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Do science parks promote research and technology? A scientometric analysis of the UK

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Abstract This study investigates whether scientific publications can give plausible suggestions about whether R&D support infrastructures in the UK successfully foster scientific activity and cooperation. For this, research publications associated with UK SPs were identified from Scopus for the years 1975–2010 and analysed by region, infrastructure type and organisation type. There was apparently a systematic intensification of R&D from the 90s as evidenced by the publications of on-park firms and research institutions. Science Parks and Research Parks were the most successful infrastructures in fostering cooperation and research production, in comparison to Science and Innovation centres, Technology parks, Incubators and other parks, and HEIs were the major off-park partners for the on-park businesses. The East of England, the South East, and Scotland concentrate the highest proportion of parks, each of these three major geographical agglomerations exhibit distinct areas of scientific specialisation. Parks seem to have a positive impact on the overall level of collaboration and production of science and technology, which are highly concentrated in competitive regions. Nevertheless, industry-academia collaborations show that on-park firms tend to collaborate with partners beyond their local region rather than the local HEI. Support infrastructures may therefore not help to reduce the uneven development and geographic distribution of research-intensive industries in the UK.

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Introduction

While cutting-edge sciences and technologies are becoming increasingly important for regional competitiveness and economic growth, the interactions between producers and consumers of research-based knowledge and skills are becoming a central issue for the development of policies and regional innovation strategies that aim to increase the absorptive capacity and application of scientific research by fostering closer linkages between university and industry (Cooke 2002; Etzkowitz 2008). For instance, the EU's Competitiveness and Innovation Framework Programme (CIP) aims to foster successful engagements between both communities to enhance the competitiveness and integration in the region (European Commission 2012). In the case of the United Kingdom (UK), with its shrinking manufacturing sector and high dependence on the service sector, there is a need for upgrading and diversifying the manufacturing sector to compete with advanced and globalising economies (Porter and Ketels 2003). UK efforts are currently focusing on exploiting its prominent position in high-value added sectors of manufacturing (Willetts 2013), and on improving the process of translating science into economic gains (Dyson 2010; Hauser 2010; Lambert 2003).

These UK policy priorities are not new. Since the 1980s an innovation structure formed by the establishment of science parks, research parks and technology parks across the country has systematically been developed. These physical infrastructures, although having somewhat different characteristics, are often known by the generic term science park and are a policy tool to nurture academia-industry collaboration to boost technological innovation and ultimately to generate socio-economic growth (Link and Scott 2007; Vedovello 1997).[1] Most SPs are the result of partnerships between research-intensive universities, public authorities and private investors, and take advantage of their strong ties with these three sectors to bring together heterogeneous actors, such as universities, research centres, consulting organisations, technology transfer offices, investors, incubators, local and regional government agencies, intermediaries, and firms (Van Geenhuizen and Soetanto 2008; Suvinen et al. 2010). In such a highly dynamic environment the tri-lateral combination of research excellence, entrepreneurial activity and public support strategies enable academia to gain external resources and promote employment through the commercialisation of research in the form of licence agreements, consultancy services, patents, collaboration projects, and university spin-off companies. The private sector also takes advantage of this supportive physical infrastructure to establish or relocate start-up companies, spin-off companies, and R&D units to tap into innovative ideas, market science-related services to potential customers, and engage in ventures and investments with reduced risk and high growth potential. At the same time, government benefits from these

[1] The umbrella term SP is used to define different research-based infrastructures with the following general characteristics: formal and operational linkages with HEIs or research institutes (RIs); support the formation and growth of knowledge-intensive commercial businesses; active engagement in the transfer of science-based technologies and business skills (UKSPA 2003). Commercial-based infrastructures or industrial infrastructures on the other hand do not necessarily have operational links with HEIs or RIs.

agglomerations to promote partnerships and establish intermediary organisations that facilitate the allocation of capital (funds, research grants, or seed capital) to support promising projects and new ventures, with the likelihood of generating employment opportunities and economic growth in the region (Etzkowitz 2008; Howells 2006; Minguillo and Thelwall 2011). Thus, policy makers expect HEIs and RIs play a central role in supporting the development of these public–private environments to in turn provide the desired academia-industry synergies and economic added-value.

SPs are prime candidates for collecting empirical evidence on the emergence and development of knowledge-intensive industries. However, despite a growing interest in SPs, findings differ about whether SPs clearly support the growth of on-site knowledge-intensive firms (Löfsten and Lindelöf 2002; Siegel et al. 2003b; Lindelöf and Löfsten 2004; Schwartz 2009) or not (Quintas et al. 1992; Westhead and Storey 1995; Westhead and Batstone 1998; Bakouros et al. 2002; Siegel et al. 2003a; Radosevic and Myrzakhmet 2009). Therefore the main policy objective relating to the economic impact of SPs is debated. To some extent, this debate continues because the 'SP movement'[2] in the UK is originally based on a linear model of innovation with the oversimplified assumption that an adjacent location to HEIs or research institutions (RIs) should facilitate the transfer and utilization of economically valuable research findings (Phillimore 1999; Quintas et al. 1992). Hence, some researchers (Bøllingtoft and Ulhøi 2005; Hansson et al. 2005; Phan et al. 2005) argue that this assumption has led to ignoring or under representing the informal nature of SP links and associated networks, as well as the productivity and functionality of those 'hidden' connections and interactions (Suvinen et al. 2010). Most empirical studies basically rely on crude econometric indicators and surveys to measure formal R&D outputs, characteristics of firms or economic statistics, such as firm formation and performance (Quintas et al. 1992), employment growth, trading relationships (Colombo and Delmastro 2002), firm survival rates (Ferguson and Olofsson 2004; Westhead and Storey 1995), sales growth and profitability (Lindelöf and Löfsten 2004; Löfsten and Lindelöf 2002), patents, copyrights, new products and services (Siegel et al. 2003a). Only recently has a dedicated attempt been made to uncover the formal and informal articulation of the networks formed around SPs by examining communication and interaction patterns on the Web (Minguillo and Thelwall 2011, 2012). However, studies of the influence of SPs on hosting universities and academic R&D activities are still limited (Link and Scott 2003; Siegel et al. 2003a). Quantitative studies are therefore needed to determine the effect of SPs on the 'third mission' of universities (i.e. knowledge transfer) as well as to what extent SPs promote an entrepreneurial identity among HEIs, and to what extent they support firms to evolve from a passive knowledge-consumer role to actively engage in the creation of new knowledge and research. And despite publications are considered as an unreliable proxy to describe the research activity of private firms (Rafols et al. 2012), the growing contextualisation of scientific research has led to a growing interaction with industry in certain fields and the Mertonian view of science may underestimate the diversity of organisations and institutional orders within international higher education and public R&D sectors (Perkmann et al. 2013). Therefore, more work is needed that focuses on the university-industry partnership as a bidirectional interaction and with mutual benefits and impacts (Hansson et al. 2005; Phillimore 1999).

[2] The term 'science parks movement' was introduced by the UKSPA (The United Kingdom Science Park Association) to refer to the broad science park community or group of infrastructures which are formally linked with universities to support the development of knowledge-based companies.

