From exogenous to endogenous growth in Sophia-Antipolis:

The implications for the evolution of its knowledge network

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This research was financed by the VolkswagenStiftung

Preliminary version

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Abstract

The business park of Sophia-Antipolis originates from a private initiative to turn a 'greenfield' site just off shore the Côte d'Azur into a high-tech park. High-tech activities started to be co-located there from the 1970s onwards. International high-tech firms were attracted mostly by standard locational features like the pleasant climate. This implies that the 'cluster' was originally nothing more than pure co-location of high-tech firms; a local interaction structure was completely lacking. This has changed through the course of time. The cluster of Sophia-Antipolis gradually became more endogenous through the rise of the number of spin-offs and high-tech start-ups. At the same time several research and education institutes were attracted to the park. In this paper we test whether this change in growth regime from mainly exogenous to mainly endogenous in the early 1990s made the park evolve into an innovation system, characterized by collective learning practices among local firms and between firms and research centres. By means of cooperation networks reconstructed on the basis of patent data we find that in the ICT industry local cooperation has increased substantially from the early 1990s onwards, though not at the expense of cooperation at higher spatial scales. In the pharmaceutical industry in Sophia-Antipolis local cooperation remained stable, whereas cooperation at higher spatial scales increased.

Sophia-Antipolis originates from the private initiative of Pierre Laffitte to turn a ‘greenfield’ site just off shore the Côte d’Azur into a high-tech park. Partly due to public support and marketing, high-tech activities started to be co-located there from the 1970s onwards. International high-tech firms, that mainly wanted to adapt their products to the requirements of the European market, were attracted mostly by standard locational features like the pleasant climate and the presence of an extensive tourist infrastructure. This implies that the ‘cluster’ was originally nothing more than pure co-location of high-tech firms, completely lacking a local interaction structure. This has changed through the course of time. The cluster of Sophia-Antipolis attracted several research and education institutes and the growth of the park gradually became more endogenous through the rise of the number of spin-offs and high-tech start-ups. Longhi and Quéré (1997) and Quéré (2007) argued that the change in growth regime from mainly exogenous to mainly endogenous made the park evolve steadily into an innovation system. That is, collective learning practices started to emerge through interaction among local firms and between firms and research centres.

This paper aims to test this hypothesis empirically by illustrating the evolution of the cooperation network of the firms in Sophia-Antipolis. First, section 1 introduces the wider theoretical context of the evolution of clusters and networks. Second, in section 2 we aim to illustrate the evolution of the cluster of Sophia-Antipolis. In a merely qualitative manner we describe how Sophia-Antipolis evolved from a park of co-located firms to an endogenously growing cluster and how the potential for interactive learning grew accordingly. It results in the formulation of a series of testable hypotheses. Third, in section 3 we present our research methodology. In particular we explain how we reconstructed the evolution of the cooperation networks in Sophia-Antipolis on the basis of patent data from the European Patent Office (EPO). Subsequently, section 4 provides the empirical results by means of the patent-based cooperation networks. Finally, section 5 concludes.

1. Co-evolution of clusters and networks

Through the course of time clusters experience evolutionary processes. Before discussing in more detail the contextual framework of the evolution of clusters it needs to be specified in what terms the evolution of a cluster can be described. Clusters are generally defined as geographical concentrations of specialized firms within a particular industry that are strongly interlinked through relationships of various kinds (Porter 1990). That is, it is a dense local network of inter-firm or science-industry relationships that makes a set of co-located firms to be called a cluster. Although we agree completely with this widely held view on clusters, for the purpose of this paper we propose to disentangle the co-location element from the network element. Taking an evolutionary perspective an interesting question to be asked is how the evolution in terms of pure co-location is related to the emergence and evolution of an interaction structure as described by a network.

Furthermore, disentangling a cluster into a co-location and a network component has another advantage. Whereas co-location is – by definition – a spatially defined concept, a network certainly is not. Although an industry network needs to be geographically concentrated to a considerable degree for a set of co-located firms to be called a cluster, this connection between geography and networks is not automatic. Some geographical concentrations of specialized firms might lack a strong local network, while the industry-wide network is either not concentrated in a particular area at all or is concentrated in other regions with co-located firms (that then might be called clusters). This logic describing the possible, but not automatic coupling between geographical concentration of firm location and the geographical concentration of parts of the industry's network in those particular areas might be particularly related to the stage of development of a cluster.

Within the context of a particular industry – itself being subject to evolution - clusters co-evolve with networks. Generally the evolution of a cluster is described in four distinct phases, ranging from an introductory phase via a growth and maturity stage through a final phase of decline and possible regeneration (Maskell and Malmberg 2007). These phases are analogous to phases described by the industry life cycle model as developed by Abernathy and Utterback (1978) and Klepper (1997). The next section explains in more detail which mechanisms may be at work in the co-evolution of networks and clusters at the various stages of the industry life cycle (see also Ter Wal and Boschma forthcoming). For the purpose of this paper we limit ourselves to the first two phases of evolution, describing the emergence and growth of industries, clusters and networks. Being the main unit of investigation of this study, neither the ICT and pharmaceutical industries nor the cluster of Sophia-Antipolis show signs of maturity or decline.

A life cycle model of cluster and network evolution

Networks and clusters co-evolve during the various life cycle stages of industry evolution. The first, introductory stage is characterized by pioneering firms introducing radical innovations that mark the emergence of a new industry. The technological regime of the industry at this stage is characterized by a high level of uncertainty and a predominantly tacit nature of the industry's knowledge base (Suarez and Utterback 1995; Nooteboom and Klein Woolthuis 2005). At the level of geographical concentration of firms this uncertainty is reflected in an unstable clustering pattern. In the initial situation this pattern reflects the unstructured location pattern of pioneering activity. This patterns depends to a considerable degree is on chance factors and an unpredictable mix of prior industrial structure that – through processes of related or unrelated variety – may have generated new industrial activity (Frenken et al. 2007). At the level of the network the introductory phase of the life cycle is characterized by unstable and volatile network structure. On the one hand the uncertainty about technological direction makes firms eager to interact. On the other uncertainty about who are to be the main players in the field make firms easily change partners.

