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REJUVENATING NANOCLUSTERS WITH ‘SLEEPING ANCHORS’: PRE-ADAPTATION AND LIFE CYCLE

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Abstract

This article investigates how anchor firms sustain high tech clusters rejuvenation by means of technological pre-adaptation. Based on evidences are drawn from the comparison of the evolution of two nano-electronics clusters, i.e., Grenoble (France) and Catania (Italy) clusters which are sharing the same anchor tenant firm STMicroelectronics. Cluster rejuvenation comes from pre-adaptation of actors (scientific and technological diversity), competition amongst anchor tenant firms, competition and overlap amongst networks and the mobilization of sleeping anchors tenant organizations to renew actors and technologies. As soon as the process of specialization (asset specificity, network specificity, technology speciation) starts, it is important to stimulate pre-adaptation to avoid lock-in of the cluster on one technological trajectory.

Keywords: rejuvenation, cluster growth, industry life cycle, anchor tenant firm, pre-adaptation

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1. INTRODUCTION

Over the last decade, firms clustering has drawn a renewed scholarly attention since clusters have become a prevalent form of industrial organization, and conceived as a key source of regional and national competitiveness (Braczyk *et al.*, 1998; Maskell, 2001; Piore *et al.*, 1984). Despite a growing body of literature in economics and geography assumes that clusters promote innovation and enhance firm performance, only some handful clusters have become “hot spots” (Pouder *et al.*, 1996), while the others mostly struggle to sustain their growth and cope with international competition.

Actor variety within clusters, technological diversity, the presence of large organizations as well as cluster governance mechanisms (Bell *et al.*, 2009) influence the evolution of the cluster (Mangematin *et al.*, 2010) and the firm performance (Castellacci, 2008; Rothaermel *et al.*, 2008). Prior work on high tech clusters points to the relevance of leading, large, R&D oriented firms, termed as *anchor tenant firms* (Agrawal *et al.*, 2003; Romanelli, 2004), in fostering knowledge mobilization, knowledge transfer and 'learning' within local clustered actors, built on trust, reciprocal local exchange and structural embeddedness. This is consistent with evidence on nanotech clusters where large firms control the processes in which nanotechnologies are incorporated, and thus contribute to the development of R&D facilities and technological platforms (Robinson *et al.*, 2007). This view emphasizes cooperative relationships between clustered firms and the importance of proximity (Boschma, 2005). However, it tends to neglect the role of industry/ technological crises that hurts the international competitiveness and attractiveness of the regional industry cluster. The issue of sustaining competitive advantage in face of new market conditions is especially critical in nanotechnology clusters where superior performance depends on consistent innovations resulted by exploiting and combining prior knowledge across different domains. Technology life cycles (Dalum *et al.*, 2005) influence the creation of new ventures (Lemarie *et al.*, 2000), the evolution of clusters (Menzel *et al.*, 2010) and the forms of collaborations (Guerrieri *et al.*, 2004). Since nanotechnologies are commonly viewed as convergent technologies that enhance existing technological competences, they represent a suitable empirical setting to analyze the effects of technological life cycle in shaping the overall cluster rejuvenation. We build on the notions of technological life cycle and pre-adaptation to analyze how the presence and

strategies of anchor tenant firms can help sustain nanoelectronic clusters and help shape their overall rejuvenation (Baden-Fuller, 1994). We focus on the *firm level* – i.e., anchor tenant firms – and address the following research questions: *How are clusters rejuvenated? Which is the role of anchor tenant firms in cluster rejuvenation to improve firm business performance?* The main argument is that clusters may contain the seeds of their own destruction, leading to poor growth and exit of major economic actors. When one actor is dominating the cluster, shaping scientific and technological avenues, it leads to convergence and isomorphism amongst actors. Diversity is reducing and the sources of renewal are diminishing. The cluster lacks of fresh air and goes to suffocation and death. On the other side, we believe that clusters contain the seed of their own rejuvenation by leveraging technological pre-adaptation, which is based on the accumulation of knowledge over time, in related technical fields but without necessarily anticipating its subsequent use (Cattani, 2005; 2006). We argue that cluster rejuvenation calls for competition amongst potential or ‘sleeping’ anchors that will revitalize the cluster. Competition amongst firms and organizations boosts the exploitation of several technological trajectories, facilitates knowledge accumulation, and promotes cluster pre-adaptation.

Evidences are drawn from the analysis of the evolutionary forces underlying the dynamics of two nano-electronics clusters, i.e., Grenoble (France) and Catania (Italy) clusters, and one anchor firm, namely STMicroelectronics, which is active in both of them.

Our goal in this paper is to contribute to cluster rejuvenation understanding as follows. First, we propose to adapt the notion of technological pre-adaptation to cluster as a source of rejuvenation. Second, we identify the engines of cluster renewal in the case of nanodistrict. Third, instead of attributing cluster heterogeneity to initial conditions defined *a priori* (e.g., (Porter, 1998; Stinchcombe, 1965), we seek to unpack sources of clusters heterogeneity by first tracing differences in initial conditions and then by examining to what extent policy makers initiatives have effectively created fruitful conditions for technological pre-adaptation. The paper is organized as follows. Section 2 highlights the theoretical framework and the knowledge gaps. In particular, it first explains how technological life cycle influences the evolution of the cluster while pre-adaptation contributes to clusters’ rejuvenation; second, it concentrates on the actors’ strategies to facilitate technological pre-adaptation. Section 3 gives details on the empirical settings and analyzes the two illustrative cases of Catania (Italy) and Grenoble (France) nanotech clusters. Section 4 discusses the findings, highlights implications for firms and policy makers, and suggests a few avenues and strands for future research.

