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Entry, exit and knowledge: evidence from a cluster in the info-communications industry

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Abstract

The process by which knowledge is created, accumulated and eventually destroyed appears crucial to many industrial dynamics patterns, since it shapes the profile of evolution of industries by favouring the entry of new companies, the co-existence of incumbents and new entrants and, eventually, their selective or joint exit over time. Though problematic, and all too often neglected, the connection between two nodes of interest, *Industrial Dynamics* on the one hand, and *Knowledge Dynamics* on the other hand, thus appears as a promising field of research. On the basis of a case study in the info-communications industry, we start by emphasizing that this field of research has direct importance at the empirical level. Knowledge dynamics can create specific models of evolution among firms at the local level, such as non-shakeout patterns within the cluster, which significantly differ from more global patterns of evolution in the info-communications industry, now generally oriented towards trends of decline and bust. We further argue in favour of the development of *Knowledge-Based Industrial Dynamics*, an approach that lies at the interface of industry and knowledge dynamics, and which can explain how a cluster may decrease the barriers to knowledge of clustered companies and, further, create a specific knowledge dynamics that is able to shape the industrial dynamics. Finally, we document how this process of knowledge dynamics was collectively implemented in our case study on the info-communications cluster and decompose the mechanisms that led to a local non-shakeout pattern of industrial dynamics. We conclude with some remarks on the policy implications.

JEL classification: L 86; L 96; O 31

Keywords: Shakeout and non-shakeout patterns of evolution; Knowledge dynamics and industrial dynamics; Turbulence; Innovation; Cluster

1. Introduction

This paper examines the link between entry, exit and knowledge, and draws some evidence on this link from a case study in the info-communications industry in

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France.[1] Observation of the processes of entry and exit of info-communications companies in a representative French cluster generates some paradoxical empirical findings which can only be explained by considering the role that knowledge plays in shaping the evolution of industries and by investigating the interactions between knowledge dynamics and industrial dynamics. These empirical findings are related to key questions that have emerged recently in the literature, and contribute to the general debate by providing complementary arguments.

The first empirical finding is that global patterns of evolution differ from local patterns to a significant degree. Though the info-communications industry is characterized by a generalized shakeout process, non-shakeout models of evolution can nevertheless be observed at the local level within the cluster. Here, knowledge dynamics produced at the local level by companies, but also by other key actors, such as education and research institutes, standards development and research consortia, etc. have resulted in an important shift in industrial demographic trends by ensuring, at the local level, a regular process of entry and a long-term viability of incumbents. The recurrent question about the collective (i.e. technological, industrial and institutional) character of local knowledge emphasized in various contributions (Antonelli, 2001, 2003; Dosi and Malerba, 2002; Klepper, 1997, 2002) can thus be reframed on the basis of our empirical findings and focused on the way in which local knowledge dynamics may preserve clustered companies from shakeout.

The second finding is that, while info-communications companies emerge in most places, and do not necessarily follow a pattern of geographic concentration, the case study shows that an important element in the viability of observed companies is how the industry forms clusters, and even layers. Here, also, the debate on the need to cluster, which was much discussed in recent contributions (Löfsten and Lindelöf, 2002; Colombo and Delmastro, 2002; Steinle and Schiele, 2002; Maskell and Malmberg, 1999), can be re-visited on the basis of our case study on the info-communications industry. In a sense, what the case study stresses is that we need to acknowledge that an industry which is not deemed to cluster from a technological point of view, clusters and layers nevertheless.

The third finding is that pure agglomeration of large, leading companies in a cluster is not a sufficient condition to create a non-shakeout model of evolution, nor is the multiplication of new technology-based firms (NTBFs) in a specific geographical area. As already shown in the literature, innovation and the emergence of a new knowledge dynamics do not come only from companies: they are linked with the development of a combined process of change involving supporting institutions, such as universities and government agencies and policies (Pavitt, 2001; Nelson, 1994; Metcalfe, 1995; Witt, 2003). Moreover, coordination problems between firms (large and small, and incumbents and new entrants), and also between education and research institutes, standards development organizations and research consortia, are not spontaneously resolved, since they concern how knowledge is created, shared and diffused among these key actors (Fransman, 1994, 2002; Saviotti, 1996, 2001). Our case study contributes to providing some evidence on how the process of knowledge generation has to be coordinated among the different actors in order to stimulate industrial dynamics and avoid dramatic shakeout.

In this paper, we advance the view that (i) a cluster effect (and even a layer effect) exists in an industry in which there is no necessity to cluster from a technological point of view, (ii) whether to cluster is related to how knowledge is produced, shared and diffused within the cluster, i.e. among companies, universities and research consortia, and (iii) the cluster interactions can decrease the barriers to knowledge exchange between these different actors, and produce a local knowledge dynamics, which, in turn, attracts new entries and limits exits, and thus avoids shakeout at least at the local level.

The paper focuses on a significant and specialized French info-communications cluster, namely Sophia Antipolis (SA), France. Major stylized facts of this cluster are described, and especially how local knowledge dynamics have shaped industrial dynamics at the local level towards a non-shakeout pattern of evolution. These major stylized facts have some direct

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implications at a more theoretical level, since they question the possible connections between knowledge dynamics and industrial dynamics (Section 2). We argue that the analysis should evolve towards the development of a knowledge-based industrial dynamics. We show that, despite the inherent difficulties in integrating two complementary, yet distinct centres of interest, demonstrated in the recent literature, it is on the basis of such a combination that we can understand why and how a cluster may decrease the barriers to knowledge of the clustered companies, resulting in specific knowledge dynamics that can shape the industrial dynamics (Section 3). Finally, we document how this process of local knowledge dynamics involving companies, education and research institutes, standards development organizations and research consortia, and also clubs and associations, and the dedicated physical/financial facilities provided by public policies or private initiatives, generate a regular and continuous entry process accompanied by a limited exit process characterizing a non-shakeout pattern of evolution (Section 4). We conclude with a discussion on the implications for policy (Section 5).

2. Major stylized facts in the info-communications cluster

In this section, we focus on the distinctive features of the info-communications industry in Sophia Antipolis. First, though SA is not the largest new information and communication technology (NICT) cluster in France, it is one of the most specialized in terms of firms and employment. Since the mid-1990s, the accumulation of new firms has been regular, with a progressive specialization from the computer industry to the telecom and Internet industries. Secondly, the info-communications industry can generally be decomposed into key building blocks (infrastructure, platforms and applications) and, conventionally, there is a wide disparity of concentration between firms specialized in infrastructure (a few large companies) and firms that provide applications (numerous small companies). In SA, the info-communications industry is characterized by a greater homogeneity in the representation of each type of company among the different layers that make up the industry. Thirdly, the info-communications industry generally shows a shakeout pattern of evolution at the national level, which is not observed in SA: the local process of entry has been preserved and exits have been limited in the current period of global downturn. These local specificities with respect to the global/French info-communications structure can thus be captured best by the definition of three major stylized facts: (1) the info-communications industry in SA is a significant and specialized pole of activity; (2) the info-communications industry in SA has a layered and relatively homogenous structure; (3) the info-communications industry in SA is characterized by a non-shakeout pattern of evolution. In what follows, we elaborate these stylized facts, and suggest that the local knowledge dynamics can shape the industrial dynamics quite significantly.[2]

2.1. *A significant and specialized pole in info-communications activities*

2.1.1. *A significant NICT cluster in the national context*

Network industries today have a key specificity. New companies can preserve their relative independence from the incumbents since the provision of network services is often technologically interfaced and market mediated. This specificity generally stimulates the birth of new companies, and alleviates their technological constraints, as well as their choices in terms of location. According to this specificity, activities related to the NICT have exploded in the last few years in France, and generated a multiplicity of new companies. The geographic location of these companies, however, remains highly unequally distributed. There is a dominance by Ile de France (Paris) where most of the NICT activities related to the computer industry (hardware and software), electrical component, electronics, telecoms, connectivity, test and control are concentrated. Then there is a group of medium-sized NICT areas, such as Provence Alpes Côte d'Azur (PACA), and Rhône Alpes; and further group of smaller areas, such as Aquitaine and Bretagne (see Table 1).