In the second phase the industry grows. The growing market potential for the new industry provokes a massive flow of entry that is fed through spin-offs and imitators on the one hand or through expanding firms opening subsidiaries in new locations on the other

(Utterback 1994). At the level of spatial clustering some forces towards clustering are likely to be observed. Evolutionary economic models (e.g. Arthur 1994) show that entry through imitation and the spin-off mechanism tends to produce unequal patterns of spatial clustering. Even if the chance of generating an imitator or spin-off is equal for all pioneering firms across all regions, the probabilistic nature of the entry processes probably leads to clustering in particular regions. As soon as some clusters emerge, these forces towards clustering will be complemented by agglomeration advantages (Brenner 2004). Agglomeration advantages of various kinds – ranging from shared specialized services and facilities, the emergence of local buzz to the build-up of a good 'regional' reputation – make it increasingly attractive for new firms to locate in the concentration area. The same might hold for new subsidiaries of existing firms. The more this process of concentration proceeds in a number of locations, the less likely it is that other regions might join and become an important player in the emergent industry (Storper and Walker 1989).

Also at the level of the network forces towards stability are likely to be observed. As new firms enter the industry, the network will grow, since new entrants select one of the existing firms to interact with (Orsenigo et al. 1998). The growth of the network tends to take place through the process of preferential attachment, in which the probability of a node to be selected by the new entrants is proportional to the number links a firm already has (Barabási and Albert 1999). This 'rich-get-richer' or 'success-breeds-success' logic is – among other things – fed by a self-reinforcing mechanism that is the result of a mutual relationship between technological capabilities and network centrality. Technologically advanced firms are attractive to be connected too, get centrally positioned in the industry network and as a result of this position might get more technologically advanced (Gay and Dousset 2005).

From the above might be concluded that the evolution of the spatial pattern of clustering and the evolution of the industry's network take place independently from each other and are driven by different forces. However, when throughout the emergence and growth of an industry its constituent firms come to be concentrated in specific locations, the process of network evolution can no longer be considered separately from the evolution of clustering. That is, forces of preferential attachment shaping network evolution might be complemented or counteracted by forces of proximity. Interaction across firms is facilitated by geographical proximity. The highly tacit nature of the industry's knowledge base at the emergence and growth stages of the industry life cycle makes knowledge to be transferred easier through face-to-face contacts that predominantly will take place at a local scale (Cowan et al. 2004). At the same time social, institutional and cognitive proximity – producing shared norms and values, a high level of trust and an easy mutual understanding – tend to coincide with geographical proximity and thus increase the likelihood of one firm collaborating with the other (Boschma 2005; Cantner and Meder 2006). For this process to play a role in network evolution, at least some locations should have reached a critical mass in terms of number of related firms.

In short, network evolution might be result from forces of preferential attachment and proximity. These two forces either reinforce or counteract each other. As a result, the choice of a new network partner will be the outcome of a probabilistic process dependent on the tension field between technological capabilities – feeding the preferential attachment process – and geographical proximity.

As a consequence, network evolution – particularly preferential attachment – might show overlap with the pattern of spatial clustering. That is to say, parts of the industry network might come to be concentrated in geographical concentration areas that then come to function as integrated clusters. However, this coupling between the evolution of clustering and network is neither automatic nor necessary. As a result, some concentration areas of a certain area might never generate a dense structure of inter-firm interactions and hence never become an integrated cluster. Whether or not a set of co-located firms come to function as an integrated cluster – characterized by a dense local interaction structure – depends on the accumulation process itself as well as on institutional factors determining when a critical mass has been reached. How this accumulation process took place in the business park of Sophia-Antipolis and which implications this might have for the evolution of the cooperation network will be discussed in the next section.

2. The evolution of Sophia-Antipolis

Emergence

Nowadays it is widely agreed upon that it is very hard to create clusters or innovation systems in an artificial way through planning or regional policy. Cohesive clusters and innovation systems are mostly considered as being the result of 'natural' developments, which at best can be facilitated or further stimulated by policy initiatives. Sophia-Antipolis constitutes a quite unique example of a cluster in that it is to a large extent created artificially. However, the starting point was not in the public sphere. The very beginning of Sophia-Antipolis stems from the private initiative of Pierre Laffitte (Member of the Board of the "Ecole Nationale Supérieure des Mines de Paris") in the late 1960s, early 1970s. He envisioned a City of Science, Culture and Wisdom in the South of France where its participants would be attracted by the so-called Sunbelt effect, i.e. the pleasant climate and other comfortable living conditions. He acquired a forested plain between Antibes and Valbonne in order to realise his plans. This area can be viewed upon as a 'vacant space' or 'greenfield site', lacking any industrial or university tradition (Longhi 1999). The first buildings arose in 1972.

The initial project ended up soon in severe budgetary problems. The high costs of providing the necessary infrastructure did not outweigh the benefits that accrued out of the initiative. However, being interested to diversify the economy of the Côte d'Azur from mere tourism, the local public authorities supported the initiative already in an early stage and soon the project transformed completely from a private initiative into a public one. With this transformation the focus of the project shifted more explicitly towards high-tech activities, since this type of activity could easily complement tourism without causing negative externalities (e.g. pollution) to the region's main economic resource (Quéré 2002, 2007).