Surprisingly, despite the knowledge-intensive nature of SPs, and even though Siegel et al. (2003a, b) and different researchers (Bigliardi et al. 2006; Fukugawa 2006; Link and Scott 2003) have suggested using scientific publications to assess university-industry interactions as proxy for the R&D activities generated within support infrastructures, public–private co-authorship of publications and patents have only recently been applied. One study assessed, for example, how the underlying knowledge creation and diffusion in the Hsinchu region benefits the innovation capability and success of Hsinchu SP in Taiwan, employing on-park firms' patenting and patent citations (Hu 2011). A similar study examined the use of public science in on-park firms based on Hsinchu SP, including (non-)patent citation, and public–private co-authorship of publications and patents, to show that U-I collaboration has constantly increased in terms of publications, while the patterns related to the patenting activity is stable or even declining (Hung 2012). A lack of studies is particularly surprising since the quantity of scientific publications (co-)produced by industry is substantial and increasing (Godin 1996) and is considered one of the more important outputs of research cooperation with the academic community (Cohen et al. 2002; Vedovello 1997), especially among R&D intensive firms in science-dependent sectors (BIS 2009; Calero et al. 2007; Cockburn and Henderson 1998). Similarly, universities also perceive that their involvement with SPs has a bigger impact on research output than funding or patents (Link and Scott 2003). Furthermore, the effects of the applied policies have resulted in an increasing diversification of research-producing organisations where universities play a central role (Godin and Gingras 2000). Consequently, the main objective of this study is to use scientific publications for mapping and monitoring the creation of new knowledge by research-intensive organisations located on different types of support infrastructures across the UK. This objective is summarised in the following research question:

- Can the analysis of scientific publications help to map the research activities within the different support infrastructures established across the UK?

In order to address this question, we provide the following evidence that can be drawn from scientific research publications: (1) the chronological development of the research activities of the science park movement: (2) what types of innovation infrastructures are established across the country, and which organisations, infrastructures and regions are the most research-intensive; (3) how onsite-organisations collaborate, the collaboration between on-park firms with knowledge producers, and how these links extend across the country and beyond; (4) what scientific disciplines underpin these industries. These aspects are mainly analysed at three levels: on-park organisations, support infrastructures, and regions.

These aspects will provide an insight into the knowledge that can be obtained from the R&D activities within UK-based SPs, and also show that the existing battery of indicators can add a quantitative approach that make it possible to systematically monitor support infrastructures on a large-scale. This is important because besides the UKSPA evaluation (2003) most of the previous studies in the UK have only focused on one or a few SPs, making it difficult to draw general conclusions as SPs are not only unique physical infrastructures and social entities, they are also strongly influenced by external conditions (Link and Scott 2007). This provides complementary statistical information to that provided by socio-economic indicators and surveys to obtain a better picture of the heterogeneous SP movement (Van Geenhuizen and Soetanto 2008).

Data and methodology

Publications associated with UK SPS were retrieved from Elsevier's Scopus database covering a period of 35 years (1975–2010). We used two different approaches to retrieve the records of the research publications produced by any organisation located within a SP in the UK. First, with the help of the SP list provided by the UKSPA and the electronic version of the *Atlas of Innovation* created by the *World Alliance for Innovation* (Wainova) we identified the names of 82 full members across the country. This allowed for the creation of queries with the specific names of the different SPs (i.e. *AFFIL* ("*norwich research park*") *AND* (*LIMIT-TO*(*AFFILCOUNTRY*, "*United Kingdom*"))). Second, with the intention to extend the first search and identify potential non-members of the UKSPA and also track down the high diversity of the SP movement, we used truncated queries with terms that are broadly used to name research-based infrastructures in the country, such as science-, technology-, innovation park, incubator, etc., as well as terms of commercial-based infrastructures, such as business-, industrial-, enterprise park, and business centre (i.e. *AFFIL*("*sci* park*") *AND* (*LIMIT-TO*(*AFFILCOUNTRY*, "*United Kingdom*")). Both specific and truncated queries were restricted to the year 2010 covering journals, book series, and conference proceedings, while excluding editorials, erratum, letters, and notes.[3] The search yielded 10,920 records. A similar search strategy was used on the Web of Science (WoS) database (Thomson Reuters) but approximately two thousand fewer records were retrieved using this method (Minguillo and Thelwall 2013). Note that not all onsite organisations mention the SPs where they are located as part of their affiliation addresses in research publications, so this search approach may not take all the relevant publications into account.

The bibliographic data of these publications, such as titles, authors, affiliations, abstracts, and sources, were then exported to the ad-hoc relational database created for this study. Data cleaning and standardisation was used to identify all publications listing at least one author address referring to a UK SP, and the author address was checked to be assigned to the organisation stated by the author. The research produced by departments, sub-units, or company groups are assigned to the parent entity, and only research centres associated with HEIs are treated independently in order to get more fine-grained results. In the case of firms, name changes, mergers, or acquisitions are taken into account where possible. But in most cases organisations with different physical locations are treated separately to quantify the impact of SPs on the immediate environment. Most hospitals in SPs are teaching hospitals and are classified as HEIs, as recommended in the *Frascati Manual* (OECD 2002). For conciseness, multiple health centres or hospitals from the same region or city are collapsed into one organisational entity. Similarly, non-UK organisations are broadly classified according to country and grouped together into different types of organisation (higher education, industry, government, and on-park organisation), while UK-based organisations are clustered into six groups (higher education, industry, government, on-park organisation, non-profit organisation, and research institute). The 'foreign on-park organisation' group includes organisations located in a SP outside the UK. In addition to this typology, they are also grouped according to four other main attributes (type of organisation, location, type of location, and district). We obtained 9,771 publications produced by at least one onsite-organisation.

[3] This selection of document types is based on their relevance as public communication channels for industry research outputs (Cohen et al. 2002).

Results and discussion

Historical development of the SP movement in the UK

The trend analysis of research publication outputs sheds light on the historical development of the SP movement, and the degree of research activity relating to its various types of infrastructures during the last three decades. The increase in SPs that are involved in research (Fig. 1) coincides with the constant growth of the output (see Fig. 2). Before the 1990s there were on average 4.5 research-active SPs every year. During the course of a decade this number increased up to 24.5 and resulted in more than a two-fold increase by 2010 to a total of 61 SPs. Similarly, the output trend started to become substantial at the beginning of the 1990s, reaching over 400 publications in 2000 with a further three-fold increase by 2010. According to Wainova, the UKSPA covers about 80 % of SPs across the country and only in the last 3 years have there been a higher number of research-oriented infrastructures[4] than UKSPA members, which suggests that not all infrastructures host R&D-active organisations. Interestingly, the total number of 319 infrastructures identified in this study is similar to the estimation of the UK Business Incubation (UKBI), which states that the broad SP movement is approximately formed by 300 infrastructures in the UK. Furthermore, according to the number of on-park companies located on the premises of the UKSPA infrastructure members (UKSPA 2012) this study covers 31 % of the tenants, being similar to the proportion of on-park organisations that pursue a competitive strategy focused on radical research (Westhead 1997).