[2] Data presented in this section come from various statistical sources compiled by the author: INSEE (National Institute for Statistics and Economic Studies), Chambers of Commerce and Industry, Fondation Sophia Antipolis, and SAEM Sophia Antipolis Côte d'Azur.

Table 1
Concentration of NICT firms and employment in France (2002)

Regions/areas/clusters	NICT firms	Total firms	Firms specialization	NICT employment	Total employment	Employment specialization
France	45,694	2,870,888	1.5	876,325	15,443,000	5.6
Ile de France	8870	662,674	1.3	255,502	5,042,724	5.7
PACA	4500	283,106	1.5	32,000	1,576,085	2.0
In which SA	215	1300	16.5	8,000	25,000	32.0
Rhône Alpes	4000	292,885	1.3	60,000	2,263,018	2.6
Aquitaine	2018	148,959	1.3	21,000	1,105,435	1.9
Bretagne	719	119,497	0.6	22,483	1,112,583	2.0

Looking more specifically at the medium- and small-sized areas, it can be seen from Table 1 that:

- PACA is one of the most specialized areas in terms of firms (1.5, as compared to 1.3 in other areas), despite its lower specialization indices in terms of employment (2.0, as compared to 5.7 for Ile de France, and 2.6 for Rhône Alpes).
- Within PACA, SA attracts the vast majority of companies and employment in the domain of NICT. More than 16% of companies in the area are info-communications companies, and more than a third of the local employment is dedicated to this industry. If related activities, such as auditing, training and technical assistance companies are included, the levels increase to 25% of companies and 45% of employment. It can be seen, therefore, that SA is an important NICT pole in France.

2.1.2. *Emergence and shifting specialization*

Since the date of its creation, SA has had overall success with a significant entry process starting in the 1970s, and persisting throughout the 1980s and 1990s. Over the last 20 years, SA has attracted many companies, which have generated high levels of employment. This global picture needs to be complemented with more detail, however. Growth rates are quite important: entry rates at 16.1% per year over the last 20 years, and employment rates at 10.2%. Fig. 1 shows that entry rates displayed large, high frequency swings from 1982 to 1992, with smoother profiles of evolution from 1992 to 2002, ranging from 2 to 8% in terms of growth. Employment rates also varied much more before 1992.

These differences in terms of entry and employment rates broadly correspond to two distinct phases in the development of SA: first, the emergence of a multi-high-technology cluster (1982–1992) and, secondly, the progressive and shifting specialization towards info-communications (1992–2002).

Within the first period, the multi-high-tech era (1982–1992), SA companies were operating in four main industries: Information Technologies (IT), essentially hardware and semi-conductors; Chemicals; Life sciences; and Environmental/Earth sciences. Initially the development of these four sectors was sustained by the entry into SA of large US and French companies: *IBM* and *Texas Instruments* entered in the early 1960s, *Digital Equipment* in 1980, *Vlsi* in the mid-1980s, *Rohm and Hass* and *Dow Chemical* in the

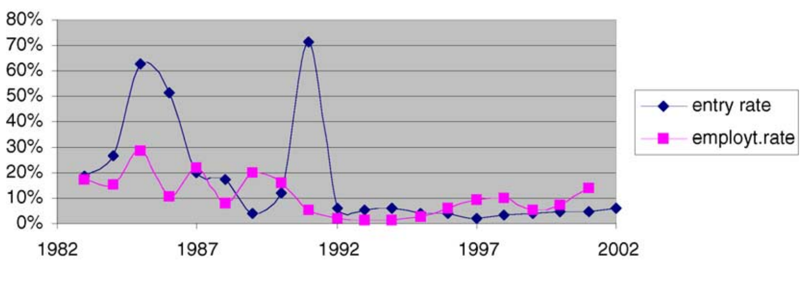

Fig. 1. Evolution of entry and employment rates (1982–2002).

mid-1970s and early 1980s, respectively, and *Wellcome* and *Rhone-Poulenc*, which entered in the late 1980s. During this first period, the average size of companies was relatively large, employing on average 80 people. Despite the presence of these big players during the emergence phase, SA was characterized by a somewhat chaotic process of development, attested by very irregular entry processes and large exit waves. On this basis, various contributions (Gaffard and Quéré, 1996; Longhi and Quéré, 1997) have questioned the economic viability of SA as a local system of innovation and, especially, the need to re-orientate the initial model of economic development (essentially driven by an external process of growth) towards a new model of economic development (more endogenous-driven, similar to what has been implemented in other regions or nations, see for instance Monck et al., 1988; Freeman, 1989; Quintas and alii, 1992).

In the second period (1992–2002), however, waves of entry have been increasingly composed of firms coming from the info-communications industry with a sharp orientation, since 1997, towards telecoms (equipment and networks), Internet connectivity, data transmission, e-security and e-commerce. This info-communications era in the economic development of SA is characterized by the following key elements:

- The pace and structure of the cohorts of new entrants have modified over time. Before the 1990s, a small number of info-communications companies entered each year, and these firms were closely related to the computer industry (hardware, semi-conductors). After the 1990s, entry related purely to the computer hardware industry became rare (less than 5% of new entrants), and semi-conductor companies started to diversify into the telecoms field with the development of mobile systems and applications. Throughout the 1990s, there were larger cohorts of entrants, with a wider diversity of activities being undertaken by the companies: telecommunications, Internet, e-commerce, media. In 2001 and 2002, net entry rates fell and although the total number of firms increased, the rate of growth was affected (Fig. 2a).
- NICT employment gradually progressed, with a leap in 1997 (Fig. 2b). The date of entry seems to be quite important in this job creation. Companies which were located in SA before 1982 generated only new 30 jobs; companies located in SA between 1982 and 1992 were responsible for 520 positions (17% of the total job creation). But the real contributors to this job creation are companies, which entered SA from 1992 (responsible for 82% of the total job creation). The companies that are now in SA originate from Germany, the UK, Italy, Sweden, Finland and the Netherlands, and not exclusively from the US. They are smaller compared to the companies in the first period (average employment per company is 22).
- Within this info-communications era, other industries initially developed on site showed a gradual decline in terms of significance. For instance, in 2000–2002, the relative weight of info-communications was much higher than life sciences, in terms of number of companies (16–25%, as compared to 4%), employment (30–45%, as compared to 8%), and geographical occupancy (30%, as compared to 12%).
- This new dynamic, which is info-communications-oriented, has been greatly helped and stimulated by the development in SA of various specialist institutions related to education and research (there

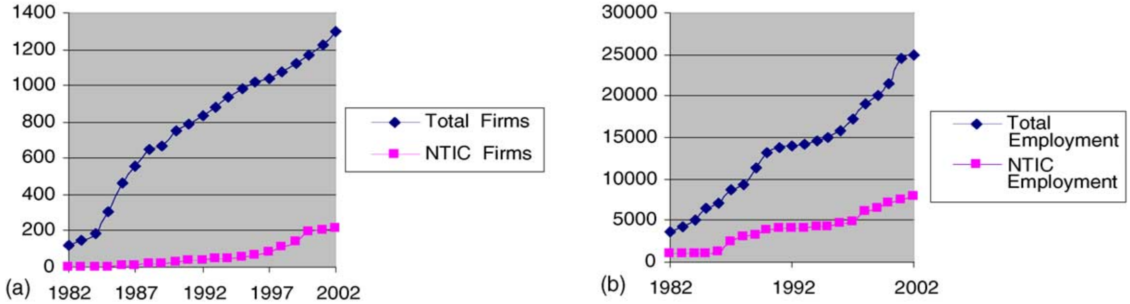

Fig. 2. (a) Total firms and NICT firms in SA. (b) Total employment and NICT employment in SA.

are some key public research institutes, as well as incubators and R&D laboratories of major info-communications companies), norms and standards (the *European Telecommunications Standards Institute*, ETSI, and the *World Wide Web Consortium, W3C*), dedicated facilities (physical and financial facilities are provided on site for info-communications companies), and clubs and associations (re-grouping most of the info-communications companies located on site).