2. THEORETICAL FRAMEWORK

Building on the work of Kuhn on the structure of scientific revolutions (Kuhn, 1962), technology life cycle (TLC) theories suggest that the cognitive conditions, the industrial structure by which knowledge is generated and the spatial organizations of scientific and economic activities change over time as the technology matures. TLC theories exhibit two major phases. Each of these phases presents a deep internal coherence in the way knowledge is being produced (Dosi, 1982; Tushman *et al.*, 1986). The first phase is characterised by rapid technological change whereas the second phase is characterised by some sort of technological consolidation around a dominant design (Anderson *et al.*, 1990). The two phases and the subsequent set of identified problems are associated with possible solutions that can lead to new productive services or new market opportunities (Afuah *et al.*, 1997; Utterback *et al.*, 1993).

Emergence of technology and radical innovation

The first phase opens with the introduction of a breakthrough innovation, which changes production costs, productive services, commercialization modes and market opportunities. Far from providing a stable and economically superior set of solutions at a stroke, the exploitation of the new technology calls for further exploration, opening different trajectories: scientific and technological hypotheses have to be tested against one another (Anderson *et al.*, 1990), existing value chains are questioned. Hence the exploration of competing technological hypotheses or trajectories takes place in a highly uncertain and turbulent environment, where the introduction of alternative solutions, while providing new insights, amplifies uncertainty instead of reducing it.

The arrival of a breakthrough technology often equates with firm creation, either entering an existing industry or constituting an entirely new industry. In that stage, technology is not specific and remains generic. Speciation begins when a dominant design emerges (Cattani 2006). These new ventures are based on their distinctive technical skills and have been formed on independent research projects exploring competing trajectories, *i.e.* technological opportunities. Hite and Hesterly (Hite *et al.*, 2001) point out those start-ups face huge uncertainty about the efficiency of their ill-defined routines and products and environment during the early stage of the industry. In biotech during the 80's-90's, spin-off creation has been one of the ways to transfer knowledge and know-how from academia to industry, these relations were generally based on geographic proximity leading to the formation of scientific

clusters (Audretsch *et al.*, 1996; Zucker *et al.*, 1998). These identity-based relations embedded in local interactions are key to explain the observed concentration of firms active in science-based industries around renown universities (Powell *et al.*, 2002). Indeed, when scientific activities remain close to the edge of knowledge, the knowledge produced incorporates a large proportion of tacitness and remains embodied in those who produce it. It follows that the circulation of knowledge equates with the circulation of researchers or engineers themselves (Almeida *et al.*, 1999; Bozeman *et al.*, 2004a; Bozeman *et al.*, 2004b).

This does not deny the fact that in the meantime, incumbent firms may equally invest in the new technology. Technology acquisition is far from being quick or cheap. It requires long-term investments in knowledge creation and acquisition. Large firms do establish solid ties with research-oriented institutions. They are also dealing with small firms as sub-contractors or knowledge providers. Large firms broadened their knowledge base by investing establishing ties with those who had the seminal scientific knowledge and associated technical skills.

To sum up, breakthrough innovations in science-based sector locate innovation within scientifically magnificent areas where inter-organisational alliances based on predominantly inter-personal ties allow sticky knowledge to circulate. In the early phase, knowledge within the cluster is focused but not completely specific as it is an emergent field (Afuah *et al.*, 1997; Jina *et al.*, 2010).

Technological maturation and consolidation

As the new technology is being explored, a dominant design emerges, leading to some sort of scientific and technological stabilization. Trajectories are set up, and emerging paradigms still need refinement regarding the effective integration of the new technology to the old ones. The consolidation of the industry around a dominant design is characterised by an industry shake-out (Klepper, 1997; 2003). Some start-ups fail, other grows. The mean size of firms increases. This suggests that the allocation of resources to innovation changes towards larger research projects: firms internalise more stable knowledge, so that critical competencies can be found within other organisation more systematically. As technology reaches maturity, it becomes more specific, more dedicated. Key partners are better identified and alliances are formed on a dyad basis. The number of partners reduces and firms concentrate on the most promising research avenues. At the level of the industry, the changing nature of the technological environment leads to more market-based relations, competition amongst firms intensifies. At the cluster level, this phase is critical. Menzel *et al.* (Menzel *et al.*, 2010) proposed a model

based on two processes: the first is that the emergence and growth of the cluster depend on the technological heterogeneity of firms; the second is that maturation leads to technological convergence when learning takes place within the cluster. Relations amongst cluster members stabilized and diversity reduces, slowing down the cluster growth (Mangematin *et al.*, 2010). To summarise, the exploitation of few promising trajectories leads to technological speciation (Afuah *et al.*, 1997; Cattani, 2006). It also induces evolutions of the industrial and cluster patterns. As technology matures, the rhythm of start-up creation decreases, barriers to entry are erected and patterns of collaboration within clusters are being rigid. To continue to growth, clusters need to rejuvenate, engaging new collaboration, facilitating the emerging of new technologies and exploring the formation of new alliances outside the clusters, including relations within multi-located firms.