On the other hand, the commercial-based infrastructures started to become research active from the 90s and have exhibited rapid growth during recent years, whereas the number of UKSPA full members and research-oriented infrastructures has levelled off, indicating stagnation in the creation of new SPs. The high proportion of commercially-oriented infrastructures is the result of the fact that less resources and effort is needed in comparison with the research-oriented ones, and as expected the research capacity of these infrastructures is scarce. Despite the fact that the Business Parks (BPs) are the main contributor to the visibility of commercial-oriented infrastructures, they are still the fourth most important subcategory of infrastructure in terms of research production (with only 584 publications spread across 174 different BPs, representing only 3.4 publications for each BP) (see Fig. 2), while the subcategory science- or research parks produce 107 and 315 publications on average respectively. This significant difference points out a still sporadic production of the commercial-oriented infrastructures but it leads to the question of whether BPs are actively supporting R&D activities now as a way to tackle the lack of public funding and investments, knowledge-based companies, and in general add value to improve the reputation of BPs (Gower & Harris 1994).

During the first 5 years discussed only two Research and Science parks appeared, located in Scotland and the East of England. In 1984–1987 the first Innovation centres, Industrial- and Business parks emerged, and the SP movement spread across nine regions. In the next 5 years there was a total increase in the number of infrastructures, from 22 in 1988 to 53 in 1992, and Research Campus and Technology Parks were set up. The following period shows a considerable increase in Research and Science Parks, reaching 27 (34 %) different infrastructures in 1995 and sharing 46 and 26 % of the total output respectively, while Science & Innovation Centres produce 18 % of the output. This led to a

[4] Research-oriented infrastructures means all the infrastructures found, excluding Business and Industrial parks.

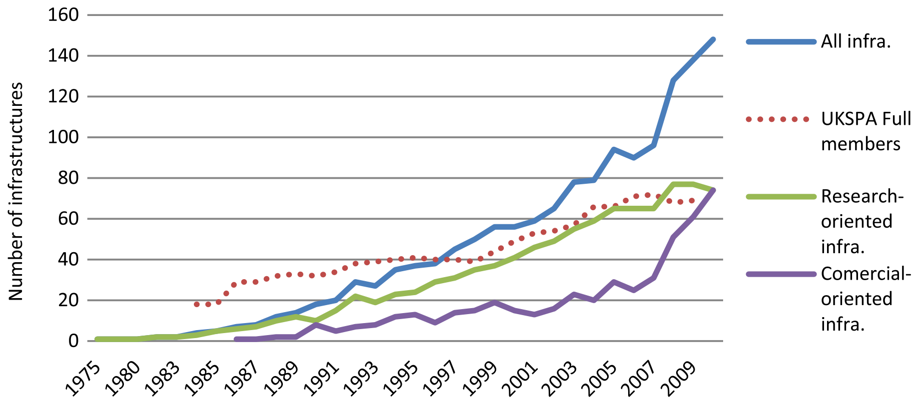

Fig. 1 Comparison between the number of research- and commercial infrastructures producing research publications in each year with the number of UKSPA full members from 1975 to 2010

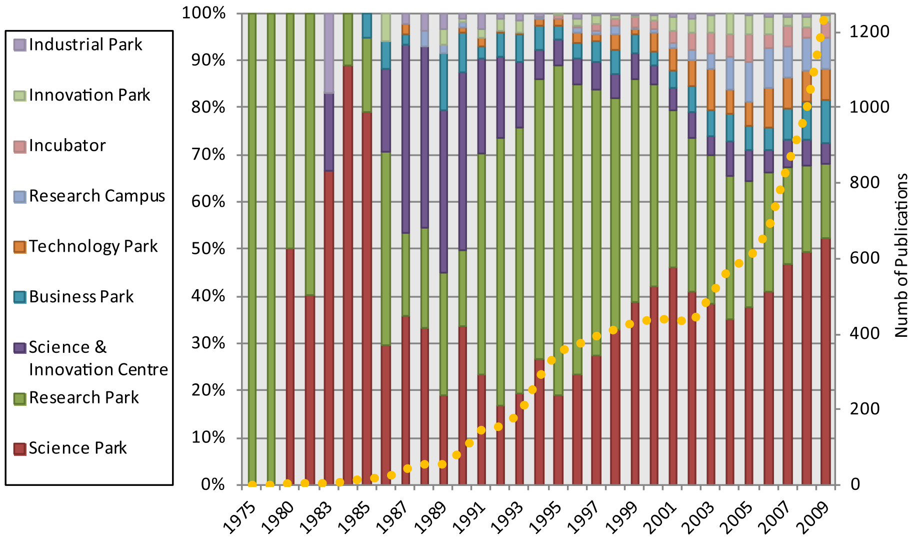

Fig. 2 Infrastructures' share of publications produced in each year (*left axis*) in relation with the total number of publications (*dotted line*) produced in each year (*right axis*) (*Source*: Scopus 1975–2010)

steady publication growth in the following years. In the period 1996–1999 the development continues with Incubators as the newcomers, and during the early years of this century the first Bioincubator, BioCentre, and Science Centres appeared, while Business Centres and Enterprise Parks started to get involved in R&D activities later. In the last 15 years the output was still predominantly from Science- (40 %) and Research parks (32 %) despite the high variety and maturity of the infrastructures, while other infrastructures such as Business Parks (6 %) and Technology Parks (5 %) only played a peripheral role in spite of their recent increase in publications.

Regions and types of organisations involved in the SP movement

Traditionally, the SP movement has been driven by the assumption that physical proximity between industry and sources of knowledge should trigger innovation (Link and Scott 2003; Vedovello 1997). Since these infrastructures are oriented to support research-intensive industries as a means to generate growth and employment by adding synergy and dynamism to a socio-economic context, SPs are also essential for the development of research intensive clusters (Saublens 2007). Therefore, this section shows the research activity and types of organisations of the movement across regions, if it forms part of larger clusters and if it could be related to regional innovative performance and finally, which organisations are the major driving forces of research visibility in the SP movement.

As Annex A reports, 52 % of the SP Scopus publications are from the East of England followed by the South East (14 %) and Scotland (12 %), and these regions also have the highest number of on-park organisations. In contrast, Northern Ireland, London and Wales provide the lowest rate of research output. In terms of established infrastructures, the largest agglomerations are formed in the South East (20 %), the East of England (13 %), and Scotland (13 %). The high visibility of these areas reflects the fact that knowledge creation and absorptive capacity may have a direct impact on the industrial competitiveness. This is shown by these particular three regions, excluding inner London, being the major centres of biotechnology in the UK according to the knowledge-space dynamics produced by the interaction and synergy of capabilities embedded in these regions (biotech firms, public science basis and funding, patents and publications, biotech organisations, and formal alliances) (Birch 2009; Cooke 2001; Kitson et al. 2009).

A closer look at the patterns of the two groups of infrastructures reveals the research or commercial orientation of the different regions (see Annex A). Those with the highest number of infrastructures, such as the East of England and Scotland, have a balance between research- and commercial oriented ones and their main research activity is based on the former. The South East, despite being a research-active region it also provides the largest research-active commercial structure across the country, having a high visibility in both areas due to the activity and number of industrial and scientific organisations. All this agrees with previous findings (Birch 2009; Cooke 2001) that the South East is more market-driven whilst the East and Scotland are university-based clusters. Other regions with a probable commercial identity are the South West and the North West, as shown by their large commercial structures. However, their limited research capacity suggests a similar situation to the other regions. Porter and Ketels (2003) also highlights the lack of university-company interaction outside the life sciences and the university-based cluster around Oxford and Cambridge.