2.2. The layered structure of the info-communications industry

The NICT industry generally comprises three main building blocks: the pipes (equipment, networks and hardware), the platforms (interfaces and software) and the uses (content and applications). The usual model of development in this industry is that, because of the technical separation between infrastructure and applications that occurred in the 1990s with the development of Transmission Control Protocol/Internet Protocol (TCP/IP), a large number of service providers were able to emerge and prosper without being dependent on infrastructure and facilities-based companies. Since they did not need to own or control the infrastructure to operate in the industry, they simply bought services from infrastructure and facilities-based companies. The outcome is that in this industry (and other network industries), a large number of small companies without facilities have emerged that have no necessity to be in direct technological and geographical proximity with the few, large companies operating in the facilities-based building blocks (pipes and platforms).

The SA info-communications industry, however, differs from this general model of development. There has not been an explosion in the number of facilities-less companies. Facilities-based companies are still present on site, and the local structure of the industry appears homogenous, with roughly the same number of companies located in the main building blocks that comprise the industry. In fact, the structure of the SA info-communications industry can be more adequately captured by an even finer decomposition into five different layers (see Fransman, 2002, 2003; Fransman and Krafft, 2002; Krafft, 2003, for a general presentation of the layer model, including its applications and limits):

- Layer 1 re-groups equipment and component providers. Layer 1 is thus composed of firms that provide network equipment and customer equipment, and also includes companies that develop and produce wires and cables, the passive and active components that are involved in the production of equipment.
- Layer 2 re-groups telecommunications carriers (local, long distance and international operators), which use various technologies, such as optical fibre, radio access, cable, DSL, satellite.
- Layer 3 re-groups companies – the Internet Service Providers and Internet Access Providers (ISPs/IAPs) – that provide connectivity access and services, such as e-mail, voice over the Internet, web hosting.
- Layer 4 re-groups companies that provide the services that ‘sit on the top’ of the connectivity provided in Layer 3. Navigation-related services include browsers, search engines and portals. Middleware products include security systems, such as firewalls and electronic payment systems.
- Layer 5 re-groups Internet Content Providers (ICPs). With networks, connectivity, navigation and middleware being provided, it is possible for applications to be developed and distributed. These applications include the creation and packaging of content. Examples of services provided in this layer include video-on-demand; electronic commerce services, such as online shopping, banking and auctions, social services, such as online health and education services; web design; mobile phone services, such as stock market prices, news and weather, premium services, such as racing results; databases; broadcast.

Based on this, it is possible to categorize SA info-communications companies. Table 2 synthesizes further elements in terms of entry, exit and mergers and acquisitions (M&A), and contributes to clarifying the local situation with respect to the more global French info-communications dynamics. Indicators for France are given in parenthesis.

This table indicates in particular that:

- At the national level, the “production” part of the industry – represented by Layers 1–3 – represent about 5% of the total number of firms and 40% of total employment. This high concentration in the upstream layers has to be contrasted with what occurs in the “service” part of the industry (Layers 4 and

Table 2
The layer structure of the info-communications industry in Sophia Antipolis and France

Layers	Number of firms	Employment	Mergers acquisitions	Companies
1 (France)	66 (1193)	5208 (239,096)	16 (∼200)	Cisco, Nortel, Lucent, Alcatel
2 (France)	9 (104)	176 (146,200)	0 (∼35)	France Telecom, Cegetel, Bouygues
3 (France)	22 (710)	595 (168,592)	8 (∼150)	Uunet, Isdnet, Equant, Qualcomm
4 (France: L4 + L5)	82 (43,687)	1576 (613,351)	7 (∼5000)	Wanadoo, Castify Networks, Opteway
5 (France: L4 + L5)	21 (43,687)	321 (613,351)	1 (∼5000)	Aucland, Realviz
Total (France)	200 (45,694)	7992 (876,325)	32	

5), which re-groups a large majority of companies (95% of the total number) with a relative small size (60% of employment).

- In SA, such breakdown production/service is not reflected. Layers 1–3 re-group 49% of companies and 75% of employment, while Layers 4 and 5 regroup 51% of companies and 25% of employment.
- M&As occur at the national and local levels, except for Layer 2 in which no local M&A is observed.
- Top players in the industry, at the global or national level, are also present in SA.

2.3. The local non-shakeout pattern of evolution

A shakeout generally occurs when an industry is in a stage of maturity, and consists of a large and sudden process of exit of companies.[3] If we consider the evolution of the number of info-communications companies at the national and local levels, we can see that, over recent years, the info-communications industry has evolved according to a shakeout pattern at the national level, but that this was not the case in SA (Fig. 3). This local non-shakeout pattern of evolution applies to the whole info-communications industry in SA, and also to each layer within the industry.[4]

This duality in terms of patterns of evolution suggests the following key elements:

- While the info-communications industry generally underwent the most dramatic bust of its history in 2000, and today tends to be characterized by important restructurings, failures, bankruptcies and exits in France, and also worldwide, some local environments, such as SA, have apparently protected info-communications companies from this downturn.
- In these local environments, the entry process of info-communications firms is sustained and the survival of incumbents and new entrants is preserved, despite the fact that a shakeout has occurred at the global/national level. The global shakeout seems to be counterbalanced by local forces and mechanisms, which tend to maintain the viability of some info-communications firms.

2.4. Summing up

The preceding paragraphs have described how the info-communications industry in SA is experiencing a local non-shakeout pattern of evolution, despite more global/French dynamics characterized by massive exit trends. In contrast to what is generally observed, we have seen that the process of accumulation of companies has been progressive, and homogenous across the different layers. The outcome of this accumulation process is that a complete layered structure of info-communications companies is present in SA (from Layers 1 to 5). This is quite unusual, since applications companies (from downstream layers, Layers 4 and 5) could have emerged without being directly connected to facilities-based companies (from upstream layers, Layers 1 to 3), and thus could have developed in any location. This complete layered structure is also uncommon, even in significant NICT clusters in France. Moreover, the accumulation process in SA has developed with the entry of large firms, but is not solely based on that. The first stages of development of SA show that the presence of large firms was a necessary,

[3] For a complete and proper definition of a shakeout, see Klepper (1997) and Klepper and Miller (1995) who stress that an industry is deemed not to have experienced a shakeout if the number of firms never declines below 70% of the peak number, or if it does, subsequently recovers to over 90% of the peak.

[4] The description of the non-shakeout pattern of evolution of each layer is not reproduced here. Details can be obtained direct from the author.

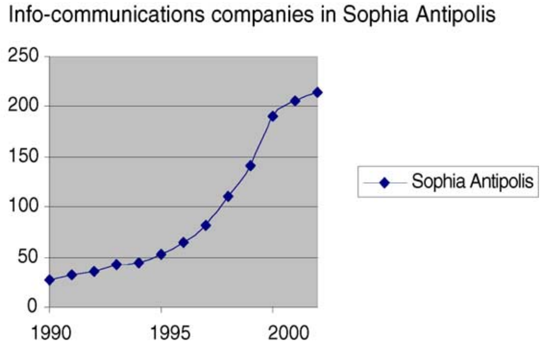

Fig. 3. Patterns of evolution: shakeout at the national level, non-shakeout at the local level.

though not sufficient condition, for the accumulation process to be sustained over time. In fact, the shifting specialization towards info-communications in SA was driven and accompanied by different forces, which jointly contributed to the emergence of a non-shakeout profile of evolution. These forces are linked to what comprises the local area and include not only firms (large and small), but also universities, and specialized (private and public) institutions providing physical, financial and network facilities.

These elements raise questions about how industrial dynamics operate at the global and local levels, and how we can try to capture the co-evolution, and sometimes the gap, between these different levels of observation. In fact, a key lesson of these stylized facts is that a shakeout observed at the global level is not necessarily the outcome of smaller and similar local shakeouts. A global shakeout can co-exist with a local non-shakeout pattern, and the determinants of this co-existence need to be investigated. Among these determinants, the dynamics on which local knowledge is created, coordinated between firms, research institutes and universities, transformed and developed into new technological and market opportunities with the help of specialized institutions providing physical, financial, and network facilities, and further diffused in the society, appear as a potent element explaining the distinctive performance of local areas. In fact, if the knowledge dynamics were similar everywhere, and for each of the actors involved in the process, we would end up with an homogenous model of evolution, either shakeout or non-shakeout. We know from the case study that this does not always occur. From the literature on knowledge dynamics, we know also that this cannot be taken for granted. In this perspective, industrial dynamics results must be articulated with, or complemented by basic teaching in knowledge dynamics.