From then, about 1977, the accumulation of firms and employment in the park started. This can be considered the first phase of development of the business park of Sophia-Antipolis and consisted mainly of the entry of extra-European firms that wanted to open an R&D facility in which they could adapt their products to the specific requirements of the European market. Although it did not result from an explicit strategy, particularly ICT firms – and to a lesser extent firms in the pharmaceutical and energy industries – turned out to be attracted to Sophia-Antipolis (Longhi and Quéré 1997).

Three main reasons can be held responsible for this successful take-off, at least in quantitative terms (Quéré 2002). First, there are some structural characteristics of the region that made the Côte d'Azur, in itself a region without any prior industrial background, an attractive region for foreign investment. These characteristics included the pleasant climate and other natural conditions, the presence of an extensive tourist infrastructure, including an international airport, but also conference rooms, hotels etc. The newly established firms could benefit easily from this present physical infrastructure. Second, but not less importantly, the local authorities developed an explicit and active advertising strategy to promote Sophia-Antipolis as a high-tech business park, especially in the United States. A third factor that stimulated the accumulation of firms in Sophia-Antipolis was the explicit decentralisation policy the French government exerted during the 1970s in order to promote economic development outside the traditional booming regions (Longhi 1999). In this light the early arrival of France Télécom in the area can be seen as a crucial development. France Télécom provided a modern and efficient fibre-optical network that worked out as an important pull factor for other ICT-related firms that could use this advanced infrastructure base to develop applications readily and efficiently (Lazaric et al 2004).

In short, the initial accumulation of firms in Sophia-Antipolis has shown to depend considerably on chance factors. First of all, the visionary pioneer Pierre Laffitte happened to be located in the region. Moreover, the attraction of international firms' subsidiaries to Sophia-Antipolis on the basis of its pleasant climate is at least remarkable, especially when considering a completely lacking industrial tradition in the region and the wide set of alternative locations across Europe. The subsequent take-off of accumulation, however, has been much less dependent on chance factors. The active promotion strategy and the creation of the first agglomeration advantages – for instance related to France Télécom's internet infrastructure – make firms' localization decisions come to be based on harder, more traditional locational characteristics. By the end of the 1980s, however, this change in firms' strategies gradually become more of a disadvantage for the accumulation of firms.

Intermediate crisis

At the end of the 1980s the accumulation process in terms of number of firms and employment started to slow down. Sophia-Antipolis started to suffer from a number of important shortcomings. First, Sophia-Antipolis lost competitiveness relative to other regions concerning the attraction and keeping of international companies, since those companies changed and expanded their set of location requirements and got a deeper knowledge of the alternatives. These developments took place in the light of a changing ‘regime of globalisation’ at the edge of the decade. Ireland and Scotland, for instance, could provide qualified labour more cheaply in comparison to Sophia-Antipolis, while central cities like Paris and London offered a closer proximity to customers and/or financial and administrative services (Quéré 2002). Whereas Sophia-Antipolis was highly competitive in the ‘globalisation regime’ of the 1980s, the park was much less advantaged in the 1990s. In the 1980s companies were to a large extent vertically integrated and firm location decisions were mainly based on costs and the presence of facilities. In the 1990s, however, these decisions started to be built more on locational features that might stimulate innovation (Lazaric et al. 2004; Longhi 2002), since high-tech firms acknowledged more the importance of knowledge from outside the company for reaching innovation. As a consequence of this shift in globalisation, not only the accumulation of companies in Sophia-Antipolis stagnated, some of the established companies even decided to relocate to other areas (Quéré 2002).

A second, related shortcoming concerns Sophia-Antipolis as a cluster of innovative activity. Beside the fact that through the course of time many companies had been attracted on site that did not focus explicitly on R&D and innovation, innovation in Sophia-Antipolis took place exclusively within the boundaries of the firms. In other words: until the end of the 1980s at least, Sophia-Antipolis was not a cluster in the ‘Porter’ sense, where innovations accrue through interaction of related firms. By contrast, it was nothing more than a concentration of firms that were co-located on the basis of a similar set of pull factors. Obviously, the local accumulation process of related firms is a necessary, but insufficient condition for constituting an innovation system (Longhi and Quéré 1997). Considering also, that most of the companies did not have their market locally, Sophia-Antipolis could be viewed upon as a compilation of highly footloose firms (Quéré 2002). In other words: Sophia-Antipolis functioned as a ‘satellite platform’, as defined by Markusen (1996), where the companies due to their international background had a wide array of international relations beyond the cluster’s boundaries, whereas local interactions were almost completely absent (Lazaric et al. 2004; Longhi 1999).

Growth

However, it is exactly the ‘crisis’ of the disappearing international firms that triggered important endogenous developments. We expect that these endogenous development have enabled Sophia-Antipolis, at least as far as ICT is concerned, to function as a more coherent cluster characterized by local collective learning processes.

The relocating international companies left a pool of highly qualified labour that to a large extent did not move along with the company, but that wanted to stay in the Côte d’Azur region. Many of those people started their own companies. Consequently, the shock of the shrinking presence of multinationals provided a stimulus for endogenous growth of the park that resulted in the emergence of technologically advanced SMEs (Quéré 2007). Accordingly, the population of firms present on site diversified largely in terms of size. At the same time, however, Sophia-Antipolis specialised progressively towards the ICT-industries at the relative expense of pharmaceutical or life sciences companies and energy and earth sciences. Within the ICT-industry the focus got more and more on internet and telecom industries. The three main building blocks of these industries – infrastructure (equipments, networks and hardware), platforms (interfaces and software) and applications (including services) are more or less equally present in Sophia-Antipolis (Krafft 2004). As figure 1 shows the accumulation of firms in the pharmaceutical sector has always proceeded at a lower rate than in the ICT-sector. Nowadays, ICT-firms constitute about 75% of Sophia-Antipolis' high-tech companies, whereas pharmaceutical firms make roughly 13% (SYMISA 2004).