In general, the SP movement depicts a gap between the south and north of the country, with the exception of Scotland and the North West. A similar regional divide is found in SP funding and establishment policy, with the south being largely privately funded and the rest of the country being publicly supported (Quintas et al. 1992), with infrastructures located in prosperous environments in the south, becoming relatively more developed, and those established in depressed and disadvantaged areas in the north to encourage industrial regeneration (Westhead and Batstone 1998). Finally, the low position of London is clearly influenced by a scarce SP infrastructure, which makes it impossible to uncover its science and technology-based industry or leading HEIs. Annex B displays maps of the agglomerations of infrastructures and outputs across the UK.

The two southern regions also occupy top positions in the UK Competitive Index (UKCI), i.e., a composite index that benchmarks regions and localities based on a set of factors that reflect the link between macro-economic performance and innovative business behaviour (Huggins 2003). Furthermore, significant correlations were found between the number of infrastructures (0.63), output (0.70), and onsite-organisations (0.80) with the UKCI input factors.[5] It could suggest that the SP movement plays a significant role in the design of regional innovation strategies and the on-park research activity to some extent might reflect the degree of competitiveness of the region. However, this also calls into question whether SPs are adequate mechanisms to regenerate declining industries and less competitive areas, rather than intermediaries that support and maximise the exploitation of already existing dynamism and learning capabilities embedded in innovative areas. Also, to what extent could policies be successful in promoting SPs in areas that lack support capabilities, dynamism and a high quality and strong research basis? Besides this, the relationship found between the SP movement and biotech concentrations, as well as the concentration of the movement's research production in life science and bio-related fields (see Fig. 5), indicates that, at least among research-active parks, they might provide the right conditions for the expansion of high technology industries.

Regarding the type of organisations that produce research and technology publications, industry (48 %) and RIs (44 %) are the main onsite producers. Figure 3 shows how the activity trend of the private sector has followed an exponential trajectory since the 90s and experienced a striking upward growth after 2005. RIs, on the other hand, were the major research producers during the 1990s and although they have kept growing, businesses now lead the output. This suggests that industry's passive role as a traditional knowledge consumer might have changed to a learning-by-doing process to actively produce specific knowledge and remain plugged into the scientific network, particularly in high tech sectors where there is high dependence of high quality research (Marston 2011). However, this distribution varies in relation to the type of infrastructure. Figure 4 shows that, although this categorisation is subjective in the sense that is based on the names of the parks, the R&D activities found in the groups of infrastructures are in line with the research intensity expected according to their definitions. Thus, the output of public science producers tends to be based in research-based environments, such as Research parks and campuses, which have more than three quarters of the output, while a more diverse collection of research producers is primarily found in Science and Technology parks. This is a result of the majority of high-tech tenants heavily engaging in basic and applied research and development. Incubators with prominent private activity reflect the limited capacity of newly founded and young ventures to undertake research. On the other hand, the infrastructures with no formal ties with HEIs like Innovation Parks, Science & Innovation Centres, and Business & Industrial Parks, reveal the limited R&D capacity of their research-intensive tenants.

Although the aggregate data shows that the research is produced by organisations that are usually based on the expected infrastructures and it helps to a more accurate distinction between infrastructures, it conceals important differences between infrastructures. For example, the fifteen most research-active infrastructures show how R&D activities differ among similar infrastructures (see Table 1). In regard to the region and type of infrastructure, again the East of England, the South East, and Scotland, and the Science- and Research Parks dominate the top positions in terms of research output. Cooke (2001)

[5] Input factors: R&D Expenditure; Economic Activity Rates; Business Start-up Rates per 1,000 inhabitants; Number of Business per 1,000 inhabitants; GCSE Results—5 or more grades A* to C; Proportion of Working Age Population with NVQ Level 4 or Higher; Proportion of Knowledge-Based Business (Huggins and Thompson 2010).

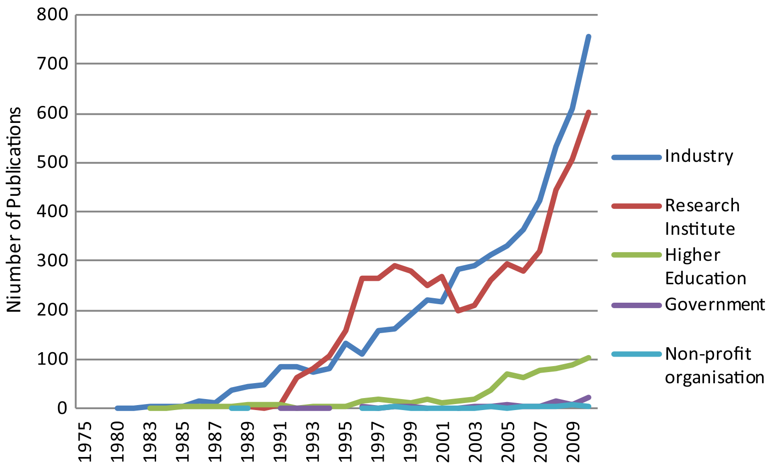

Fig. 3 Chronological output of research publications in terms of on-park organisation type (*Source*: Scopus 1975–2010; $n = 10{,}920$)

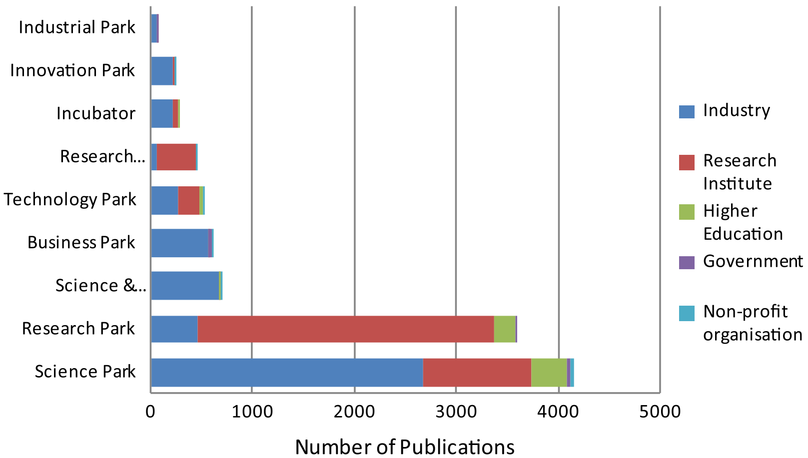

Fig. 4 Number of publications of the different types of support infrastructures in terms of on-park organisation type (*Source*: Scopus; 1975–2010; $n = 10{,}920$)

considers this as an important catalyst in the development of the biotechnology industry in the three regions. However, the differences regarding the organisations driving the R&D activities within each park depict three main profiles;

- Parks whose production is the result of an anchor research institution (Norwich RP, Pentlands SP, Babraham RC, Scottish Enterprise TP, Roslin BioCentre);
- Parks whose production relies on relocated R&D units of multinational high-tech and pharmaceutical companies (New Frontiers SP, Wilton Centre, Birmingham RP);
- Parks whose production relies on a significant number of small and medium new-technology based companies and academic spin-offs, as a result of apparently better

Table 1 Scopus publications of the fifteen most research-publishing support infrastructures in the UK