3. Industry and knowledge dynamics: questions and puzzles

In this section, we stress that knowledge is not absent from the industrial dynamics literature, but rather is fundamental to it. Knowledge is an important element, since it shapes the (cyclical) profile of the evolution of industries. However, we would suggest going beyond this interpretation, which we consider to be too restrictive. In a sense, going back to fundamentals, we consider more precisely what we know today about knowledge dynamics (Antonelli, 2001, 2003; Fransman, 1994, 2002; Richardson, 1998; Loasby, 1999; Saviotti, 2003; Foster and Hölzl, 2004). First, we know that knowledge itself is localized, specialized and dispersed. The dynamics of its creation, coordination and diffusion are thus necessarily diverse, heterogeneous, and area-specific. Secondly, we know that this process of creation, coordination and diffusion is not immediate, but rather has to be implemented step-by-step, with each event in a given period having some irreversible effects on the next period. In what follows, we integrate these characteristics to develop the basis of a knowledge-based industrial dynamics.

3.1. Knowledge in industrial dynamics

A large part of the current literature on industrial dynamics is dedicated to analysing the processes of entry/exit in various sectors and to putting forward new analytical propositions based on these empirical investigations. This procedure is not new, and stems from the 1980s. However, the analysis of "shakeout", which defines a large process of exit, or "turbulence" – the global term used to stress entry/exit mechanisms – has certainly attracted a significant renewal of interest, indicated by both the quality and quantity of the articles and books published in this domain (for comprehensive reviews, see the special issues of the *International Journal of Industrial Organization*, 1995 and *Industrial and Corporate Change*, 1997).The role of information and knowledge in the process of entry and exit is generally present in this literature, since it plays a role in industrial dynamics.

In the literature on industry life cycles (Klepper, 1997; Afuah and Utterback, 1997), various authors argue that during the initial stages of development of the industry, information on new technological and market opportunities is freely and immediately accessible to any new entrant, and that this fact favours the entry process. By contrast, the final stages of development of an industry are generally characterized by a scarcity of information related to the accumulation of experience from the older incumbent firms. This produces knowledge entry barriers, involving in turn the exit – eventually the shakeout – of new companies. The knowledge required comes either from outside the industry or inside the industry depending on the phase of the life cycle. The existence of cyclical behaviour depends on certain factor (knowledge) being very abundant initially and becoming progressively scarce as the life cycle progresses.

In the literature on the dynamics of market structure (Sutton, 1998; Audretsch, 1997; Jensen and McGuckin, 1997; Geroski, 1991, 1995), a large number of empirical explorations based on a longitudinal dataset have been carried out and exhibit some stylized facts which explicitly consider the role of knowledge. Among the key regularities, the authors consider that, in most industries: (1) entry generates innovation, especially by the introduction of new knowledge (related to technologies, markets, modes of organization); (2) older cohorts tend to survive over the long-run better than younger cohorts, essentially because oldest companies have been able to expand their knowledge base as a result of accumulated experience; (3) de novo entry is more common, but less successful than entry by diversification where knowledge complementarities can be developed. The diversity of firms (in the sense of firms belonging to different cohorts, and to different categories of entrants), and the implications in terms of performance and survival are related to the characteristics of knowledge, which is either embodied in firms or not.

The role of knowledge is thus present in these developments on industrial dynamics, but the process by which knowledge is created, accumulated and eventually destroyed has been largely neglected, though it appears crucial in many industrial dynamics patterns (Dosi and Malerba, 2002; Antonelli, 2001; Klepper, 1997; Saviotti, 1996, 2001; Malerba and Orsenigo, 1996, 1999). Industrial dynamics essentially focuses on knowledge that is either internal or external, and which is characterized by stages of development in which there are high or low barriers to knowledge. The conditions under which knowledge is endogenously created by companies, and shapes the profile of industry, remain beyond the scope of analysis of industrial dynamics. These conditions must be complemented by key elements about knowledge dynamics, and the analysis structured in terms of a knowledge-based industrial dynamics.

3.2. Knowledge-based industrial dynamics

Initially, industrial dynamics is directly concerned with the development and diffusion of an innovation, of new knowledge (though incorporated in a product). Let us thus elaborate on these fundamentals, with the prerequisites that (a) knowledge is in itself localized, specialized and dispersed; and (b) the process of knowledge generation, coordination and diffusion is implemented step-by-step, through the contribution of various actors, and with irreversible effects on the following period. These prerequisites stress a very basic idea: industrial dynamics cannot be analysed without taking account all key components of industries (companies, research institutes and universities, etc.). The profile of evolution is not pre-determined, but rather is the result of a process of various actions implemented by these key components. This does not mean that the profile of evolution of industries is completely unpredictable, but only that some elements, which are normally predicted (such as shakeout) do not necessarily occur.

In this perspective, knowledge-based industrial dynamics is concerned with the identification of each piece of knowledge that could potentially be involved in the development of the innovation, as well as the key actors holding these bits of knowledge (Antonelli, 2003; Fransman, 1994). Further, knowledge-based industrial dynamics has to focus on the way in which these different bits of knowledge should be reassembled in order to implement the innovation process, as well as on the way in which the different actors need to be organized in order to participate in the innovation process in a complementary manner. Finally, knowledge-based industrial dynamics evolve according to specific paths that are primarily built up step-by-step by the actors themselves, rather than being imposed by external forces. In a sense, therefore, these actors play a decisive role in the entry into new knowledge areas, and the exit from (what they consider are) declining ones in the coordination of efforts around a specific innovative project or field of activity, and the neglect of activities, which (they consider) are performing poorly. In this context, innovation trajectories are necessarily diverse, depending on the bits of knowledge that are available locally, the actors involved, and their choices in terms of targeted outcomes and modes of coordination. Related to that, the evaluation of innovation trajectories can only be operated ex post, since it is strongly connected to a sequential process, to the combination over time of various competences, incentives and selected modes of organization.

Knowledge-based industrial dynamics is consistent with the emergence and co-existence of poles of excellence and clusters that perform better than the average in terms of entry/exit, and some other areas with lower performance. In this view, knowledge-based industrial dynamics is concerned with the attractiveness of a local environment: local forces and mechanisms may tend to maintain the long-term viability of companies, and may limit the impact of a global shakeout. The local level can act to decrease the barriers to knowledge accumulation by companies, regardless of any specific stage of development (i.e. the usual early stages/late stages decomposition in industrial dynamics). Clusters can prevent companies from making premature exits, and protect against sharp shakeout movements. In this perspective, recent knowledge dynamics approaches provide further key milestones for understanding the main forces that sustain the development of a local dynamics. These approaches raise the following arguments, based on knowledge coordination and the role of learning, and jointly contribute to explaining the emergence of non-shakeout patterns of evolution within the cluster. In fact, there are three sources of barriers to knowledge that a cluster can help to decrease:

(1) Industrial barriers to knowledge generation. The complementary accumulation of specific knowledge from different, but related industries (or related layers within a particular industry) can have a positive outcome on both the entry of new entrants and the viability of incumbent companies located in a cluster. Firms can benefit from the complementarity and integration between internal competencies (i.e. their own characteristics) and external knowledge (i.e. the characteristics of other, related companies) as far as some organizational connections or interfaces are possible between these firms (Loasby, 1999; Richardson, 1998). The way in which, within each cluster, complementarities in terms of knowledge are arranged, organizational interfaces are favoured, and thus barriers to knowledge are decreased, is a key element in the distinctive performance of the geographical area.
(2) Institutional barriers to knowledge generation. The interaction between companies' innovative behaviour, academic infrastructures and public policy resources and incentives at the local level is a key driver of the performance of the cluster. Here, the creation of technological knowledge has to be considered in a collective dimension, which includes not only learning in companies, but also learning generated by the academic infrastructure and other specialized institutions (Stephan, 1996; Pavitt, 2001). The presence of these institutions in a cluster, and their active insertion into networks of companies that are dependent on such institutional knowledge (science-based companies, or companies that are dependent on the evolution of norms and standards) are important elements in the development of an effective local knowledge dynamics.
(3) Communication barriers to knowledge generation. Finally, knowledge dynamics result from the cumulative recombination of dispersed, yet complementary, internal and external, tacit and codified pieces of knowledge (Antonelli, 1999; Patrucco,

2005). In a sense, once technological knowledge is created on the basis of interactions among companies, and between companies and other institutional sources of knowledge, the transformation into innovation or market opportunities still has to be completed. In most cases, this transformation is not immediate or spontaneous and requires the development of financial and physical infrastructures/institutions to support the development of innovative projects, and to decrease the barriers to knowledge of companies, in relation to technological or market opportunities. The more the cluster is able to provide a wide spectrum of such infrastructures/institutions for companies that face this transformation problem, the better the chances of development.