Second, the transformation from exogenous to endogenous growth was further reinforced by the arrival of public and private education and research institutes in Sophia-Antipolis. Most of these institutes, like the University of Nice Sophia-Antipolis, INRIA (National Research Institute on Informatics and Automation), INRA (National Research Institute of Agronomics) and CNRS (National Centre of Scientific Research) for instance, were not present on site already in the early stages of development of the park, but were established in a later stage only. Considering that generally most of the attempts to build a science park start with the location of research institutes in the park, this makes Sophia-Antipolis an atypical, 'reverse' science park (Quéré 2007). The research institutes have been attracted in the second half of the 1980s on the basis of an explicit strategy of the national and regional authorities to promote synergies between science and industry. These synergies consist for instance of building a highly qualified local labour market, but of PhD students doing traineeships or projects in firms as well. As a result, the crisis at the edge of the 1980s and 1990s turned out to be only a relatively short interruption between the initial emergence of the cluster and the subsequent follow-up phase of extensive growth. The period of transition from exogenous to endogenous growth took off from the middle of the 1990s onwards and still continues nowadays (for more details, see Lazaric et al. 2004; Quéré 2007).

Based on the differences in firm accumulation between the ICT and pharmaceutical industries we expect some differences in the evolution of the respective networks. Concerning the ICT-industry, we expect that both the emergence of public and private research institutes and the growth of technological SMEs and spin-off and start-up firms have created a critical mass for the emergence of collective learning. In the mainly exogenous phase of entry the boundaries of the firms have become less sharp as they have been in the first, endogenous phase of accumulation. An important contribution to this opening up of the firms is made as well by the Telecom Valley Association that strongly promoted the emergence of clubs and associations that are aimed to link SMEs mutually, SMEs with larger firms or firms with research institutes with the explicit aim to stimulate networking and local interactive learning (Lazaric et al. 2004; Longhi 1999). It could be observed that in the cyclical downturn the ICT-industry experienced at the turn of the century did not affect the firm population in Sophia-Antipolis. Whereas at the national level of France a clear shake-out pattern of ICT-companies can be observed, the number of ICT-companies in Sophia-Antipolis continued to grow, although at a slightly lower pace. This development could be a sign of well-functioning local knowledge dynamics that positively affect the performance and survival of the firms involved (Krafft 2004). In synthesis, we therefore hypothesize for the ICT-network in Sophia-Antipolis that through the course of time – particularly when by the second half of the 1990s the growth regime became mainly endogenous – a trend towards more local-local interaction at the expense of local-national and local-international interaction can be observed.

We expect the situation in the pharmaceutical sector to be rather different from the one in ICT, since a critical mass of companies does not seem to be reached (Longhi and Quéré 1997; Quéré 2007). Another reason for a supposed lack of collective learning taking place in that sector of the park might be that the specialities among the companies in the park differ largely and hence the potential for complementarities might be limited (Longhi 1999). As a result, we hypothesize for the pharmaceutical network in Sophia-Antipolis that through the course of time no trend towards increasing local-local interaction at the expense of local-national and local-international interaction can be observed, not even when in the second half of the 1990s the growth regime of Sophia-Antipolis changed from mainly exogenous to mainly endogenous.

These hypotheses will be tested by means of reconstruction of inter-organizational networks on the basis of patent data. Through this procedure we limit our empirical analysis to *cooperation* networks. Although we acknowledge that other valuable forms of inter-organizational knowledge-based interaction (e.g. through communities of technicians or 'local buzz') might exist, we argue that cooperation is the most tangible form of knowledge-based interaction among actors leading relatively directly to potential financial gains. Therefore we consider the cooperation network as a natural basis for identifying the existence of a local, national or internationally oriented interaction structure. How cooperation networks can be traced through this methodology will be explained in the next section.

3. Methodology: reconstructing cooperation networks from patent data

Patent documents have come to be a rich source of information on knowledge production and innovation activity. Although it can be easily argued that patents do not capture the whole spectrum of innovation activity and therefore patent documents are not the ideal sources of information in that respect, the highly detailed information they contain provides ample opportunities for studying the geography of innovation activity. For instance, patents – that are not equally distributed in space – are widely used in economics as a measure of regional knowledge production (Acs et al. 2002). Moreover information on patent citations is used for tracing back knowledge spillovers across firms and to investigate the role of geographical or other forms of proximity in their spatial pattern (Jaffe et al. 1993; Breschi and Lissoni 2003).

A relatively new use of patent data is their application to the reconstruction of cooperation networks back in time (Breschi and Lissoni 2004). In this paper we will use patent data to reconstruct the cooperation networks in which firms from Sophia-Antipolis have been involved. That is to say, in this case we aim to construct *local* cooperation networks in the sense that the constructed network encloses all local actors and the non-local actors they are connected too. Doing so we are able to compare the extent to which the cooperation takes place purely within the local system with the extent to which the system and its actors are opened up to the external world by means of collaboration with actors outside the local system.

In order to do so we selected all patents from the European Patent Office for the period of 1978 till 2004 for which at least one inventor is resident in Alpes-Maritimes – the surrounding province of Sophia-Antipolis. Patents have been deliberately selected on the basis of the inventors' home address, since generally patents developed by a subsidiary of a multi-establishment firm tend to be assigned to the headquarter. As long as the spatial unit of analysis is not too small – i.e. not smaller than a labour-market area – taking the inventor address as the selection basis is an appropriate and commonly applied method for allocating patents to the geographical origin in which the innovation has been factually developed.

To test our hypotheses concerning the evolution of the cooperation network of Sophia-Antipolis – and particularly its geographical component – it is necessary to trace all cooperation linkages in which at least one firm from Sophia-Antipolis has been involved. Patent applicants are the nodes in our network, being either firms, research institutes or private persons.