Infrastructure name	Type of infra.	Region	Firms	RIs	HEIs	Gov.	NOP	Total
Norwich Research Park	Research Pk	East of England	29 (0.9)	2,876 (93.7)	165 (5.4)			3,070
Cambridge Science Park	Science Pk	East of England	646 (92.4)		46 (6.6)		7 (1.0)	699
Harwell Oxford	Science Pk	South East	253 (38.6)	402 (61.4)				655
New Frontiers Science Park	Science Pk	East of England	502 (100.0)					502
Pentlands Science Park	Science Pk	Scotland	30 (6.1)	459 (93.7)			1 (0.2)	490
Wilton Centre	S&I Centre	North East	424 (100.0)					424
Granta Park	Science Pk	East of England	335 (100.0)					335
Babraham Research Campus	Research Camp	East of England	62 (23.0)	204 (75.6)			4 (1.5)	270
Scottish Enterprise Technology Park	Technology Pk	Scotland	10 (4.4)	215 (95.6)				225
St. John's Innovation Park	Innovation Pk	East of England	163 (98.8)				2 (1.2)	165
Surrey Research Park	Research Pk	South East	140 (92.7)	1 (0.7)	10 (6.6)			151
Manchester Science Park	Science Pk	North West	94 (69.1)		42 (30.9)			136
Roslin BioCentre	Science Pk	Scotland	24 (18.9)	103 (81.1)				127
Heriot-Watt Research Park	Research Pk	Scotland	81 (65.3)	11 (8.9)	21 (16.9)	11 (8.9)		124
Birmingham Research Park	Research Pk	West Midlands	97 (79.5)	13 (10.7)	11 (9.0)	1 (0.8)		122

support and networking activities (Cambridge SP, Granta P, St. John's IP, Surrey RP, Manchester SP, Heriot-Watt RP).

This confirms the high diversity of the movement and it is in line with Castells and Hall's (1994;92–93) conclusion that parks where the development focuses on attracting multinationals and research centres only succeed at one level, bringing firms and jobs, but the synergy and cross-fertilization of an innovative environment remain minimal. Table 2 shows that even though most research active institutions and businesses are located in different infrastructures in the three top regions, both the basic-public sector and applied-industrial produce research that share a common interest around similar areas. For example, in the East of England the top industrial and public organisations are based in different parks but share the same industrial interest, namely bio-pharmacology and food biotechnology. A similar R&D interest among organisations and between both sectors was also found in the other two regions, suggesting that the agglomeration of the critical mass of knowledge and capabilities embedded in the environment could be more relevant than sharing the same roof or campus to foster fruitful knowledge exchange. The concentration of like-minded research institutions indicates the importance of regional innovation policies to guide an industrial restructuration, and the importance of the networking role played by the SP movement in building bridges between the different actors. All this leads to the consideration that the external environment could be a pre-condition in order to set up a SP, and that the design of a regional innovation strategy is essential for SPs' performance capacity.

The main partners of the SP movement

The main function of SPs' networking activities is to promote relationship building between industry and university to gain access to mutual exchange of resources as a result of joint R&D projects as well as public and private research (Westhead and Storey 1995). As the analysis of on-park organisations only uncovers part of the SP movement, and there is a need to get a better understanding of the networking function inherent in these infrastructures, this section presents the collaborative patterns of the movement to identify which types of actors are the most collaboratively oriented, which type of infrastructure fosters collaboration, which regions are the best connected, and the role of academia and off-park organisations. For this analysis, only the publications co-authored by members of two or more organisations were selected. There is an increase in the total number of organisations authoring the publications since 2003; from 1.6 and 1.7 during the 80s and 90s to 2.4 in the 21st century, reaching 3.4 in 2010. The inter-institutional collaboration represents 70 % (6,825) of the total SP movement research output. Inter-institutional collaboration can also be the result of single authors who represent two or more organisations. Here, these types of researchers primarily work for both industry and HEIs, and only reach 50 (0.005) publications.

The collaboration patterns among and between on- and off-park organisations (see Table 3) shows the limited knowledge exchange between on-park organisations in comparison to the activity of the off-park organisations in the transference of knowledge. The collaborative capacity of on-park organisations to exchange knowledge with on- and off-park organisations is basically limited to the national territory (1,101) and national off-park organisations (2,110). This depends on the fact that on-site organisations are dominated by industry (55 %) and, to a lesser extent, RIs (35 %). On the other hand, the national off-park organisations, which are dominated by academia, have established 5,488 collaborations,

Table 2 The most research-active firms and research institutes located in the East of England, South East, and Scotland

Rank	Name	Infrastrucutre name	Publications	Field	Type of company
Firms					
East of England					
1	GlaxoSmithKline [Harlow]	New Frontiers SP	502	Bio-pharma	R&D Lab (UK)
4	TWI Ltd	Granta Park	138	Technology engineering	Consultant (UK)
5	Toshiba Research Europe Ltd.	Cambridge SP	119	Computer Science and Engg.	R&D Lab (Japan)
6	Unilever [East]	Colworth SP	115	Food biotechnology	R&D Lab (UK/NL)
8	UCB Celltech-Chiroscience [Oxford GlycoSciences]	Granta Park	107	Bio-pharma	Spin-out (UK/BE)
9	Vernalis [Ribo targets/British Biotech]	Granta Park	72	Bio-pharma	Spin-out (UK)
12	Chirotech Technology Ltd	Cambridge SP	58	Bio-pharma	R&D Lab (India)
South East England					
3	Diamond Light Source Ltd.	Harwell Oxford	227	Multidisciplinary research	Synchrotron facility (UK)
7	QinetiQ Ltd. [Farnborough]	Cody Technology Pk	107	Defence technology	R&T company (UK)
18	Surrey Satellite Technology Ltd	Surrey Research Pk	35	Aerospace	Spin-out (UK/France)
Scotland					
10	Quintiles Scotland Ltd [Syntex Research Centre]	Heriot-Watt Research Pk	62	Bio-pharma	Consultant (USA)
24	Biomathematics and Statistics Scotland	Edinburgh Tech Transfer Cent	25	Bioinformatics	Consultant (UK)
30	Codivien [CardioDigital Ltd]	Elvingston Science Cent	22	Bio-pharma	R&D Lab (USA)
Research institutes					
East of England					
1	Institute of Food Research	Norwich RP	1756	Food biotechnology	BBSRC
2	John Innes Centre	Norwich RP	1042	Food biotechnology	BBSRC

Table 2 continued

Rank	Name	Infrastrucutre name	Publications	Field	Type of company
6	Babraham Institute	Babraham Research Camp	199	Functional genomics	BBSRC
7	Sainsbury Laboratory	Norwich RP	153	Food biotechnology	Gatsby—BBSRC
12	Sanger Institute	Wellcome Trust Genome Camp	52	Functional genomics	Wellcome Trust
14	European Bioinformatics Institute	Wellcome Trust Genome Camp	30	bioinformatics	EC-Wellcome Trust
South East England					
4	Rutherford Appleton Laboratory	Harwell Oxford	363	Multidisciplinary research	STFC
11	IT Innovation Centre	Chilworth SP	57	IT	Univ of Southampton
13	Mammalian Genetics Unit	Harwell Oxford	39	Human genetics and functional genomics	MRC
Scotland					
3	Moredun Research Institute	Pentlands SP	402	Agro-biotech	EBAR
5	NERC Radiocarbon Facility	Scottish Enterprise Tech Pk	215	Earth and Environmental Science	SUERC—NERC
8	Roslin Institute	Roslin BioCentre	103	Agro-biotech	BBSRC
10	Veterinary Laboratories Agency	Pentlands SP	72	Agro-biotech	DEFRA

Table 3 Distribution of collaborations between on- and off-park organisations

Type of collaboration	National	International	Total
On-park org–on-park org	1,101 (0.13)	64 (0.01)	1,165 (0.11)
On-park org–off-park org	2,110 (0.24)	1,626 (0.16)	3,736 (0.35)
Off-park org–on-park org	5,488 (0.63)	257 (0.13)	5,745 (0.54)
Total	8,699	1,947	10,646

making HEIs the main partners of on-park organisations for R&D activities. Overall, the dynamism of on-park organisation to get involved in inter-organisational collaboration (46 %) is similar to the extent of collaborative ties built by external organisations with the SP movement (54 %). Another interesting fact is that 83 % of on-park firms generated collaborative research in the last 10 years, resulting in a growing interest by onsite firms in taking advantage of public research produced by HEIs and RIs.

