|
| | (1) Log likel | (2) # obs | (3) Wald χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 | (1) Log likel | (2) # obs | (3) Wald χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 |
| 6mm lag | -146.5 | 184 | 75.5 | 0 | 0.48 | -127.26 | 184 | 191.01 | 0 | 0.55 |
| 12mm lag | -123.11 | 184 | 89.3 | 0 | 0.54 | -107.53 | 184 | 202.15 | 0 | 0.6 |
| 18mm lag | -95.47 | 184 | 117.54 | 0 | 0.61 | -84.3 | 184 | 270.7 | 0 | 0.65 |
| 24mm lag | -77.77 | 184 | 161.76 | 0 | 0.66 | -71.59 | 184 | 264.85 | 0 | 0.69 |

| | ncom | big | uni | incub | area | spold | howm | flem | group | yyout | npout | yyin | soft&ICT | electr | biot | cons |
|-----------------|--------------------|---------------------|----------------------|--------------------|--------------------|---------------------|--------------------|--------------------|----------------------|---------------------|--------------------|--------------------|-------------------|---------------------|---------------------|----------------------|
| 6mm lag | .0413** (-3.22) | 2.9482** (-2.87) | -2.6943** (-2.36) | -0.4522 (-0.36) | -0.4753 (-0.83) | -.4893** (-2.77) | .2548** (-2.3) | .0009** (-2.69) | -1.3012** (-2.46) | -.0947** (-2.54) | .2619** (-3.61) | .2002** (-5.79) | | | | 1.0533 (-0.9) |
| 12mm lag | .0345** (-2.57) | 3.9022** (-3.43) | -2.9918** (-2.46) | -1.1659 (-0.91) | -0.5589 (-0.88) | -.3571** (-2.26) | .3086** (-3.5) | .0009** (-2.48) | -1.6912** (-2.80) | -.1237** (-2.71) | .2661** (-3.57) | .2263** (-6.77) | | | | -0.2138 (-0.17) |
| 18mm lag | .0366** (-2.27) | 4.4853** (-3.37) | -3.0207** (-2.33) | -0.2881 (-0.20) | -0.3527 (-0.48) | -.5257** (-2.85) | .4086** (-5.05) | .0007** (-2.22) | -1.6495** (-2.87) | -.1420** (-2.82) | .3081** (-4.1) | .2792** (-6.79) | | | | 0.332 (-0.27) |
| 24mm lag | .0394** (-2.04) | 4.9088** (-2.82) | -3.2059** (-2.13) | -0.7294 (-0.48) | -0.8135 (-1.08) | -.5606** (-2.77) | .5223** (-6.73) | .0006* (-1.85) | -1.8059** (-3.26) | -.1248** (-2.53) | .3292** (-4.47) | .3167** (-6.06) | | | | 0.5627 (-0.47) |
| 6mm lag | 0.0204 (-1.58) | 2.0092* (-1.91) | -1.2065 (-1.06) | 0.8785 (-0.7) | 0.4599 (-0.71) | -.2779* (-1.65) | .2392** (-2.99) | .0006* (-1.95) | -1.1672** (-2.26) | -0.0388 (-1.33) | .1848** (-2.76) | .1648** (-5.5) | 0.5894 (-0.95) | 1.8024** (-4.32) | 2.3520** (-4.23) | -2.9502** (-2.38) |
| 12mm lag | 0.0133 (-1.2) | 2.8856** (-2.44) | -1.4452 (-1.26) | 0.2663 (-0.22) | 0.4362 (-0.65) | -0.1543 (-1.42) | .2914** (-3.65) | 0.0005 (-1.54) | -1.4891** (-2.70) | -0.047 (-1.29) | .1742** (-2.49) | .1930** (-7.25) | 0.9762 (-1.39) | 1.9667** (-3.98) | 2.6847** (-4.16) | -4.5330** (-3.32) |
| 18mm lag | 0.0117 (-0.69) | 3.4395** (-2.57) | -1.1199 (-0.85) | 1.6599 (-1.29) | 1.0378 (-1.41) | -.3202* (-1.87) | .3495** (-3.64) | 0.0004 (-0.84) | -1.1901** (-2.18) | -0.067 (-1.31) | .2073** (-2.41) | .2485** (-6.76) | 0.4342 (-0.52) | 1.5467** (-2.38) | 2.6404** (-3.56) | -4.3412 (-2.91) |
| 24mm lag | 0.0169 (-0.8) | 4.0036** (-2.15) | -1.692 (-1.00) | 0.4381 (-0.28) | 0.3496 (-0.42) | -.3324* (-1.72) | .5131** (-5.12) | 0.0002 (-0.53) | -1.6390** (-2.85) | -0.0584 (-1.05) | .2510** (-2.77) | .2944** (-5.87) | 0.7764 (-0.9) | 1.2559 (-1.6) | 2.4747** (-3.09) | -3.7692** (-2.94) |

Legend: Top part of the table: model overall fit statistics. Bottom part of the table: estimated model coefficients, with and without sector-related variables.