Rejuvenating clusters by leveraging technological pre-adaptation

Recent literature on clusters has pointed out that firms benefit from clustering as geographic proximity stimulates exchange of scientific and technological knowledge (mostly in the emerging phase) and support their market strategies by leveraging cluster visibility (mostly in the exploitation phase). To benefit from these opportunities, firms need a certain degree of absorptive capacity and local embeddedness provides local actors with diversity of knowledge. Cooperation is a crucial element for influencing regional innovation performance and therefore a large number of works concluded that higher levels of intra-cluster cooperation induce higher innovation performance (Asheim *et al.*, 2002). However, too much cooperation, over time, can be detrimental for innovation, affecting explorative firms behavior and their innovative outcomes. Clustered firms embedded in a stable local network can be trapped in their own net (Gargiulo *et al.*, 2000), generating a risk of technological lock-in. The occurrence of a lock-in renders a cluster potentially inefficient, because it loses its capability to provide benefits for firms that are already in the cluster and for those that are considering to move in. This is consistent with studies from evolutionary economics that stress the dynamic nature of entrapping or locking processes in technological innovation (Arthur, 1994). These studies conceive lock-in effects as the results of the accumulation of self-reinforcing processes that is likely to occur at a specific point during the cluster life cycle.

Agrawal and Cockburn (Agrawal *et al.*, 2003) explore the effects of the presence of large firms within clusters. By analogy with the “anchor tenant organization” approach which studies the externalities generated by large department store on the retail shopping mall, they apply the approach to large firms within clusters, defining anchor tenant as a large firm that is:

1) heavily engaged in R&D in general and 2) has at least minor absorptive capacity in a particular technology within a particular region. Anchor tenants can be very important in both creating and capturing externalities within local innovation systems, are likely to be important in stimulating both the demand and supply sides of local markets for innovation, and may be an important channel for transmission of spillovers. Agrawal and Cockburn show that anchor tenant technology firms form an important aspect of the institutional structure of local economies. However, when clusters are dominated by an anchor tenant firm, diversity reduces as it may orient research activities to its own benefit on the short run. This evolution is concomitant to the technology speciation which describes the specialization process of technology providers as dominant design emerges and market becomes more specific (Takeda *et al.*, 2008). As the cluster provides less and less technological opportunities to other firms new entrants are discouraged from relocating, so that cluster growth is limited, while the convergence on the anchor tenant firm's scientific and technological fields reduces the diversity and munificence of the regional environment, all increasing the risk of collective failure and regional decline.

Pre-adaptation counter-balances technological speciation (Cattani, 2005; 2006). It describes how firms invest in long term, with a long R&D accumulation without anticipation or foresight of subsequent uses, simply accruing new information on market and customer needs. We can apply the same notion to clusters. The knowledge base of a cluster follows the evolution of its participants' knowledge bases: when diversity remains high within the cluster, each actor having pursued its strategy and different technological trajectories have been explored, pre-adaptation remains significant. When scientific and technological developments are at the edge of the knowledge, exchange of tacit knowledge is important, and during this emerging phase, geographic proximity is central to knowledge exchange between organizations. The proximity allows actors to benefit from each other's knowledge bases and pre-adaptation to hybridize technologies, while the accumulation of technological knowledge and its low degree of speciation enable it to be transferred across domains readily. The same firm knowledge base can in fact enhance the ability to generate valuable innovations in market domains with similar technological trajectories.

Technological pre-adaptation represents a source of new opportunities for clustered firms and consequently, at cluster level, can positively shape cluster rejuvenation dynamics. This led us to propose the following proposition:

Proposition 1: Clusters that include anchor organizations develop technological pre-adaptation and can respond to technological change

As mentioned before, anchor tenant firms with a large and cumulative knowledge base may exploit their prior experience in different market applications. When anchor tenant firms are organizing the cluster to its own benefit, it may reduce diversity, enhancing convergence around its own knowledge base. It will reduce the cluster's pre-adaptation. The relationships between anchor firm and the other clustered members (i.e. local firms, universities and PROs, local agencies,) shape the level of technological preadaptation. If different actors are competing to organize and coordinate the cluster, competition among cluster members to coordinate reopens technological trajectories and avoids early lock-in and stimulates pre-adaptation at the cluster level. Competition also stimulates external collaborations with other partners who may reinforce technological pre-adaptation through dyadic collaborations. In line with this reasoning, to rejuvenate cluster, and to face decline, competition amongst cluster members to coordinate the cluster allows diversification and pre-adaptation. Clusters may have some mechanisms that allow changes in the power relations to renew technological influence and to rejuvenate technological knowledge base through pre-adaptation. Technological breakthrough or radical changes can threaten the existing power of anchor tenant firms, altering cluster identity. However, competition amongst large players is necessary to rejuvenate the cluster. In presence of technological discontinuity, to maintain cluster lively, pre-adaptation is important and different actors should be influential within the cluster to prepare the future.

Proposition 2: Domination by one anchor tenant actor boosts clusters on the short run, but reduces the chances of them developing through technological pre-adaptation: competition amongst large firms boosts clusters in the long run.

To explore these two propositions and the role of competition amongst anchor tenant firms, a comparative longitudinal approach is necessary to track short and medium term effects.

3. METHODS

To explore our two propositions and the role of competition amongst anchor tenant firms, we adopted a comparative longitudinal approach to explore the evolution of clusters, simultaneously tracking the organization, the main actor evolution and the performance of clusters in the short and medium run. These dynamics can change dramatically: the KPMG study *Competitive Alternatives*, 2002 into micro and nano-electronics clusters ranked Catania

2nd and Grenoble 12th, but the same study conducted in 2010 saw Grenoble ranked 5th position but Catania now 8th. We chose to analyze the short and medium term evolution of these two regional clusters as a comparative case study based on longitudinal data.