Since the patents have been selected on the basis of the inventor address, the patent applicants are not necessarily located in Sophia-Antipolis or even Alpes-Maritimes. Therefore we categorized and coded the applicants on the basis of their location, distinguishing local actors (in Sophia-Antipolis), national actors (in the rest of France) and international actors (outside France). Multi-establishment firms having a subsidiary in Sophia-Antipolis have been allocated to the local set of firms, though categorized in a distinct way as to separate them from other local firms. That is, the category of local firms contains endogenously created local firms, subsidiaries of French multinationals and subsidiaries of foreign multinationals. Table 1 shows an overview of the different types of actors and the number of patents they possess.

The main assumption in the construction of the networks is that a link between two firms occurs either through co-patenting or through multi-applicant inventorship. Co-patenting is the purest form of cooperation. In that case two or more firms are indicated as the assignee – i.e. the holder – of the patent. However, in many cases a cooperative patent is assigned to one of the partnering firms only. Additional contracts between the firms might have been created to further specify the rights and obligations concerning the patents and when cooperation results in more patents over time the partnering firms divide the patents over the various partners (see also Cantner and Meder forthcoming).

Table 1: Patents with at least one inventor resident in Alpes-Maritimes (1978-2004)

Spatial scale	*Type of actor*	*Actors*	*Patents*	*Patents per actor*
Alpes-Maritimes	Local firm	131	357	2,7
	Subsidiary of multinational	31	998	32,2
	Research institute	9	88	9,8
	Private person	460	583	1,3
	Total	631	2026	3,2
Rest of France	Firm	190	727	3,8
	Research institute	23	38	1,7
	Private person	61	88	1,4
	Total	274	853	3,1
Rest of the world	Firm	137	286	2,1
	Research institute	8	9	1,1
	Private person	24	30	1,3
	Total	169	325	1,9
Total		**1074**	**3204** [1]	**2,9**

Source: EPO Patents, provided by the Netherlands Institute of Spatial Planning

In order to capture also these hidden collaborations not only co-patenting results in inter-firm linkages, also multi-applicant inventorship does. Multi-applicant inventorship encompasses all cases in which an inventor occurs at patents assigned to multiple firms. Multi-applicant inventorship generally is interpreted as being the result of labour mobility. However, as Laforgia and Lissoni (2006) have showed in their study of Italian patents, labour mobility accounts only for a minor part of multi-applicant inventorship. Next to hidden cooperation multiple applicant inventorship might be the result of the 'market for technology'. The patent applicant has bought a patent from another firm, which is not directly mentioned on the patent document but whose employees are still mentioned as an inventor. Hidden cooperation and selling patents are responsible for a considerable part of the cases of multi-applicant inventorship. In their study of the European biotechnology industry Laforgia and Lissoni (2006) found that only 20% of multiple applicant inventorship was clearly the result of labour mobility.

In our subset of patents each case of multi-applicant inventorship has been taken into account and interpreted as a network linkage, irrespective of the fact whether it is a hidden cooperation, market for technology, a pure case of labour mobility or else. In a sense, even a pure case of labour mobility can be interpreted at least as a one-directional knowledge flow between the firms involved. At the same time relations of labour mobility between firms might provoke some more informal, bidirectional knowledge flows between (the employees of) the firms. As a consequence multi-applicant inventorship fits in our framework of detecting the

[1] Higher than the total number of patents due to double counting at co-patents.

interaction structure of the local system of Sophia-Antipolis, even in case of pure labour mobility.

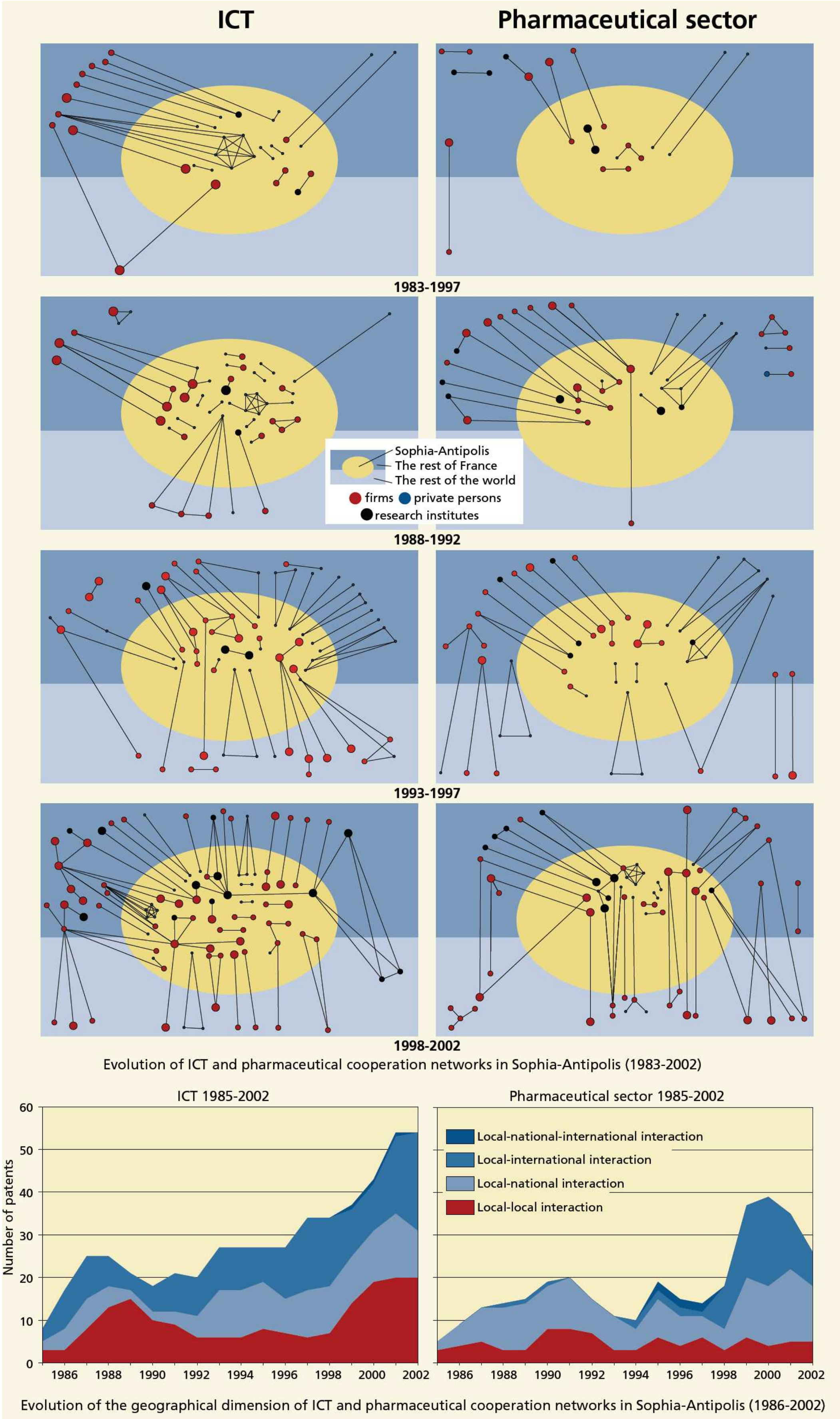
The only condition for a relation of multi-applicant inventorship to be included in our analysis is the time lag between the patents of the inventor involved. Only the cases in which the time lag between two subsequent patents is 10 years or less are included in our analysis. To our view, taking a larger time lag is not in line with our interpretation of multi-applicant inventorship. Moreover pure labour mobility might have lost its relevance when there is more than 10 years between the two employments, since the knowledge accumulated at the prior employer might be no longer valuable and effects of provoking informal knowledge-based networks might have decayed in the meantime (SOURCE).