(1) log likelihood of the fitted model; (2) number of observations used in the Poisson regression; (3) Wald χ^2 test statistic; (4) probability of getting a test statistic as extreme as, or more so, than the one observed under the null hypothesis; (5) McFadden's pseudo R-square.

** = significant at 5%level; * = significant at 10%level; z (P and NB) and t (T) values in parentheses

Table 6: Robust Poisson Estimates with ($npatin_{ij}$), Lagged Variables (6 - 24 months), and Interaction Variables

| | Log likel | # obs | Wald χ^2 | Prob> χ^2 | Pseudo R ² |
|-----------------|--------------|-------|---------------|-------------------|--------------------------|
| No lag | -128 | 184 | 307.2 | 0 | 0.55 |
| 6mm lag | -121.97 | 184 | 282.65 | 0 | 0.57 |
| 12mm lag | -101.33 | 184 | 359.95 | 0 | 0.62 |
| 18mm lag | -81.24 | 184 | 320.34 | 0 | 0.67 |
| 24mm lag | -69.48 | 184 | 275.2 | 0 | 0.7 |

| | ncom | big | uni | incub | area | spold | howm | fiein | group | yyout | npout | yyin | soft& ICT | electr | biot | unibio | bigele | cons |
|-----------------|-------------------|---------------------|---------------------|-------------------|--------------------|--------------------|--------------------|--------------------|---------------------|--------------------|--------------------|--------------------|------------------|-------------------|---------------------|--------------------|--------------------|----------------------|
| No lag | 0.0199 (-1.48) | 2.0263** (-1.99) | -2.0755* (-1.83) | 1.3907 (-1.12) | 1.1732 (-1.59) | -.3121* (-1.68) | .1545* (-1.94) | .0007** (-2.23) | -0.7533 (-1.52) | -0.0527 (-1.58) | .2706** (-3.93) | .0664* (-1.66) | 0.542 (-1.06) | 0.3511 (-0.42) | 1.1795* (-1.71) | .1550** (-2.39) | .1351** (-2.39) | -1.8293 (-1.47) |
| 6mm lag | 0.0185 (-1.39) | 1.9399* (-1.86) | -1.7742 (-1.55) | 1.3375 (-1.03) | 0.9956 (-1.32) | -.3041* (-1.65) | .2174** (-2.61) | 0.0005 (-1.59) | -.9308* (-1.83) | -0.0324 (-1.05) | .2421** (-3.62) | .0917** (-2.06) | 0.671 (-1.2) | 0.7597 (-0.9) | 1.5693** (-2.35) | .1336** (-1.99) | .1198** (-1.99) | -2.0985* (-1.68) |
| 12mm lag | 0.0087 (-0.7) | 2.9655** (-2.21) | -2.2035 (-1.60) | 0.9063 (-0.68) | 1.3797 (-1.52) | -0.1704 (-1.16) | .2440** (-2.85) | 0.0004 (-1.19) | -1.0271* (-1.95) | -0.0471 (-1.15) | .2569** (-3.51) | .1011** (-2.05) | 1.004 (-1.62) | 0.6492 (-0.93) | 1.5842** (-2.23) | .1944** (-2.34) | .1461** (-2.58) | -3.8154** (-2.63) |
| 18mm lag | 0.0078 (-0.44) | 3.6341** (-2.18) | -1.991 (-1.21) | 2.1077 (-1.49) | 2.0113* (-1.68) | -.3277* (-1.74) | .2984** (-2.83) | 0.0004 (-0.75) | -0.7186 (-1.29) | -0.0786 (-1.25) | .2893** (-2.65) | .1682** (-2.61) | 0.5 (-0.68) | 0.5769 (-0.77) | 1.6236* (-1.96) | .1895* (-1.66) | .1118* (-1.68) | -3.7873** (-2.30) |
| 24mm lag | 0.0171 (-0.76) | 3.9633* (-1.74) | -2.4199 (-1.13) | 0.8539 (-0.55) | 1.1715 (-0.97) | -.3825* (-1.67) | .4416** (-3.97) | 0.0002 (-0.42) | -0.9678 (-1.59) | -0.0626 (-1.06) | .3062** (-2.94) | .2109** (-2.52) | 0.729 (-0.96) | 0.0427 (-0.04) | 1.5482* (-1.78) | 0.1714 (-1.28) | 0.1264 (-1.53) | -2.7569* (-1.77) |