Method: research design and data collection

The research design is based on longitudinal comparative case studies for collecting fine-grained description of cluster evolution as well as of actors' strategy and actions so as to better understand and characterize the change under scrutiny: Who are the clusters' actors? How are the clusters coordinated? What are their modes of governance? Does one actor dominate the cluster? Are anchor tenant firms competing? What is the story behind the comparative success of the Grenoble area and the decline of Catania? Consistent with Yin (2008), we document how the two clusters and their anchor firms have evolved over time by analyzing archival data, internal documents and reports, academic publications, and several interviews with key managers, researchers, and crucial actors from both private and public spheres. Because of the importance of the clusters and the wide attention that events relating to them and their firms had received from academics and national and international public opinion, we were also able to integrate and triangulate the data we already possessed (Patton, 1990) with a great amount of external data. Specifically, our external sources consisted of articles published by specialized press and archived by the Factiva, ABI and Delphi databases, as well as several institutional reports (i.e., KPMG Report, 2002; AEPI Report, 2008; Potter and Miranda, 2009) and academic papers (i.e., Druilhe and Garnsey, 2000; Mangematin et al. 2005; Robinson et al., 2007; Lawton-Smith, 2003; Santangelo, 2004) even though they were written with different purposes and for different audiences. Finally, we looked at several institutional websites. Specifically (for the Catania cluster) we examined Etnavalley.com (the regional cluster's institutional website) and Distretti-tecnologici.it (the Catania technological district's institutional website), while for the Grenoble cluster on we consulted Competivite.gouv.fr (the French pôles de compétitivité's institutional website), Grenoble.cci.fr (Chambre de Commerce et Industrie de Grenoble), Inpi.fr (Institut National de la Propriété Industriale), and Insee.fr (Institut National de la Statistique et des Etudes Economiques). Given the proposed framework, our focus is on the main actors involved (i.e., anchor firms), the activities and technologies that cluster firms explored and exploited and the network of relationships they established.

Our data collection also included a further primary source, i.e., structured and unstructured interviews with policy officials, top managers of nanotech cluster firms and academic

researchers, held between September 2009 and April 2010, which allowed us to dig deeper in the evolution of the two clusters, figure out the characteristics of their actors and examine the role of policy makers. Two teams collected data on site in each nano-electronics cluster location, and we used a natural temporal bracketing (Langley, 1999) to organize it. Actors reported three phases: *emerging phase*, when the cluster is first identified as a cluster and institutionalized; the *growth phase* as the cluster gained investment, technologies become more specific, firms grow and the cluster prepares to face the next wave of technological discontinuity. The *Challenge phase* describes this period, after the first wave of innovation has been exploited and a new exploration phase starts with the emergence of new technological discontinuities. These three phases can be identified, in each region, as follows:

- *Emergence Phase*. The first cluster evolution phase in Catania covered the period 1987-1994, while the Grenoble first phase was from 1992-2000.
- *Growth Phase*. In Catania the second phase covered the period 1994-2004, while in Grenoble the period was 2000-2004.
- *Challenge Phase*. In both regions the third and final phase of cluster evolution covered the period 2004-2010.

Comparing Grenoble and Catania nanotech clusters

Catania nanotech cluster at a glance

Located in Southern Italy, Catania represents the economic engine and business centre of Sicily. Catania hosts Etna Valley, one of the most attractive European hightech cluster, and the Technological District for Micro and Nano Systems, where different organizations collaborate with the ultimate goal of establishing the whole cycle of activities required for semiconductor, microelectronics and nanotechnologies: education and basic research (the University), oriented research (IMM-CNR and MATIS-INFN), Research & Development and production (STMicroelectronics, Nokia, IBM, and other small companies, as well as firm consortia, such as Etna Hitech).

The history of the microelectronics and nanoelectronics industry in Sicily originated in 1962 when STMicroelectronics decided to locate in the Catania regional area. At that time, it was in fact the Sicilian production plant of the Società Finanziaria Telefonica, a subsidiary of IRI, an Italian state-owned conglomerate. Despite that, the development of the microelectronics business in the Catania area really took off in 1987, when STMicroelectronics got involved in

a research agreement with the University of Catania and CNR (the Italian National Research Council) to enhance the productivity of internal R&D. At the same time, Co.Ri.M.Me. (Consortium for Microelectronics Research in Mezzogiorno) and Catania Ricerche Consortium were founded to foster innovation research by means of dedicated public investments. During the last two decades, a great deal of efforts have been devoted to the development of the Catania hi-tech district, eventually called “Etna Valley” (Foresta Martin, 1987; Betts, 2000).