The links that have been detected on the basis of co-patenting and multi-applicant inventorship have been allocated to the ICT industry, the pharmaceutical industry or else. We have used the OST-INPI/FhG-ISI technology nomenclature as developed by Schmoch et al. (2003) to recode the patent IPC technology classes in sector codes. Which sectors have allocated to the ICT and pharmaceutical industries is explained in appendix 1. In case of multi-applicant inventorship it is possible that the patents resulting in the network linkages occur to different sectors. As long as one of the patents belong to the ICT or pharmaceutical industry, they are included in the analysis.

All network linkages – irrespective of the fact whether they have been caused by co-patenting or multi-applicant inventorship – are also grouped in five-year periods, ranging from 1978-1982 till 1998-2002. The early years have been left out of consideration due to the low number of patents (which is in turn due to the low number of companies on site). The years 2003 and 2004 have been omitted as well, since not all patents applied for in these years have been officially assigned yet and as a consequence were not present in the patent data file. Including these years would result in a downturn in the total number of patents and an incomplete picture in terms of network relationships. In case of multi-applicant inventorship the relationship is dated in every year the inventor has worked for two or more different applicants or – in case the years do not show overlap – in the year of the last patent (since the knowledge flow and possible indirect network effects can take place only from the moment the inventor has moved to the new employer).

As shortly noted already, patents are not the ideal sources of information for studying innovation activity or cooperation networks. At the end they do not provide the complete network of cooperation in which the firms of Sophia-Antipolis have been involved. Cooperation activity that did not lead to a patent is not captured by the methodology. This implies that for instance more informal collaborations as well as unsuccessful collaborations are neglected. More importantly, the ICT firms differ in their tendency to protect their innovations by patents. Especially software producers rarely patent and consequently will be hardly represented in the constructed networks. Hence, when interpreting the networks these drawbacks need to be acknowledged.

Figure 1: Evolution of the cooperation network in Sophia-Antipolis



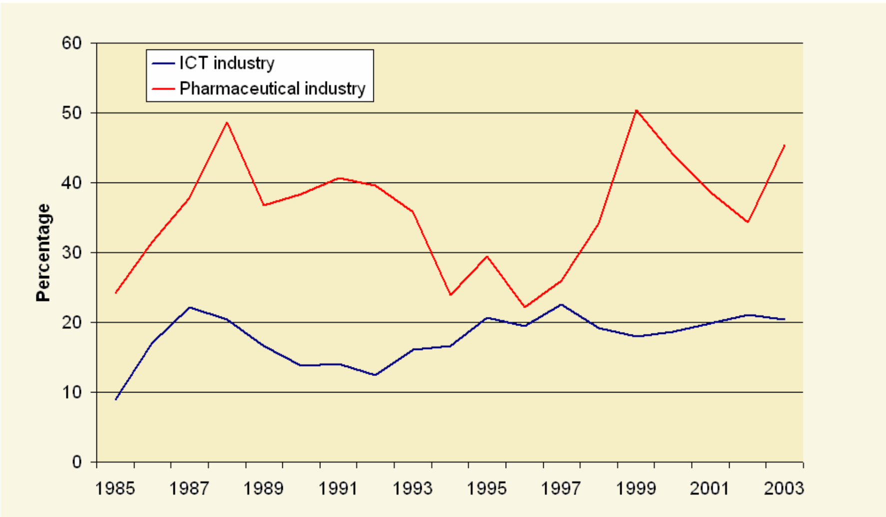
Source: EPO Patents, provided by the Netherlands Institute of Spatial Planning

4. Empirics

Figure 1 displays the evolution of the cooperation network for the ICT and pharmaceutical industries. The upper part shows how the structure of the networks evolved including both cluster-internal and cluster-external interaction for four different five-year time periods. The lower part plots the trends concerning the spatial scale of interaction using a moving window of three years with the upper line representing the total number of patents that have resulted in a collaborative link.