In the next section, we document how this knowledge-based industrial dynamics operated in the info-communications industry in SA, and how barriers to knowledge were reduced within the cluster, by the combination of different, namely industrial, institutional and communication, sources of interaction and coordination.

4. The knowledge-based industrial dynamics in the info-communications cluster

4.1. The decline of industrial barriers to knowledge generation

Industrial barriers in the generation of knowledge were decreased within the cluster as long as a critical mass of related companies continued to be present on site and were able to develop user–producer relationships as well as innovation networks. These specific modes of division of labour among the different layers coincided with the shifting specialization of the cluster towards the development of telecoms and Internet competencies and applications.

4.1.1. Critical mass of related companies and emergence of a complete layered industry

This evolution of the number of firms can be broken down into three different periods (see Fig. 4 for a representation of these periods). In the first period (1980–1985), the entry process emerges, but remains stagnant for all layers. This phase corresponds to the emergence stage of development of SA, where large info-communications companies entered but did not generate any further dynamics in terms of entry rates. Over this period, 11 top players in the hardware and software computer industries entered SA, producing staggering rates of growth (the number of employees jumped from 0 to 689), but no entry of smaller firms, and especially no creation of local start-ups.

In the second period (1985–1997), Layers 1 and 4 were characterized by a large entry process, while Layers 2 to 5 remained dormant. Though the presence during the phase of emergence of firms specialized in hardware and software generated little entry in the 1980s, their diversification towards the provision of equipment and middleware with the Internet and mobile revolution, favoured in the 1990s a process of fast entry of vertically related companies. Liberalization of fixed and mobile communications, which affected the

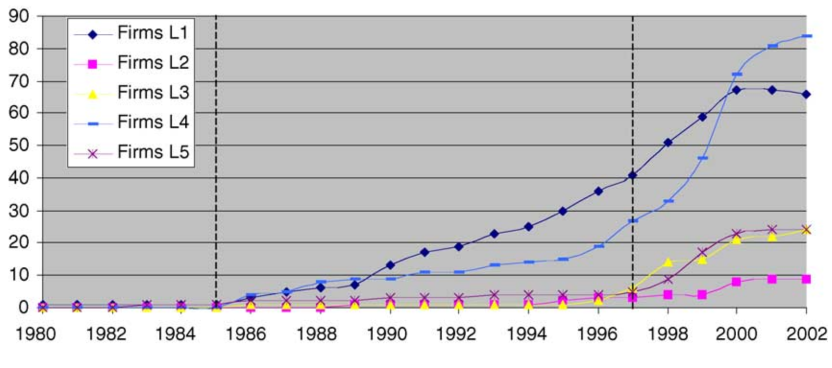

Fig. 4. Evolution of the number of firms in the different layers.

companies in Layers 2 and 3 at the national level (and also worldwide), progressively spurred these companies to enter different geographical areas, and especially areas where end-users (essentially residents, but also large, multi-national companies) and technology providers (equipment and component companies) were already located. Layer 5 companies were, at that time, the service providers for large, multi-national companies whether belonging to the info-communications industry or not, but located in SA. In that period, high growth rates for incumbents coexisted with fast entry: 152 new companies entered, and employment increased to 58,957.

During the third period (1997–2002), the entry process was stimulated in all layers, with 172 new companies entering, and 50,193 new jobs (about 80% of new jobs) being created essentially by large, incumbent companies. The development of a complete layered structure, which was initiated in the second period, persisted and was even reinforced. Layers 2 and 3 largely increased their penetration in SA at that time, and Layer 5 greatly increased its representation with the development of the Internet and mobile applications.

From this description of the accumulation of the key layers comprising the SA info-communications industry, we can see first that the progressive shift in technological specialization from the computer to the telecom industry favoured the development of Internet and mobile applications. Second, this specific accumulation also shows that large companies, especially those located in the upstream layers, have played – though not immediately, i.e. only when the shifting technological specialization was achieved – a key role in the subsequent development of downstream layers. The development of technical facilities in SA by these large, upstream firms attracted user companies over time on the basis of common technical and practical knowledge, which was easily diffused. In most cases, knowledge barriers were reduced by user–producer relationships among the different vertically related and complementary layers. These user–producer relationships grew out of (a) the provision of facilities-based equipment and network according to the customer's specific requirements, and (b) the transfer of adequate knowledge, skills and experience embodied in the facilities-based element and diffused by a specific staff from the provider to the customer.

4.1.2. Division of labour between layers and the role of innovation networks

The overall level of M&A in the SA info-communications is low, compared to the rest of France (see Table 2 in Section 2). The creation and diffusion of local knowledge was rarely based on integration, but on the multiplicity of independent companies. Technological specialization was complemented by an increasing division of labour where companies were not competing directly against each other, but rather were involved in various innovation networks. Over time, two specific types of innovation networks developed within the cluster. Innovation networks that were centred on a combination of complementary skills, experience and knowledge of companies focusing on a specific technology, such as mobile (transition from *2G* to *3G*) or Internet (*ADSL*, optical fibres), and innovation networks organized around the specific needs of client industries, particularly early info-communications adopters, such as banks (data transfer and security), aeronautics (avionics), life sciences (tests and data storage), but also tourism (hotels and restaurants) and the media (music and movies).

Within these innovation networks, companies involved in the different layers were present, from Layers 1 to 5. New info-communications applications could thus be produced and developed from the articulation and coordination of different sources of knowledge embodied in companies undertaking complementary activities. These innovation networks also favoured the creation of new start-ups, whose role was to develop a specific bit of knowledge, useful in the development of the innovation (technology or end-user-oriented). In this perspective, innovation networks can contribute to the removal of barriers to knowledge within the cluster.

4.2. The decline of institutional barriers to knowledge generation

The decline of institutional barriers was achieved by increasing the connections with education and research institutes, and also with standards development organizations and research consortia. These connections materialized because the cluster was composed of a number of vertically related companies, and was strongly motivated by collaborative projects, oriented towards the development of a new technology or end-user applications.

4.2.1. Connexions with education and research institutes

Both public and private institutions involved in basic research, technology development, and basic and technical training, have played a key role in the creation of new technological knowledge, and its dissemination within the overall SA info-communications industry.

Public institutions, such as *INRIA*,[5] *Ecole des Mines de Paris*,[6] *Eurecom*,[7] *CNRS* and *University of Nice-Sophia Antipolis*,[8] played an early role in the transformation of scientific knowledge into technical, and even commercial, applications. Though the initial purpose for most of them was to create scientific knowledge, they also generally favoured the development of connections with industry. Connections with the info-communications industry are essentially based on three specific actions. First, public education and research institutes increased their participation in contractual programmes (funded, for instance, by the *European Commission*, e.g. the *IST programme*) in which companies were also actively involved, and were increasingly concerned with innovation networks either technology or end-user-oriented. Secondly, they developed incubators within which new start-ups could emerge and grow. Since the mid-1990s about 25 new companies operating in the SA info-communications industry were initiated within these public incubators. These companies were created by professors, researchers and students of public institutions located on site. Thirdly, co-patenting between SA public institutions and companies became common in the field of mobile and wireless communications, Internet and Web protocols, security and e-commerce.