Several factors have driven to the competitive success of this area. First, a large firm (i.e., STMicroelectronics) has contributed to increase high qualified employment (Figure 1) and R&D investment (Figure 2), to attract international firms (and suppliers), to support local firms growth, to foster the spin off of new entrepreneurial ventures, encouraged new high tech ventures in other technology-based industries and attracted a large amount of public funds (Buttà and Schillaci, 2003)

Fig 1 – Trend of employees in STM Catania Site

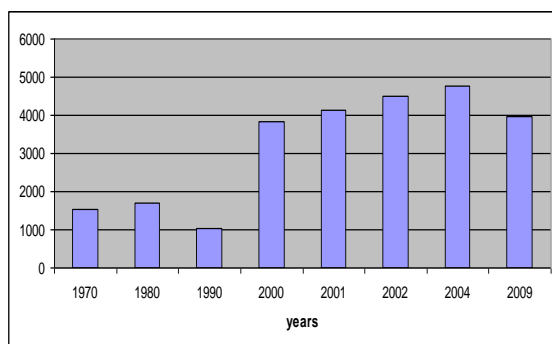
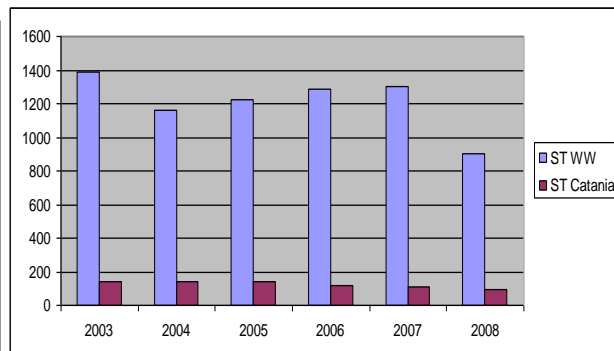


Fig 2 – Patent applications – STM Catania site



Second, the high quality of the regional research system, which includes three universities (the University of Catania, the University of Messina and the University of Palermo) and other 309 research institutions (e.g., the Institute of Microelectronics and Microsensors (IMM), the centre of Materials and Technologies for Information, Communication and Solar Energy (MATIS) and the Superlab of Catania Ricerche Consortium), has provided the area with outstanding technical capabilities and competences to operate in contexts of excellence. In addition, the region has offered wide availability of trained workers: around 170 university graduates each year in electronics and ICT related subjects, almost half of these in the Catania area.

Finally, policy makers, in particular the Italian Central Government, the Region of Sicily and the Municipality of Catania, have taken part in the area’s evolutionary path through a series of

initiatives designed to incentivize investments and the creation of new opportunities for the local workforce (suspension of social contributions for the first six years, EU funds, contributions to new plants, renewals, extensions, the construction of new research centres, R&D projects, and so on).

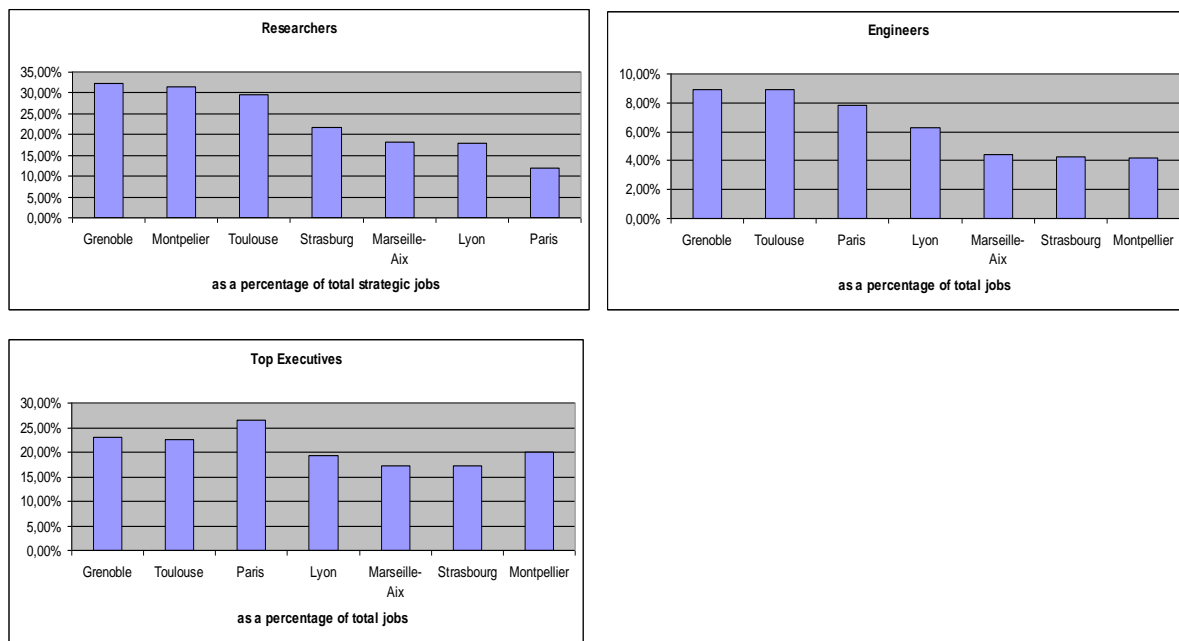
Grenoble nanotech cluster at a glance

Situated at the foot of the French Alps where the Drac joins the Isere River, Grenoble is located in the Rhône-Alpes region and is the capital of the Department of Isere. Its economy has grown strongly in the last ten years mainly driven by an internationally competitive cluster of activities involved in research, development and product design for microelectronics, nanotechnologies and related software. The cluster around Grenoble is existing for a long time. The French government institutionalized it as one of the seven “global competitiveness clusters”, or “pôles de compétitivité mondial”, bringing considerable financial support for research and development activities, and a cluster management organization, namely *Minalogic* (short for Micro Nanotechnologies and Logiciel Grenoble-Isere Compétitivité), in charge of brokering research and other collaborations between research, education and industry. Minalogic not only includes actors in micro-nanoelectronics. It also integrates users on nanodevices such as Schneider electrics for applications in electricity storage or Biomerieux for applications in biopharmaceuticals.