To identify the degree of collaboration within and outside the SP movement, Table 4 illustrates to what extent the national on- and off-park organisations collaborate with on- and off-park organisations at the national or international level. First, regarding the on-park organisations, it was found that the East of England is well connected at the national and international level, occupying the first position. The South East and Scotland also top the ranking as a result of their large R&D structures in terms of tenants and research engagement. Second, in looking at the influence of off-park organisations, the research base in the South East, Scotland and London are the most attractive sources of knowledge for national and international organisations. The top position of London also illustrates the regional research capacity and entrepreneurship available in the region, regardless of its virtually non-existing park infrastructure (Sainsbury 1999). Surprisingly, the remarkable institutional infrastructure developed in the East of England reports a low level of participation of offsite organisations, as their collaborative ties become weak outside the movement, and the main reason for this is the important role of RIs and their slightly low propensity to collaborate (Noyons et al. 1999). The South East has, on the other hand, more global links than other regions as result of the agglomeration of large firms. These two regions' interactions are similar to those based on the level of formal alliances in the biotech sector Birch (2009). The East of England concentrates a high number of local alliances, whereas the local and low connectivity patterns of London and Scotland differ from the evidence of the high inter-organisational knowledge exchange provided by the HEIs in these regions. However, all in all the high concentration of alliances (70 %) in the East of England, the South East, and London, as found by the same author, is somewhat similar to the 50 % of knowledge exchange and interactions concentrated in these regions, providing the mass of research and technology necessary.

The collaborative patterns between infrastructures and organisations help to identify which infrastructures best promote collaboration across organisations and which on- and offsite organisations are the favoured partners (non shown). Infrastructures with a large public scientific base, such as, science- and research parks, and research campuses, are the most connected, hosting organisations that equally collaborate with national and international firms. Nonetheless, their connections with HEIs and RIs remain primarily within the UK, which coincides with previous findings (BIS 2009). On the other hand, firms and HEIs concentrate 81 % of the collaborations and are the most frequent partners for the SP movement members. Indeed, firms primarily collaborate with other firms (1,209; 54 %)

Table 4 Regional ranking based on collaborations between (1) on-park and on-/off-park organisations, and between (2) off-park and on-/off-park organisations

	On-park org–on-/off-park org				Off-park org–on-/off-park org				Rank	Total
	Rank	National	Rank	International	Rank	National	Rank	International		
East of England	1	1,370	1	1,039	4	1,146	4	1,025	1	4,580
South East England	3	473	2	230	1	1,965	1	1,607	2	4,275
Scotland	2	545	3	144	2	1,615	3	1,375	3	3,679
London	8	70	8	22	3	1,331	2	1,515	4	2,938
North West England	4	255	4	83	6	961	5	932	5	2,231
Yorkshire and the Humber	9	67	10	20	5	1,012	6	717	6	1,816
West Midlands	5	139	5	47	9	520	7	507	7	1,213
South West England	6	105	7	24	8	618	8	463	8	1,210
East Midlands	7	79	6	34	7	696	9	277	9	1,086
North East England	11	55	12	12	10	280	10	64	10	411
Wales	10	34	9	22	11	219	11	47	11	322
Northern Ireland	12	19	11	13	12	100	12	30	12	162
Total		3,211		1,690		10,463		8,559		23,923

The first illustrates to what extent regional on-park firms access to external knowledge, and the latter to what extent off-park organisations, mostly HEIs, tap industry into the public sciences and HEIs (774; 34 %), while RIs' partners include HEIs (938; 44 %), industry (737; 34 %), and RIs (338; 16 %). All this underlines the central role of HEIs (Etzkowitz 2008; Godin and Gingras 2000).

Despite the low proportion of collaborations fostered by the SP movement in general, the degree of interaction and synergy among firms, HEIs, and RIs, is likely to be a sign of the good promotion of academia-industry links found previously (UKSPA 2003), and although this study does not directly compare the proportion of collaboration among off-park firms, the on-park research production exhibits higher rates of research generated in the form of inter-organisational collaboration and a stronger integration among firms, HEIs and RIs (BIS 2009; Cockburn and Henderson 1998). It therefore forms a contrast to previous findings where these interactions were found to be insignificant (Vedovello 1997), informal and with little difference to off-park firms (Quintas et al. 1992; Westhead and Storey 1995). Conversely, it might coincide with studies that argue that SPs facilitate links with HEIs and RIs (Soetanto and Jack 2013), and stimulate the research productivity among firms (Siegel et al. 2003a, b). However, this study cannot conclude that the innovation infrastructures are successful policy tools as the research and technology outputs and collaboration are phenomena well concentrated and limited to only three regions in the UK.

Since the industry-academia interaction plays a central role, it is necessary to examine from which region the demand for knowledge comes from and from which regions this knowledge is supplied. Thus, stemming from the assumption that research collaborations between industry and HEIs might represent a relationship between knowledge consumers and knowledge suppliers (Abramovsky and Simpson 2011), the links established by onsite firms with on- and offsite firms, HEIs, and RIs are seen as a sign of demand for collaboration and exchange of knowledge, while the links established by offsite HEIs, firms, and RIs with onsite firms are interpreted as a sign of supply of collaboration and exchange of knowledge (see Annex C). These two relationships developed in each region are analysed in terms of: intra-regional level, inter-regional level, European level (collaborations with countries across Europe), and global level (collaborations with countries beyond Europe), national dependency (difference between the inter-regional and intra-regional supply or demand across the country, which illustrates their degree of dependence on inputs beyond the region), and off-park influence (difference between the supply and demand at national or international level, which illustrates the degree of influence of off-park inputs).

The demand for collaboration from onsite firms is tightly related to the size of the SP infrastructure developed in each region and the regions with (East of England, the South East, and Scotland) the highest number of on-park firms also foster most R&D activities in collaboration. Hence, the East of England clearly has the highest level of ties within the region (239), across the country (311) and abroad (291). Interestingly, the overall demand for collaboration is greater at the inter-regional level than the intra-regional level, suggesting that geographical proximity is not an important factor when onsite firms establish ties with on- and off-park firms, HEIs, and RIs. This might contradict the fact that 90 % of the on-park firms, which have a link with HEIs or RIs are established with local institutions (UKSPA 2003). The regions in which the national dependence is highest are the South East, the East of England, and the West Midlands, and the overall national links are more important than the international, as they represent 68 % of the total links, while the European organisations concentrate the international demand. Finally, the share of collaborations per onsite firms indicates that on average they establish 4.4 collaborations and the East of England and the East Midlands are the most and least collaborative regions respectively.