Before starting to test our hypotheses, we need to make two brief observations concerning the general pattern of evolution of the networks, without devoting attention to its spatial dimension. First, this visual expression shows a steady increase in cooperation behaviour through time, both for the ICT and pharmaceutical industries. However, this increase is partly due to an increase in the number of patents. As figure 2 shows the share of the number of links in the total number of patents is relatively stable, particularly for the ICT industry, in which from the crisis in the early 1990s onwards only a slight increase in share can be observed. As a consequence, the observed increase in interaction seems to be mainly the result of an increase in the number of firms instead of a growing tendency of firms to cooperate. Furthermore, it appears from figure 2 that the share of links in the total number of patents is about twice as high in the pharmaceutical industry as it is in the ICT industry, although it needs to be acknowledged here again that some sub-branches of the ICT industry in particular might be underrepresented in the patent file. However, bearing in mind that the total number of firms and hence the total number of patents is considerably lower for the pharmaceutical sector than for ICT sector, the total reconstructed network is larger in the ICT than in the pharmaceutical industry.

Figure 2: Number of links by total number of patents in Sophia-Antipolis cooperation network

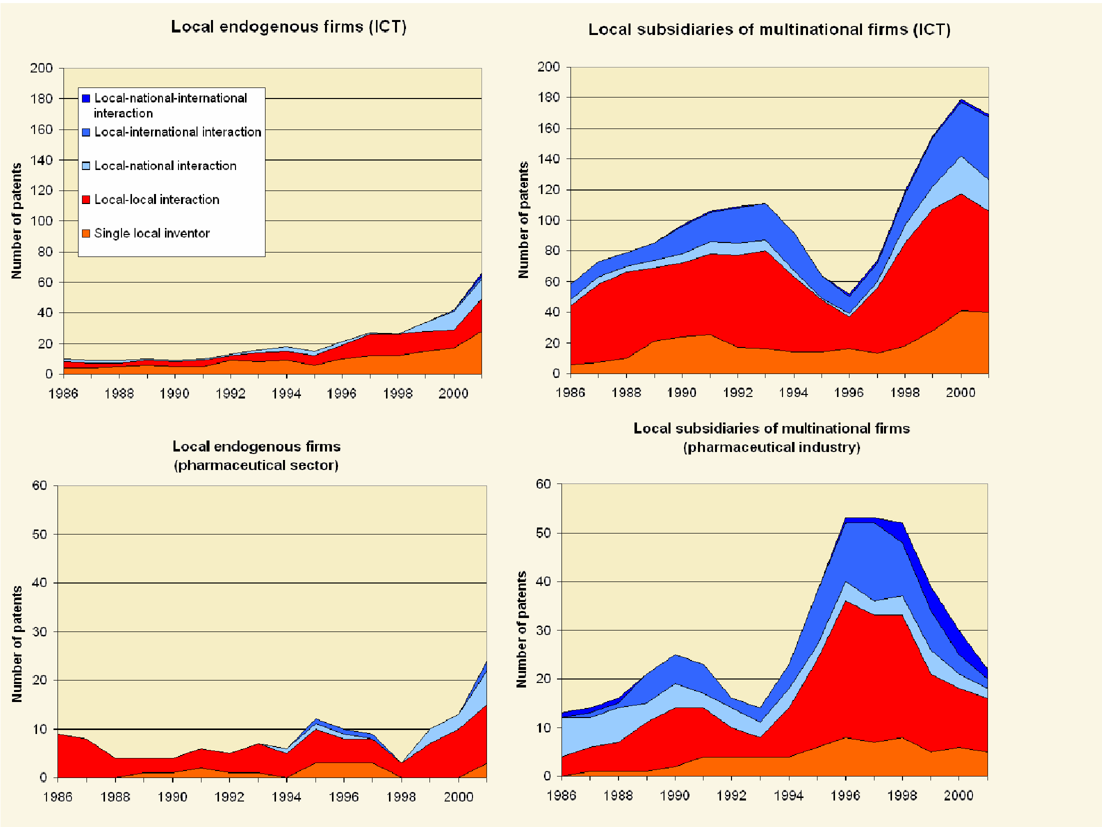


Source: EPO Patents, provided by the Netherlands Institute of Spatial Planning

In section 2 we formulated hypotheses concerning the relationship between the changing growth regime from exogenous to endogenous growth in the early 1990s and the evolution of the cooperation network. On the basis of differences in the total number of accumulated firms for the two main industries in Sophia-Antipolis, we hypothesized that for the ICT industry local-local cooperation increased at the expense of local-national or local-international cooperation, whereas this relation would be absent in the pharmaceutical industry. The lower part of figure 1 depicts the trends concerning the spatial scale of cooperation.

As expected marked differences can be observed between the ICT and pharmaceutical sector. In the ICT industry cooperation is increasing at similar rates for all spatial scales from the middle of the 1990s onwards. Local-local interaction is increasing from the middle of the 1990s onwards – when growth became increasingly endogenous – but certainly not at the expense of cooperation at higher spatial scales. In addition, the network for the last five-year period does not convincingly show an integrated and relatively dense local cooperation structure. Even the local research institutes do not seem to play a decisive role in building a dense cooperation structure. They are mainly oriented towards cooperation with other research institutes or firms outside Sophia-Antipolis. In short, figure 1 does not provide support for hypothesis 1.