Grenoble boasts one of the largest scientific communities in France and represents the largest centre for research outside Paris (Lawton-Smith, 2003). The cluster counts about 40.000 direct jobs (45% of which specialized in design and research) in 500 enterprises. Most of cluster firms are less than 10 years old and were created as spin-offs. They undertake a high level of innovation and among them over 80 per cent bring new products to market in a 3-year period (AEPI Report, 2008). Evidences drawn from a comparison between the seven global competitiveness clusters currently present in France reveal that the pole of Grenoble has benefited over time of the highest expenditures that public agencies and private instors have directed to the cluster’s projects. Similarly, Grenoble has achieved over time remarkable performance in attracting highly qualified researchers and engineers.

Second, as portrayed in Figure 3, the Grenoble regional area has shown the highest number of qualified jobs, i.e., researchers, engineers, and executives compared to the rest of France.

Fig 3: The qualified jobs in Grenoble



Source: AEPI, 2010 and INSEE, 2006

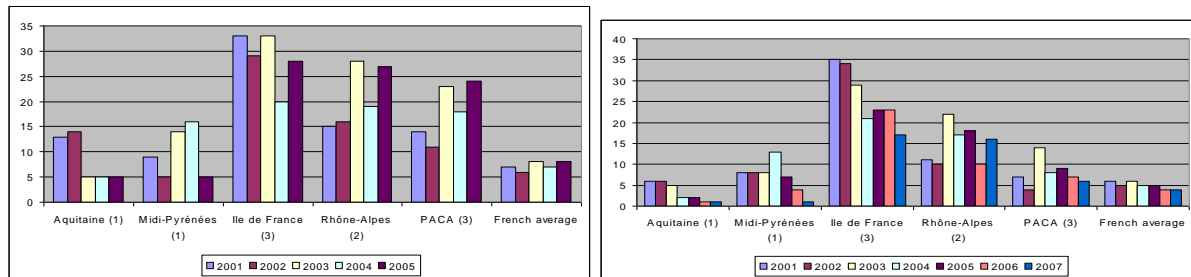
Third, the Rhône-Alpes region, with its three global competitiveness clusters: LyonBiopole, Minalogic and Tenerrdis: *LyonBiopole* (accredited in July 2005) is a global center of excellence in vaccines and diagnostics, which aims to gain a comprehensive understanding of human and animal infectious diseases. The cluster is founded upon the expertise of the Lyon-Grenoble area strengthening the synergy between the complementary know-how of these two metropolitan areas: large scale industrial production and functional biology in Lyon, and structural biology and micro & nanotechnology in Grenoble. Located in Grenoble, *Minalogic* fosters research-led innovation in smart miniaturized products and solutions for industry. It involves 100 industrial, scientific and academic players in two sub clusters: EmSoc, devoted to embedded software on chips, and MicroNano, fostering the downsizing of micro-technologies to nanotechnologies. Located in Rhône-Alpes Region (around Grenoble) *Tenerrdis* is a national competitiveness cluster covering three new energy technologies core sectors, i.e., construction, transport, and energy production. The emergence of the two clusters (*LyonBiopole* and *Tenerrdis*) when *Minalogic* entered in the challenge phase renewed the leadership and opened competition amongst firms to orchestrate the clusters.

The Rhone-Alpes region where Grenoble is located shows the second best GPD in France (Euro 173.682m, 9,9% of French GDP) and the highest number of enterprise outside Ile de France resulting from both public incubators and national competition (Insee, 2006) (see Figure 4 and Figure 5). The three clusters are linked to each others, with common members.

They are orchestrating the connexion between different technologies, and between technology providers and those who are integrating the technologies in products or services.

Fig 4: Number of enterprises created through public incubators

Fig 5: Number of enterprises resulting from a national competition meant to create new firms



Source: <http://www.competitivite.gouv.fr>

Actually, the outstanding development of the Grenoble cluster has unfolded over a long period of time and is the outcome of long-lived relationships between industry and science in an area where industrial expansion occurred with the development of hydroelectricity at the beginning of the twentieth century and the location of a branch of the government's atomic energy agency (Druilhe and Garnsey, 2000). The cluster gathered strength and grew over time, successfully updating its technologies and core competences by inventing and/or combining a number of technology staples, from the era of hydro-electric power, electrochemistry and electrometallurgy in the 1950s to the present era of micro and nanotechnology.

Grenoble has built on a very strong education sector, comprising four universities and a management school delivering a large inflow of high-skilled labour in relevant fields. It has major national or international research institutes in microelectronics and nano fields. Strong local social capital at leader level and an entrepreneurial and pro-cluster public policy have helped to drive research-industry cooperation and public-private investment projects. And there have been some important flagship projects in the last ten years, including the *Alliance Crolles* initiatives, i.e., agreements amongst STMicroelectronics, Philips-NXP and Freescale in order to pool some of their pre-competitive research efforts; the *Minatec* project, i.e., a centre for joint education, training and research for the cluster; the above mentioned *Minalogic*, which coordinates and organizes a major innovation centre, pulling together specialist skills in the design, development and production of products and solutions for smart

miniaturized services for industry; and finally *Nano 2012*, i.e., a cooperation program which aims to boost the technological lead and competitive position of the Grenoble area in the changing conditions of the global semiconductor industry and consolidate its leadership position in the development of CMOS technologies at the 32 and 22 nm scale and derivative technologies for system-on-chips (embedded memory, analog/RF devices, etc.).