Regarding the supply of knowledge by offsite HEIs, firms, and RIs to onsite firms at the national and international level, the data shows that the East of England (1,081) and the South East (1,025) concentrate the external inputs. Only the East of England reports intra-regional ties that are three times stronger than the inter-regional ties, having access to a research base capable of supporting the regional innovative infrastructure, while the most interconnected on-park firms with off-park organisation across the UK are located in London. At the international level, the contribution of Europe and other countries are similar, and the East of England and the South East are again the most connected regions and the only two whose international ties are stronger than the national ones. This clearly indicates that the public research base developed in the country represents a more relevant source of knowledge and technology than those located abroad and, in particular, within the same region. Furthermore, only the regions with a higher agglomeration establish a great amount of international links.

Finally, the share of collaborations per external suppliers indicates that on average they establish 4.3 collaborations and that their inputs are the most intense in the South East and London. On the other hand, the level of influence of external inputs across regions determined by the difference between the demand by onsite firms and the supply of external knowledge shows that London (309), Scotland (250), and Yorkshire and the Humber (232) are highly dependent on external UK based organisations, while the East of England is the only region that could be considered as independent. However, this autonomy is only limited to the national sphere because it is the second region most connected to external organisations outside the UK, only surpassed by the market-oriented South East. This may be an indication of the integration of these two regions in global life science flows, the excellence of the regional research infrastructures, and experience in technology transfer and commercialisation (Kasabov and Delbridge 2008). All this indicates that geographical proximity does not determine the university-industry interaction, which contradicts one of the main assumptions behind the development of SPs. Fukugawa (2006) who studies the propensity of on-park firms to engage in joint research with academia has also obtained similar results. In addition, firms with high levels of absorptive capacity appear to favour quality over geographical proximity when it comes to collaboration with academia, and the collaborative arrangements only remain geographical if there are top universities nearby (Laursen et al. 2011; Moodysson and Jonsson 2007). This fact explains the high proportion of local interconnection in regions with a high quality research base, such as the East of England.

Research subject areas

Scholarly journals are the main venues of interaction and communication for different like-minded scientific communities, making it possible to identify the intellectual and social aspects shared by each scientific community (Minguillo 2010). In this section, the most important scientific fields are identified based on the journals where the research is frequently disseminated. The fields are defined by the journal classification scheme proposed by the bibliographic database Scopus.

Regarding the most important research fields, the chronological development of the top nine subject areas, covering 80 % of the total output, shows that *Biochemistry, Genetics and Molecular Biology* is the main field with 18 % of the total output (Fig. 5). The high visibility of this field is also the result of the significant impact of public research in the pharmaceutical industry (Cohen et al. 2002)and the heavy publishing activity of bio-related companies (Cockburn & Henderson 1998). The other top subject areas have followed a

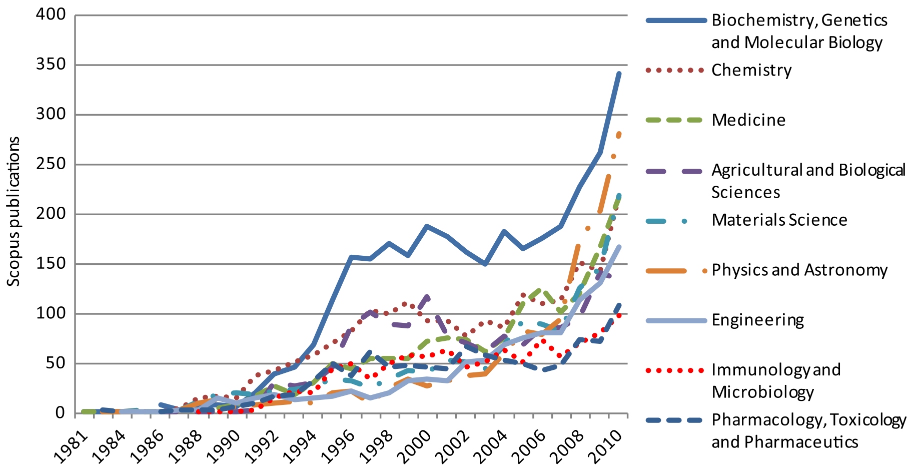

Fig. 5 Chronological development of the top nine Scopus subject areas of the SP movement

constant growth and have similarly achieved a remarkable upward increase since 2005. Nevertheless, three related areas have been subject to exponential growth in the last years, namely *Physics and Astronomy*, *Material Science*, and *Engineering*. Conversely, *Chemistry*, and *Agricultural Biological Sciences* suffered a slight decline during 2000 and 2007. These two sets of fields represent, on the one hand, the emerging physics and material engineering industrial sector, and on the other hand, the well-established health and life science industrial sector. Both sectors also differ in terms of research and technology producers as the first is slightly dominated by firms (67 %) and the second by public RIs & HEIs (57 %). This indicates the maturity of new research-based industrial sectors, which are run mostly by the private sector, and that coexist with the well established and publicly backed bio-tech industry. Moreover, despite that these top fields are the most tied to public research (Cohen et al. 2002), this development could also illustrate the influence of public strategy and SPs to facilitate the emergence of new industries (Sainsbury 1999). For example, Link and Scott (2003) also show how the historical development of SPs in the United States is also influenced by public policies.

The research profile of the three regions with the greatest innovation structures shows that the East of England with high concentration of small and large biotech firms (Birch 2009) have as main subject area *Biochemistry, Genetics and Molecular Biology*. Research in this area is highly dependent upon public RIs (see Table 2), as shows the low share of private research (38 %). This region also produces significant research in *Agricultural Biological Sciences* and *Chemistry*, and despite its high competitiveness to generate considerable research in other research fields, it is widely considered as public science-based and specialised in food-biotechnology and bio-pharmacology. The research from the South East is framed within four important areas: *Physics*, *Materials Science*, *Engineering,* and *Chemistry*, and even though there are public RIs that support the first two research areas, the role of industry as research producer is significant (63 %). Hence, the South East region seems to rely on private research to develop an industrial sector around physics and material engineering. Finally, Scotland, with a reduced private research capacity (35 %), relies on public research to concentrate research related to *Immunology*, *Medicine*, *Veterinary* and *Biochemistry, Genetics and Molecular Biology*, which in turn is exploited by the agro-biotech industry, confirming previous findings (Cooke 2001).

The explanation for the active participation of industry in R&D activities in the South East is that it needs to develop their own expertise in physics, while the life science sector relies more on external research and universities (Cohen et al. 2002; Godin 1996). Finally, the subject areas with the highest rate of private participation are *Pharmacology*, *Engineering*, and *Materials Science*. All this indicates that the interdisciplinary field of life and biomedical sciences is the main research field of the movement, and the East of England possesses the main private and public agglomeration across the country, which in turn is related to areas such as food-biotechnology and bio-pharmacology. The other two sets of top fields are tightly related to the regions of either the South East or Scotland; the first is configured by an emerging private and multidisciplinary research base that is exploited by the physics and material engineering sector, while the later region is characterized by a considerable public research base focus on agro-biotech (Cooke 2001).

Conclusion

This study draws on scientific and technology publications produced by on-park organisations in the UK with the aim of exploring whether scientific publications can be a valid tool for mapping and monitoring the R&D ability of on-park organisations. To tackle this goal, the focus has been on the analysis of four different aspects that illustrate to what extent a bibliometric approach can help to complement other methods, and also expand the knowledge of the SP movement as a whole.