Legend:

Top part of the table: model overall fit statistics. Bottom part of the table: estimated model coefficients, with and without sector-related variables.

(1) log likelihood of the fitted model; (2) number of observations used in the Poisson regression; (3) Wald χ^2 test statistic; (4) probability of getting a test statistic as extreme as, or more so, than the one observed under the null hypothesis; (5) McFadden's pseudo R-square.

** = significant at 5%level; * = significant at 10%level; z values in parentheses

Annex A

Table A1: Determinants of the Tenants' Patenting Performance while on-Park ($npatin_{ij}$) – Poisson and Negative Binomial Incidence Rate Ratios

| | Model without Sector Dummies | | | | | Model with Sector Dummies | | | | | | | |
|-------------------------------|------------------------------|--------------|----------------------|-----------------------|------------------|---------------------------|--------------|----------------------|-----------------------|------------------|--|--|--|
| | (1) Log likel | (2) # obs | (3) Wald χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 | (1) Log likel | (2) # obs | (3) Wald χ^2 | (4) Prob> χ^2 | (5) Pseudo R2 | | | |
| Robust Poisson (P) | -154.41 | 184 | 74.77 | 0 | 0.46 | -135.73 | 184 | 203.81 | 0 | 0.53 | | | |
| Robust Negative Binomial (NB) | -124.24 | 184 | 70.53 | 0 | 0.15 | -120.37 | 184 | 99.02 | 0 | 0.17 | | | |

| | ncom | big | uni | incub | area | spold | howm | fiem | group | yyout | npout | yyin | Soft&ICT | electr | biot |
|-----------|--------------------|---------------------|--------------------|------------------|------------------|--------------------|-------------------|-------------------|--------------------|--------------------|-------------------|-------------------|-----------------|-------------------|-------------------|
| P | 1.044** (-3.27) | 16.526** (-2.85) | 0.063** (-2.49) | 0.600 (-0.44) | 0.671 (-0.71) | 0.614** (-2.76) | 1.216 (1.63) | 1.001** (3.00) | 0.315** (-2.16) | 0.900** (-2.70) | 1.307** (3.57) | 1.198** (5.86) | | | |
| NB | 1.024* (1.67) | 10.828** (2.40) | 0.119* (-1.93) | 0.854 (0.82) | 1.691 (0.82) | 0.756 (-1.62) | 1.087 (0.63) | 1.001** (2.40) | 0.321 (-1.58) | 0.940* (-1.86) | 1.350** (2.06) | 1.161** (5.08) | | | |
| P | 1.023* (1.73) | 6.748* (1.92) | 0.252 (-1.26) | 2.125 (0.65) | 1.657 (0.82) | 0.756* (-1.65) | 1.194** (2.14) | 1.001** (2.53) | 0.366** (-2.02) | 0.945* (-1.78) | 1.212** (2.80) | 1.159** (5.64) | 1.539 (0.75) | 4.996** (4.00) | 8.756** (4.04) |
| NB | 1.012 (1.23) | 3.297 (1.31) | 0.354 (-1.09) | 1.685 (0.51) | 2.480 (1.37) | 0.880 (-1.29) | 1.103 (0.79) | 1.001* (1.96) | 0.331* (-1.69) | 0.953 (-1.44) | 1.348** (2.05) | 1.127** (4.14) | 1.694 (0.97) | 4.074** (2.60) | 8.381** (3.54) |

Legend:

Top part of the table: model overall fit statistics. Bottom part of the table: estimated model coefficients, with and without sector-related variables.

(1) log likelihood of the fitted model; (2) number of observations used in the Poisson regression; (3) Wald χ^2 test statistic; (4) probability of getting a test statistic as extreme as, or more so, than the one observed under the null hypothesis; (5) McFadden's pseudo R-square.

** = significant at 5% level; * = significant at 10% level; z values in parentheses

Please note:

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The Editor