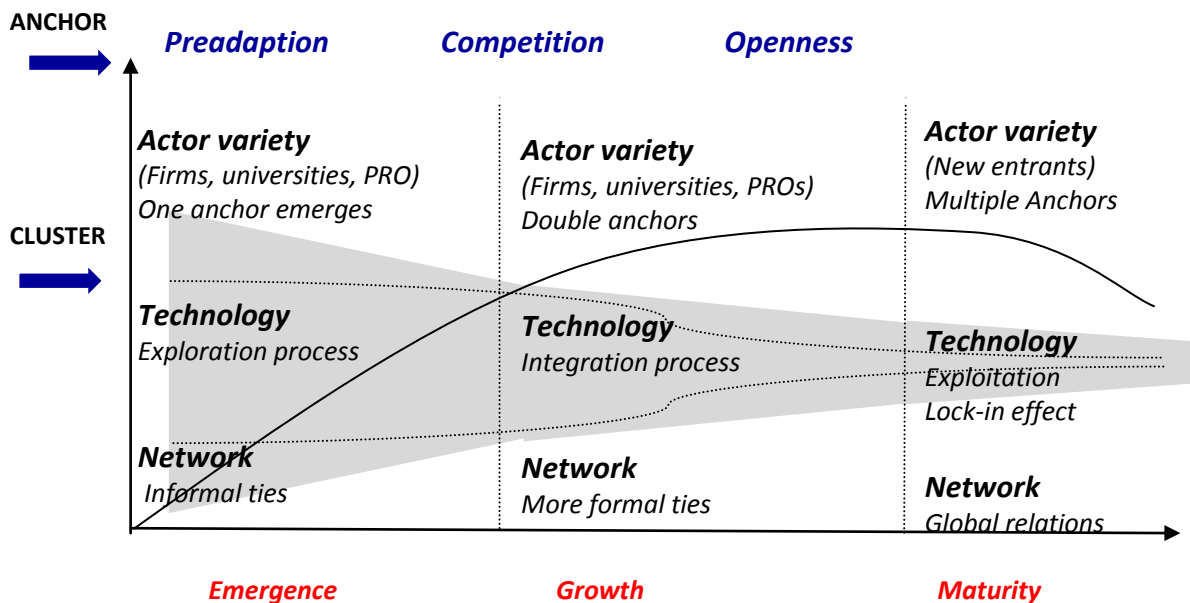
Data Analysis: comparing Catania and Grenoble nanotech clusters

We collected data on several cluster dimensions, e.g., scientific, technologic and economic evidence, concerning with the cluster performance. Data focuses not only on clusters but also on anchor tenant firms. Data are not completely comparable as most of them were collected at the cluster level, where cluster boundaries remain fuzzy. For statistical information, we have been highly constrained by information provided by clusters on the number of patents, the number of firms or employment.

We collected data on the different dimensions of clusters, scientific, technologic and economic evidence about the cluster achievements. Data are not completely comparable as most of them are collected at the cluster level, where boundaries of clusters remain fuzzy. For statistical information, we have been highly constrained by information provided by clusters on the number of patents, the number of firms or employment.

Data collected on the two clusters have been analysed following the different dimensions on cluster growth. We use temporal bracketing to analyse the different phases, emergence, growth and challenge. For each phase, we examine actor variety, evolution of the technology and the structure and evolution of the network. Figure 6 introduces the different elements that are developed in the following paragraphs.

Figure 6: dimensions of the analysis



Data are analysed bien period, for Catania and Grenoble nano-electronics clusters.

Emergence Phase

Catania 1987-1994. Catania's nano-electronics cluster (at that time micro-electronics cluster) began in 1987 when the collaboration between STMicroelectronics Catania Site and the University of Catania was institutionalized by means of the Consortium for the Microelectronics Research in Mezzogiorno (Co.Ri.M.Me). The Consortium was created on the ground of the law 64/86, i.e., "Extraordinary Interventions for Mezzogiorno", thanks to which the initiative benefitted of an incentive of Euros 181,74 million. The main mission of the consortium was to promote scientific and technical knowledge development and provide incentives to R&D activities. During its nine first years, Co.Ri.M.Me negotiated patents for about 200 inventions and, on the whole, registered 500 patents in silicon research (some of these patents were the basis for the newly created innovative field of opto-electronics). The strong collaboration with the University of Catania and the exploitation of the research carried out by Co.Ri.M.Me. allowed STMicroelectronics Catania Site to shift the pole especially focused on manufacturing of traitio devices into a site able to research, develop, engineer and design radically new micro and nanoelectronics products (in few years the R&D division had increased from 4 to 174 individuals).

Grenoble 1992-2000. The start of the nano-electronics cluster in the Grenoble area coincides with the sign in 1992 of an agreement between STMicroelectronics, L ti-CEA and France Telecom R&D, called Alliance Crolles 1. According to it, the three mentioned actors pooled their deep sub-micronic technology research resources, with prototyping and pilot production in a new R&D center to be located at STMicroelectronics in Crolles. The new pole hosted a fully 8 inch (200 mm) integrated facility with with R&D, pilot production and volume manufacturing. At the onset of 2000's STMicroelectronics Grenoble Site employed in Crolles more than 2000 people. Table 1 presents the situation of each cluster during the emergence phase. In each of them, STMicroelectronics is the central actor that is orchestrating the cluster.