Private research institutions, namely R&D laboratories of SA companies, have developed in the last decade. In fact, the major companies in Layer 1 all have an R&D unit located in SA. Over the last years, large component and equipment suppliers, and also telecommunications operators, have focused their efforts on discovering the potential applications of their own Internet and mobile technologies, such as *UMTS*, *ADSL*, *WiFi*. Thus, they have supported the generation of new technological and market opportunities by the implementation of their own private incubators in SA. Through these specific organizations, they have attempted to more effectively resolve various bits of external knowledge, embodied in individual inventors and researchers, with their own constraints in terms of future technologies and knowledge. To some extent, through these incubators, these large companies have favoured a certain diversity in terms of new applications, though in a global technological continuity with what has been done so far.[9]

[5] *National Institute of Computer Research and Automation* (*INRIA*) has had a presence in SA since 1983. It re-groups 29 fundamental and applied research centres. Over the last 20 years, *INRIA* has been the origin for about 55 new start-ups at national level, of which about 10 are located in SA. Around 40% of these 55 new start-ups have been acquired by large, international companies (6 in SA); only 5% have gone bankrupt (0 in SA).

[6] *Ecole des Mines de Paris* has had a presence in SA since 1976, and acts as an important technological knowledge provider. During the last 20 years, some 30 companies have been established as initiatives of *Ecole des Mines* (3 in SA), mostly in the fields of information technology and consultancy.

[7] *Eurecom* was founded in 1992 by *EPFL* (*Swiss Federal Institute of Technology of Lausanne*) and *Télécom Paris* (formerly Ecole Nationale Supérieure des Télécommunications). *Eurecom* has research contracts with external industrial partners (*Ascom, Swisscom, Thales, Cegetel, Motorola, France Telecom, Hitachi, Texas Instruments, ST Microelectronics and Bouygues Telecom*), all of which have branches in SA. These contracts often lead to patents and prototypes with significant potential for commercialization, in the fields of mobile and wireless communications, Internet and Web protocols, security and e-commerce.

[8] *National Centre of Scientific Research* (*CNRS*) and the *University of Nice Sophia Antipolis* have played a part in the info-communications dynamic Since 1999, *CNRS* has been at the origin of some 100 new start-ups at the national level (about 10 in SA), 24% of which are info-communications-oriented (30% in SA). Since July 2000, a public incubator (Paca-Est) has been established by the *University*, and a third of the current projects in incubation (six in total) are info-communications-oriented.

[9] Since the late 1990s–early 2000s, a number of equipment suppliers and telecommunications operators have developed their own private incubators in SA. Most of these incubators were centred on GPRS/UMTS technologies and associated content applications and services. After a few years in operation, and in a context of low performance at the global level, equipment suppliers were forced to narrow their horizons in terms of incubated new start-ups quite significantly. For instance, the largest project *CEIT* was supported by the E-Service Division of *Lucent*, the US equipment provider company, and planned to host about 20 new start-ups working in the field, but also R&D units of operators, spin-offs, and projects with public funds specialized in the content development of new applications. Two years after its creation, *CEIT* managed to attract (only) five innovative projects. *Hitachi Sophia Antipolis Laboratory* (*HSAL*) employs five persons to develop mobile and satellite communications. *Motorola, Nortel, Cisco* and *Alcatel*, as well, reduced temporarily their ambitions in terms of incubated new start-ups. In contrast, in-

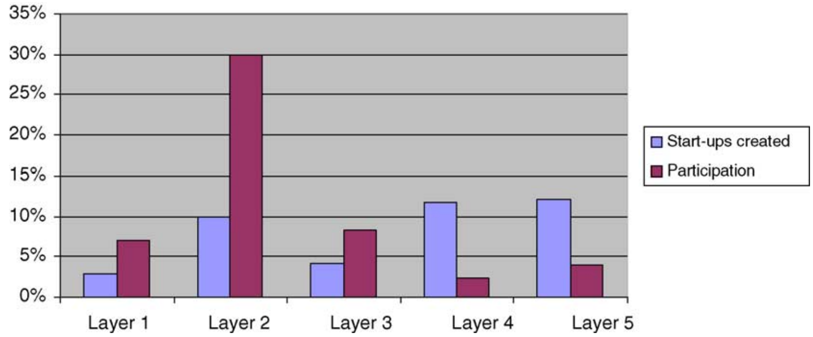

Fig. 5. Creation of start-ups, and participation of firms in their creation.

Through these various actions, education and research institutes in SA have contributed to decreasing the knowledge barriers in the development of new projects and in the creation of new start-ups. Furthermore, these actions have contributed to coordinating dispersed bits of knowledge generated in both private and public institutes, and articulated these new bits of knowledge into what characterizes the info-communications industry today.

As an additional element concerning the coordination of different bits of knowledge, Fig. 5 depicts the layers in which the impact of education and research institutes is the most important to info-communications companies, either through the creation of new start-ups, or through the participation of firms in the process of creation (for instance, development of incubators).

Fig. 5 shows a double pattern of evolution. On one hand, Layers 1 to 3 are deeply involved in the process of creating new start-ups; but, in the meantime, these layers have a low percentage of new start-ups. On the other hand, Layers 4 and 5 encompass a large percentage of start-ups; but the firms in these layers are not so involved themselves in the process of their creation. The explanation for this reverse evolution is as follows. Many start-ups in Layers 4 and 5 were established directly by academic researchers or Ph.D. students, and did not have the size or experience to generate new entities. In contrast, the large, experienced companies in Layers 1 to 3 developed good connections with education and research institutes in order to create new the start-ups that operate in Layers 4 and 5, namely in the downstream and complementary segments of activities.

cubators developed by telecommunications operators seemed to have been less affected by the global crisis. Over the recent years, *France Telecom R&D* (formerly *CNET*), *Fondation Cégétel* (which is a joint creation of *Cegetel, Siemens*, and *Monaco Telecom*), and *Bouygues Telecom* increased their strategy of incubation of start-ups and spin-offs, participation into innovative companies, and research projects in collaboration with academic research institutes (*INRIA, CNRS*) and the *University*.

4.2.2. Standards development organizations and research consortia

In the info-communications industry, standards development organizations and research consortia have a common objective: to provide companies with a series of specifications to facilitate technological compatibility and market coordination. Different actions have been implemented by these organizations (see, for further description, Hawkins, 1999). In fact, standards development organizations are essentially concerned with specifications designed to achieve technical standardization and interfacing. A standards development organization generally regroups incumbents in the info-communications industry essentially from Layers 1 to 3, which are looking for new ways to maintain and increase existing investments in network facilities in order to exploit the commercial possibilities of these new markets for value-added services, as well as new entrants wishing to develop market shares quickly by breaking some of the vertical integration that persists among incumbents. Alternatively, research consortia generally back up their specifications by offering a spectrum of services, such as information repositories and training programmes, and are more focused on the ex ante coordination of technological and market development activities. Research consortia are generally characterized by a higher representation of universities and research groups, as well as new companies and start-ups than standards development organizations.

The presence of a major standards development organization and a major research consortium in SA, such as *ETSI*[10] and the *W3C*,[11] contributes to the reinforcement of local technological complementarities via user–producer relationships and innovation networks. More particularly, these bodies create knowledge links between suppliers of the primary technologies that underpin new service environments, and suppliers of the complementary products and services that are required to establish and sustain innovation.

Fig. 6 shows the participation of SA info-communications companies, layer by layer, into ETSI (the standards development organization) and W3C (the research consortium). Overall, companies have a significant presence in these organizations, while companies located in Layers 1–3 appear to be relatively more attracted by the standards development organization than the research consortium. Presumably, the ex post coordination of knowledge more directly concerns companies that are directly involved in the current, step-by-step, and incremental development of infrastructures, networks and interfaces; while applications firms operate essentially in a field which is still evolving quite radically, and are thus concerned with an ex ante coordination.

4.3. *The decline of communication barriers to knowledge generation*

Here, also, the development of a coherent and complete structure in the info-communications industry, composed of vertically related layers, produced a reduction in the barriers to communication in the generation of knowledge. This was achieved by the creation of new clubs and associations, and by the re-orientation of existing ones towards an info-communication perspective. This was accompanied by the development of dedicated physical and financial facilities.