Figure 3: Inventor origin per type of firm (1985-2001)



Source: EPO Patent data, provided by the Netherlands Institute of Spatial Planning

Another way of investigating the geographical component of innovation activity is to look at the origin of inventors per patent. This procedure does not take into account the boundaries of the firm and takes the patent as the unit of analysis. The upper part of Figure 3 depicts the evolution of inventor origin over time for patents of endogenously created ICT-firms in Sophia-Antipolis and of exogenous subsidiaries of multinational or large French ICT-companies. The share of patents having merely local inventors is fairly constant for both types of firms in both industries. Instead, for patents of the endogenous local firms there rather seems to be a trend towards more nationally and internationally composed team of inventors in the last four years under investigation. In synthesis, the hypothesis concerning the evolution of the ICT network in Sophia-Antipolis needs to be rejected.

The evolution of the network for the pharmaceutical industry shows a clearly different picture. The network evolution is characterized by a sheer increase of local-national and local-international interaction in the last five years under investigation. Whereas the total amount of collaborative links is increasing, local-local interaction remains stable. Neither when growth became more endogenous in the early 1990s a significant increase in local-local interactions. In addition figure 3 shows a relatively constant share of patents with single or multiple local inventors in the total number of patents, both for endogenous and exogenous firms. These observations are in line with our expectations. A critical mass of local firms has not been reached in Sophia-Antipolis' pharmaceutical sector and its firms are more nationally and internationally oriented. Hence, our hypothesis concerning the pharmaceutical cannot be rejected on the basis of these results.

5. Conclusion

Networks and clusters co-evolve. In particular, forces of preferential attachment that shape the evolution of an industry's cooperation network might be complemented or counteracted by forces of geographical proximity that influence the extent to which dense parts of this industry network get concentrated in geographical clusters of firms. The structure of an industry wide network then no longer is merely an outcome of processes of preferential attachment – itself fed by heterogeneity in firms' competences. It is also the result of the interplay between the importance of geographical proximity for inter-firm cooperation and the recurrent pattern of spatial clustering in an industry, both subject to change over time.

Taking this logic as a theoretical point of departure we investigated how the accumulation of firms in the business park of Sophia-Antipolis from the late 1970s onwards is related to the geographical dimension of the cooperation network its constituent firms are involved in. In about 30 years time Sophia-Antipolis became one of the main high-tech business parks in the field of ICT and – to a lesser extent – pharmaceutics. Whereas the growth in terms of number of firms initially was largely endogenous – i.e. based on the decision of multinational firms to locate their R&D subsidiaries on site – it became much more endogenous from the first half of the 1990s onwards.

We expected this shift from exogenous to endogenous growth to play a major role in the evolution of the cooperation network in Sophia-Antipolis. The potential of geographical proximity to play a role in the evolution of the cooperation network increases with the growing pool of firms accumulated locally in the field of ICT. Hence, we expect a trend towards more local cooperation activity to be observed with the change of the growth regime from the first half of the 1990s onwards. Except for a 'critical mass' in quantitative terms, we particularly expect the emergence of endogenously created firms to have contributed to a relatively dense local interaction structure in the ICT industry. Notwithstanding the fact that growth became more endogenous in the pharmaceutical industry as well, we do not expect such a trend to be visible for this sector. Since, the accumulation of firms has always been taking place at a much lower rate than in the ICT industry we expect a critical mass in terms of spatial clustering need for local collective learning to increase substantially has not been reached yet.

On the basis of EPO patent data we reconstructed the cooperation network of ICT and pharmaceutical firms in Sophia-Antipolis from the early 1980s till 2002. Neither for the ICT industry, nor for the pharmaceutical industry, a clear trend towards more local-local cooperation activity from the first half of the 1990s onwards could be observed. Even in the last time period under investigation the local ICT-network was lacking an integrated cooperation structure. In addition both patents of local endogenous firms and of exogenous subsidiaries of multinational were rather characterized by an increase of national and international inventors than by an increasing share of patents with merely local inventors.

As a result, we reject our hypothesis concerning the ICT industry and confirm the one for the pharmaceutical industry. We acknowledge that other forms of inter-firm interaction that strict innovation-based cooperation have not been considered and that the networks reconstructed do not give the complete picture for the ICT-network. Nevertheless we argue that the networks we reconstructed constitute an essential – and more importantly – potentially valuable dimension of the inter-organizational interaction network. Although local cooperation increased in quantitative terms, no convincing relative increase of local cooperation could be traced in the 1990s. Rather an trends towards more national and international interaction has been observed. Both local cluster-based interaction and long-distance interaction across firms being crucial for firms in a cluster to remain competitive and innovative, we argue that Sophia-Antipolis is very well endowed in terms of global pipelines. In terms of local knowledge-based interaction, however, there is seems to be a large unused potential for cooperation. An increase in local interaction might further stimulate the innovative performance of the business park as a whole and as such ensure the future accumulation of companies on site. Many political, scientific and commercial actors being aware of this unused potential (as appears from many recent initiatives to create local interaction) we do not expect the growth and fame of the success story of Sophia-Antipolis to be at an end soon.

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Appendix 1

For the purpose of this paper, the ICT industry is broadly defined, including the following sub-industries as defined by Schmoch et al. (2003):

- 12 Audiovisual Technology
- 13 Telecommunications
- 14 Information Technology
- 15 Semiconductors
- 22 Analysis, measurement and control technology
- 23 Instruments – Medical Technology

For the purpose of this paper, the pharmaceutical industry includes the following sub-industries as defined by Schmoch et al. (2003)

- 23 Instruments – Medical Technology
- 31 Organic fine chemistry
- 32 Macromolecular chemistry and polymers
- 33 Pharmaceuticals, cosmetics
- 34 Biotechnology
- 35 Agriculture and food chemistry
- 36 Chemical industry, petrol industry and basic materials chemistry

Class 23 “Instruments – Medical Technology” has been allocated to either the ICT, the pharmaceutical industry or both, dependent on the classes of the other patents a firm possesses.