The results show that, first, the development of the UK SP movement is characterised by a constant increase in the research and technology production from the 90s with exponential growth since 2000. Scotland and the East of England have a high R&D intensity and are the regions where the first infrastructures were created, and the first type of infrastructures established across the country with the highest proportion of research output, namely, Science Parks, Research parks, and Science & Innovation Centres. Although the number of commercial-oriented infrastructures is higher due to the reduced need for resources in comparison with research-oriented ones, this does not lead to a higher or similar research production. Instead, as expected, a still sporadic output was found within Business- and Industrial parks. However, the recent increase in the output of commercial infrastructures represents new opportunities for R&D activities and partnerships with knowledge producers, while reflecting that despite the heterogeneity of the SP movement, the intensity of R&D activities is highly concentrated.

Second, regarding the R&D intensity at a regional level, the East of England, the South East and Scotland concentrate the highest proportion of infrastructures and R&D activities. The biotechnology industry plays a central role in the R&D activities of the SP movement, and the nature of these agglomerations differs with the East of England and Scotland being driven by public-research and the South East being driven by commercial interests. However, this high concentration of knowledge-active on-park organisations and the relation between the level of R&D intensity with the competitiveness of the infrastructure developed across the regions suggest that SPs may only be able to exploit the dynamism and competitiveness that already exist in a region—the so-called spontaneous clusters (Chiesa and Chiaroni 2005). SPs do not seem to be the most adequate tools to revitalise less-favoured regions and lead a process of industrial regeneration nor to reduce the uneven development and the unequal distribution of innovative firms in the country, having a limited impact on policy driven clusters (Chiesa and Chiaroni 2005). Hence, this study is also in contrast to the rationale underlying the development of SPs (Quintas et al. 1992; Siegel et al. 2003a, b). Regarding the most research-active organisations, it is shown that due to a remarkable increase in private R&D activities since 2000, industry has overtaken research institutions as the main research and technology producer, and both are responsible for 92 % of the overall on-park output. SPs are the infrastructures where the different types of organisations (Industry, RIs, HEIs, Government, and Non-profit organisation) involved produce knowledge, while the R&D activity of the other infrastructures fundamentally depends upon either the private (Science & Innovation Centres, Innovation Parks, Incubators, and Business and Industrial Parks) or the public research basis (Research- Parks and Campuses, and Technology Parks). The level of R&D activities among the different support infrastructures could also be useful in the formulation of a better classification scheme of the different infrastructures. This approach also shows that research activity among the different types of infrastructures is expected according to their definitions and it suggest a potential application in the formulation of a better classification scheme for the different infrastructures. However, the design of a typology scheme for potential assessment exercises needs to consider the characteristics of the total on-park tenants to achieve better results. Finally, based on the organisations driving the R&D activities within the parks, it is also possible to identify those who either rely on anchor public RIs, on R&D units of large companies, or on new technology-based firms.

Third, regarding the inter-organisational collaboration, the interconnections at a national level and with off-park organisations are the most popular, while the high number of collaborations established by off-park organisations, mostly HEIs, confirms their central role in the development of an external research network that supports on-park firms and RIs. The collaborations established by on- and off-park organisations at the regional level shows that the regions with the highest number of interactions are, as expected, those with the largest SP research agglomerations, while the regions where off-park organisations are highly associated to on-park organisations are the South East, Scotland and London. Regarding the infrastructures that best promote inter-organisational collaborations, Science- and Research parks are the most successful, and industry and HEIs are the most frequent partners for the SP movement members, with the private sector primarily connected with itself and academia. SPs have a positive impact on a higher density of academia-industry links and overall institutional involvement. However, this apparent effectiveness is only limited to the structures developed in three regions and cannot be extrapolated to the whole country.

Finally, regarding the industry-academia interaction, the public research base developed in the country represents a more relevant source of knowledge and technology than those located abroad and in particular within the same region due to the fact that on-park firms tend to collaborate with partners beyond their local region. The reason for this could be the lack of relevant and top quality universities nearby (Laursen et al. 2011). Hence, one of the main assumptions behind SPs is once again questioned by this study. Furthermore, only the regions with great agglomerations have access to many international links. The study also shows that the R&D activities are frequently generated in four subject areas: *Biochemistry, Genetics and Molecular Biology*, *Chemistry*, *Medicine*, and *Agricultural and Biological Sciences*, and as expected, the range of factors and the mass of research accumulated in the three top regions (Glasson et al. 2006; Kasabov and Delbridge 2008; Leibovitz 2004; Sainsbury 1999) lead to; (1) a public science-based research specialised in food-biotechnology and bio-pharmacology in the East of England, (2) a private science-based research specialised in physics and material engineering in the South East, and (3) a public science-based research specialised in the agro-biotech sector in Scotland. The reason for the significant private research in the South East is that its industrial sector needs to develop their own expertise, while the life science sector relies more on public scientific expertise (Audretsch 2001; Godin 1996). There are also other interesting aspects around the movement, which suggest that it has also apparently been able to redefine itself to nurture stronger university-industry links in the last two decades. However, this positive image of the movement is not completely true because the research production is clearly concentrated around only three top regions. In addition, the R&D activities involving on-site industry and academia do not follow physical proximity, questioning one of the main reasons behind the popularity of SPs as policy tools.

Overall, all this suggests that publications represent an interesting proxy to investigate the R&D dimension of SPs, answering the research question. However, the results here are only indicative because although the main goal of SPs is to facilitate knowledge and technology transfer, formal research dissemination only uncovers part of this transference. Another important limitation is that this study might not cover all of the research generated within the SP movement due to the fact that not all on-park organisations mention the name of the infrastructures where they are based as part of their affiliation address. In addition, the results could also favour the visibility of high-research intensive industrial sectors where publications play an important role, while the R&D intensity of other sectors that focus on developing new materials, ICT, hardware or software in the movement could be underrepresented and a different approach would be needed to study them. Apart from these main limitations, a scientific publication is a formal and reliable proxy of knowledge creation and exchange, and represents an interesting proxy to complement the battery of indicators already used to study the SP movement. Therefore, this study introduces a new insight as it expands knowledge about innovative infrastructures through mapping the research capacity of the UK SP movement as a whole. It represents a first step towards a better understanding of the R&D activities of the movement and can facilitate collaboration among parks, especially by promoting connectivity between entrepreneurial research institutions and businesses, since they will be able to easily identify attractive locations to be established or re-located and get information about the research profile of relevant partners or competitors at regional, national and international levels. Stakeholders and policy makers could also track highly intensive research areas, the development of new parks, parks which might develop into potential clusters, and that in turn may lead to stimulate and intensify the transference of knowledge and technology through a better funding allocation for entrepreneurial research institutions and research-oriented firms. Hence, this approach can be further exploited to obtain a deeper understanding of the inter-organisational collaboration within the SP movement, and to find the answers to important questions such as: Do SPs facilitate the collaboration between hosting universities and on-park firms? Are SPs the main intermediaries between hosting universities and industry? How long after SPs are established do they usually start to promote research creation and cross-fertilization? In addition, it can also be applied to different countries and geographical areas. Mapping the R&D activities of the SP movement across Europe, for example, would be essential to promote a better consolidation of a well-interconnected European innovation infrastructure, which is one of the main goals of the EU's Competitiveness and Innovation Framework Programme (CIP).

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