4.3.1. *Clubs and associations*

There are various clubs and associations in SA.[12] Many of them were initially not related to a particular domain of activity, and broadly represented those companies involved in information technologies, chemicals, life sciences, and environmental/earth sciences. Since the mid-1990s, a new cohort of clubs and associations has emerged, that is more info-communications related. Through these clubs and associations, regular interactions between firms were intended to diffuse information concerning the evolution of the info-communications industry, either on the technology side or on the market and applications side, and to foster the identification of the different bits of knowledge and their coordination via the development of groups of companies working in specific fields (Fixed Internet, mobile Internet, security aspects and billing systems).

[10] *European Telecommunications Standards Institute* (*ETSI*) was created in SA in 1998. It is a non-profit organization whose mission is to produce the telecommunications standards that will be used for the decades to come throughout Europe and beyond. *ETSI* was responsible for the *Universal Mobile Telecommunication System* (*UMTS*) technological standard, which allows for the development of third generation mobile phones. Today, *ETSI* continues to develop new technological specifications related to m-commerce and IP-based technologies and services, supports and advises on any e-Europe initiatives. *ETSI* comprises 912 members from 54 countries within and outside of Europe, and represents administrations, network operators, manufacturers, service providers, research bodies and users.

[11] *World Wide Web Consortium* (*W3C*) was founded in October 1994 by Tim Berners-Lee, inventor of the *World Wide Web*, at the *Massachusetts Institute of Technology, Laboratory for Computer Science* (*MIT/LCS*) in collaboration with *CERN*, where the Web originated, with support from *DARPA* and the *European Commission*. *W3C* has developed more than 40 technical specifications for the Web's infrastructure, and is attentive to meeting the growing expectations of users and the increasing power of machines, especially as computers, telecommunications and multi-media technologies converge. In April 1995, *INRIA* became the first *W3C* host in Europe, followed in 1996 by *KEIO University of Japan* in Asia. *W3C* involves around 500 member organizations from all over the world and has earned international recognition for its contributions to the growth of the web.

[12] The major ones are: *Telecom Valley*, created in 1991 by *Aérospatiale, Paradyne, Dec, ETSI, France Telecom, IBM and Texas Instruments* to promote telecommunications activities in SA; *Club Mitsa* (*Multimedia Interactivité Téléactivité de Sophia Antipolis*) that, since 1994, has comprised companies operating in the field of packaging and creation of content to be provided on different infrastructures (fixed and mobile networks, Internet infrastructure); *Data Base Forum*, set up in 1994 by *NCR, MBDS* and *Espri Concept* to be host to the developers and users of large databases; Imet (*Institut Méditerranéen de Téléactivités*) that emerged in 1994 from a joint effort of *INRIA, Eurecom, France Telecom, Fondation Sophia Antipolis, Rectorat de l'Académie de Nice*, and *CERAM*, to encourage the development of new info-communications projects, content-related; *Club Sophia Start-ups* set up in 2000 to favour the development of new companies, essentially info-communications related.

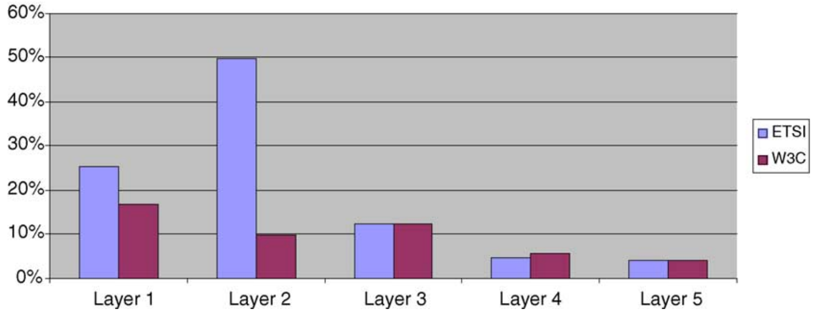

Fig. 6. Participation of firms into standards development organization (ETSI) and research consortia (W3C).

These clubs and associations are widely frequented by companies. Fig. 7 depicts, layer by layer, the percentage of companies that are members of (at least) one of the clubs and associations in SA.

For each layer, this participation ranges between 30 and 50%. This shows that clubs and association apparently contribute significantly to the combination of different types of knowledge. In fact, the coordination is two-fold. First, membership of clubs and associations can provide a more global vision of the activities of the different companies located on site. Secondly, through their membership sub-groups of companies can be identified which it might be worthwhile to integrate into a current/future project.

4.3.2. Use of dedicated facilities

The presence of dedicated facilities (physical and financial) in SA also played a key role in attracting firms located elsewhere and in the creation of SA start-ups. The development of these dedicated facilities was deemed to favour close interactions between firms. Fig. 8 presents the pattern of use of dedicated facilities by the different layers.

Fig. 8 shows that the presence of physical equipment, such as *CICA*,[13] and financial facilities, such as *IVCS*,[14] is quite significant for firms in Layers 2, 4 and 5, but of lesser importance for firms in Layers 1 and 3. However, these results should be examined in relation to the numbers and sizes of firms in the different layers. Firms in Layers 1 to 3 are generally much larger than firms in Layers 4 and 5 and, consequently, the provision of dedicated facilities has different significance for these firms. Location in *CICA* and selection by *IVCS* are survival conditions for firms in Layers 4 and 5, which is generally not the case for firms in Layers 1 to 3.

4.4. Summing up

In the preceding paragraphs, we have described and explained how various factors (industrial, institutional, and communication) significantly decreased the barriers to knowledge in the SA info-communications industry. Alternatively, one could logically consider that the absence of these factors that explain the non-shakeout in SA should also explain the shakeout in France. In what follows, we advance

[13] *International Advanced Communication Centre* (*CICA*) was created in 1992 by the *Council of Alpes Maritimes* (*Conseil Général des Alpes Maritimes*). *CICA* is a park, comprised of 9 “intelligent” buildings (14,000 m^2), which provides info-communications companies with office space, local network and high speed Internet access, meeting rooms, lecture theatres with audiovisual equipment, reception and secretarial services. Large, international groups such as *Hitachi, Bouygues, Cegetel*, or *Lucent* are located in *CICA*, as well as smaller companies (start-ups) and research/education institutes (*Eurecom*). *CICA* is thus intended to promote cross-fertilizations and synergies between the various economic players (companies, researchers and students, and decision makers), and to support innovative projects by availability of high level technical facilities.

[14] *International Venture Capital Summit* (*IVCS*) has, since 1998, attracted in SA financial and industrial investors, bankers, business angels, capital risk investors and companies looking for potential partners. While the info-communications projects represented about 60% of the *IVCS* selection in 1998, in 2002 they accounted for almost 90%. It is important to compare this evolution with more global trends in SA. Today, more than one-third of the total growth of SA is directly created by firms with international investors. *IVCS* is a strong support for the development of the info-communications industry in SA, since most of the successful new SA start-ups have been selected at least once or twice.

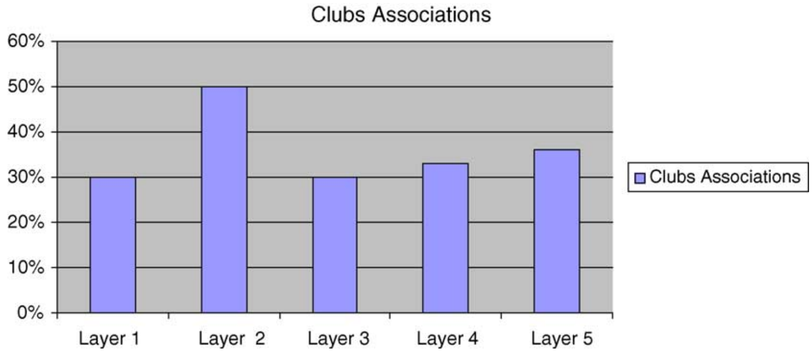

Fig. 7. Participation of firms in clubs and associations.

some (non-exhaustive) arguments on why most info-communications firms in France did not observe similar declining barriers to knowledge.

The first element is that, in most NICT areas, the population of info-communications companies is generally composed of companies coming from Layers 4 and 5. Many clusters in France, but also abroad, have developed rapidly by the creation or attraction of facilities-less companies during the Internet boom period, and declined equally rapidly when these companies disappeared during the bust period. The dotcom (sudden) mania and (subsequent) denial often revealed the fragility of clusters characterized by the absence of a significant level of accumulated knowledge embodied in facilities-based companies, and by the inability to develop interactions among different actors within coherent innovation networks. The incompleteness of the industrial structure, in the sense of over-representation of downstream companies and under-representation of upstream companies, generates instability at the level of the cluster. Problems in the creation, coordination, accumulation and diffusion of knowledge among and between the different layers are recurrent. The incomplete layered industrial structure appears as a weakness in the development of a cluster, since the set-up of technological facilities is missing in this case, and the adequate transfer of related knowledge, skills and experience to service companies is also infeasible. Moreover, the rate of survival of those companies is generally low, and opportunities to develop user–producer relationships over the long-run are significantly reduced. Turbulence also alters the emergence and growth of technology or end-user-oriented innovation networks. Industrial barriers to knowledge remain at a high level and shakeout eliminates a large share of facilities-less companies.

The second element is related to connexions with education and research institutes, but also with standards development organizations and research consortia. In most of the NICT areas, these connexions are largely encouraged, especially by local public authorities. But here also, the composition of

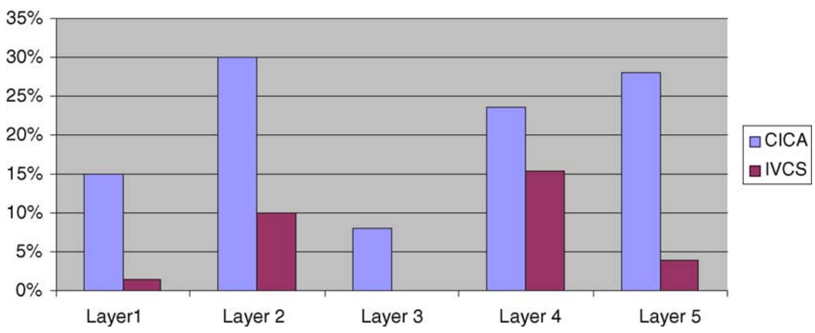

Fig. 8. Use of dedicated facilities in the different layers.

clustered companies matters and highly influences the result in terms of research collaboration and start-ups creation. Connexions between these institutions and info-communications companies are generally fostered when large upstream companies are on site, actively involved. Clusters almost exclusively composed of downstream firms have greater problems in the coordination of knowledge. Downstream companies do not undertake any R&D activity, and they usually miss the absorption capacities to integrate and accumulate external knowledge. In the development of innovation networks, we should also note that some of the key institutions, such as *ETSI*, *W3C*, are exclusively located in SA. This certainly increases the institutional barriers to knowledge of other comparable French clusters that, as a matter of fact, cannot host these standards development organization and research consortium.

The third element concerns communication aspects within clubs and associations, and the use of dedicated facilities. Participation in clubs and associations is generally important in most of the French NICT clusters, and the participation in SA is not significantly superior to the national average. However, the large spectrum of clubs and associations, their early implantation in the cluster, and their progressive specialization towards the telecoms and the Internet fields of activity, is a distinctive feature of SA as compared to other clusters. Finally, the existence of dedicated facilities, such as *IVCS* and *CICA* that are considered as pioneering experiences in France, also contributes to reduce communication barriers to knowledge to a larger extent than elsewhere.

Knowledge dynamics at the local level often failed in many NICT clusters because of the lack of interaction and coordination between key companies, supporting institutions and communication structures. In the downturn period, most of the clusters attracted very few new entrants, and did not maintain a long-term viability for incumbents. Local knowledge dynamics was thus generally insufficient to shape industrial dynamics, and did not preserve clustered companies from shakeout.

5. Conclusion and discussion on policy implications

This paper aimed to explore how the relationship between entry, exit and knowledge could operate since, at the local level, specific knowledge dynamics might emerge, that would significantly shift the industrial dynamics trends that prevailed globally, and finally produce a local non-shakeout pattern of evolution. This phenomenon, observed in a cluster in the info-communications industry, also questioned, at a more theoretical level, the relationship between knowledge dynamics and industrial dynamics. A knowledge-based industrial dynamics approach was thus proposed in order to analyse how knowledge dynamics can shape industrial dynamics. More precisely, this approach was developed to analyse how clusters can decrease the barriers to knowledge that usually provoke a shakeout pattern of evolution. We also sought to clarify that the cluster itself does not decrease these barriers to knowledge; rather, it is the interaction and complementarity that develops among companies, research institutes and dedicated policies, which contributes to attracting new entries and to limit exits over time.

In this paper, the case study was extensively used in order to (i) draw some major stylized facts on the evolution of the SA info-communications industry, distinct from what might be observed at a more global level; (ii) emphasize that a specific interaction between knowledge dynamics and industrial dynamics needed to be further investigated; (iii) document the knowledge-based industrial dynamics in practice; and (iv) see how the cluster and its various interacting components reduced the industrial, institutional and communication barriers to knowledge. Aware of the difficulty of drawing general and definitive conclusions from a case study, and in order to strengthen the main results of the current paper, we chose to implement a recurrent comparison with French/national characteristics. Future research should complement this with a more systematic comparison. In particular, from this perspective, a comparison between two distinct clusters in the French info-communications industry would be valuable, and a more global reference to European data would further enrich the investigation.

Notwithstanding this, some preliminary policy implications can be drawn from the current discussion.

A first lesson arising from this era of info-communications in SA is that, regardless of whether evolution in the earlier stages has been chaotic, the economic development of a science park can be stimulated at the mature stage. Despite the limited participation of large firms in the early stages of economic development in SA, the uncoordinated and short-term decisions made by local public authorities and the initial slow involvement of education and scientific institutions, since the mid-1990s SA has progressively become a more focused project, encompassing consistent initiatives associated with the info-communications era. To some extent, the recent evolution of SA demonstrates that the capacity for adaptation over time is sometimes more important than the initial conditions of economic development. It also shows that a non-ideal type of economic development (compared, for instance, with US and UK models of science parks) does not necessarily perform poorly.

We also learned that big players operating in academic/industry relationship must be actively involved. By actively involved, we mean that not only must they be located on site, which is the basic condition, but also that they must interact and become coordinated over time. Large companies operating in upstream layers (equipment suppliers, telcos, and IAPs/ISPs) were generally located in SA in the early 1990s, and started to be involved in the economic development of SA through various actions, one of which was the development of private incubators. The education and scientific institutions became more involved in the economic development of SA in the late 1990s. The presence of standards institutions in SA was crucial for the development of this academic/industry relationship. *ETSI* and *W3C* were dedicated to encouraging interaction between universities and firms, between fundamental and applied research, to elaborate new technological specifications for the high speed Internet and *3G* mobile phones. With these various upstream actors on site, and the burgeoning of their interactions and coordinated actions (info-communications-oriented), a further development of downstream activities – that 'sat on the top' of the upstream activities – became progressively possible, and viable over time.

Thirdly, despite the extensive possibilities for long distance, virtual interactions that characterize the use of these NICT, the info-communications industry itself still clusters, and even layers. The economic development of a given geographic area depends on the presence on site of companies belonging to the vertically related layers, as well as on the relationships that are built up within and between these layers. The order in and pace at which the different layers are constituted does have an effect on the long-term viability of companies and their local environment, and has implications for policy. For instance, the presence of a homogenous vertical structure seems to play an important part in the viability of clustered companies. From the point of view of future research, we would suggest that this factor potentially decreases the probability of exits, either directly, since network effects develop between companies in Layers 1 to 5, or indirectly, since the presence of a network of supporting associations will reduce the effects of any drastic changes.

A final element is that the upstream and downstream layers have to expand in line with a co-evolution process. Because of their connected activities, each population of firms – i.e. upstream and downstream must ensure their own viability and maintain network effects. In terms of policy, this is certainly one of the key challenges for the future, though not an easy one. First, the changing financial climate, which affects upstream layers today, may ultimately also affect the downstream layers, even though these latter companies may have survived dotcom crash. On that point, of course, local policies of economic development have no direct impact. Secondly, the move from *2G* to *3G* mobile technologies is still very uncertain and is being challenged by competing technologies such as *I-mode* and W*ireless LANs*. Thus, the increasing interaction between (i) research and education institutions, (ii) companies in upstream and downstream layers and (iii) norms and standards institutions, is certainly a key local policy focus for the future.

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