Table 1: Catania and Grenoble clusters : The emergence phase

Clusters	Catania (1987-1994)	Grenoble (1992-2000)
Actors	Existing anchor firm, i.e., STMicroelectronics	Existing anchor firm, i.e., STMicroelectronics
Technology	Revitalizing microelectronics. Existing research capabilities and R&D collaborations	Surf on the hype of nanotechnology
Networks	Industry-University collaboration CORIMME	Alliance Crolles 1, mostly with other firms to perform research, development and production

In this first phase at both clusters, technologies remained non-specific, networks remained open and new firms (start-ups and incumbents) joined both clusters (see Table 1). STMicroelectronics, as the existing anchor in both locations, orchestrated the emergence and institutionalization of the clusters, working especially with local and national policy makers.

Growth Phase

Catania 1994-2004. Actually, as a result of the STMicroelectronics public trade in the New York and Paris Stock Exchanges occurred in 1994, STMicroelectronics Catania Site left all the consortia in which it had got involved and rearranged its collaboration with the University of Catania. The Institute of Methodologies and Technologies for Microelectronics (IMETEM) replaced Co.Ri.M.Me. and external collaborations were launched with the Superlab of Catania Ricerche Consortium, and (from 2000) with the centre of Materials and Technologies for Information, Communication and Solar Energy (MATIS). The locations of centres of research such as IMETEM and Superlab within the premises of STMicroelectronics allowed to

strengthen the link between basic and applied researches thereby facilitating a fruitful collaboration with industrial researchers as the researchers had preferential access to the fabrication pilot line (which allowed making studies on real devices).

Grenoble 2000-2004. The second phase of the nanocluster evolution saw two bottom up initiatives meant to orchestrate the region and involve private and public actors: on the one side, a private-public initiative, i.e., Minatec, and on the other side, a second joint venture led by STMicroelectronics, i.e., Alliance Crolles 2.

In 2000 INPG board signed an agreement with CEA Leti for building together a new campus for Micro and Nanoelectronics Innovation Campus called Minatec. This campus is not only dedicated to training but also to develop and commercialise science and scientific innovations. The partnership was then enlarged and involved also the French government, the Rhône-Alpes region, the Isère department (which became the project owner), the Grenoble-Alpes-Métropole greater metro area, and the City of Grenoble. This public-public initiative represented a total investment of Euros 1,3 billion (capital investment and running expenses) spread over ten years, from 2002 to 2011 and it was officially aimed to support the cluster's mission of becoming one of the world's top five centres for research in micro and nanotechnologies. It groups different actors from academia and from technology transfer (mostly the CEA/LETI which bridges academia and industry).

Alliance Crolles 2 was a collaborative industrial development program in nano-electronics that started up in 2002 between STMicroelectronics, Philips-NXP and Freescale to jointly develop CMOS process technology. The three companies pooled their financial and human resources in order to cooperate on R&D issues while continuing to compete in the "downstream" part of the value chain. The alliance was the largest single industrial investment in France in the last 15 years: the joint investments amounted to €2bn and a further €1.5bn in R&D expenditure.

Table 2: Catania and Grenoble clusters: The growth phase

Clusters	Catania (1994- 2004)	Grenoble (2000-2004)
Actors	Existing anchor firm, i.e., STMicroelectronics	Double anchoring (CEA as the anchor of Minatec and STMicroelectronics at the industrial anchor of Crolles Alliances)
Technology	The relationship industry-university tends to become exclusive	Investments are highly supported by local, regional and national authorities
Networks	CNR IMM Etna Valley brand	Cluster boundaries become clearer. Variety of actors provides the cluster with multiple networks

During the growth phase, the power of the existing anchor is growing as the networks become more polarized. The cluster is more and more institutionalized and more tightly organized. Boundaries become clearer to sort out who are in and who are out of the cluster. Technology enters in the exploitation phase, dominant designs appear. In Grenoble, STMicroelectronics (from the industrial alliance) and CEA from Minatec (the academic side) are struggling for the orchestration of the cluster.

Challenge Phase

Catania 2004-2010. By 2004 the image of Etna Valley has suffered from the crisis of the worldwide microelectronics industry, the lessening of the relationship between local actors, and the reduction of investments especially by large firms (the new STMicroelectronics plant M6 was stuck). From 2005 two events resulting from two acts of firm cooperation contributed to rejuvenate the Catania cluster: on the one hand, the creation of a firm consortium, i.e., Etna Hitech (EHT), and on the other hand, the joint venture through which STMicroelectronics, Enel and Sharp to pursue photovoltaic and solar energy innovations.

Etna Hitech was established in 2005 by 33 medium and small sized companies that tried in some ways to countervail the increasing power of STMicroelectronics in the Catania area. They employed about 1,100 people with a total turnover of roughly Euros 90 million and operated in Catania hi-tech industries, i.e., Information & Communication Technology (ICT), and Micro & Nano Technology (MNT).

In 2008 STMicroelectronics, Sharp, and Enel Green Power (EGP) signed a joint venture agreement for the production of thin-film solar cells. Sharp, EGP and STM plan to start the production of thin-film solar cells in 2011, by utilizing an existing STM facility (M6 plant) in

Catania. In addition to financing from the banks, this project will be funded by investments from each company of approximately 70 million Euro each.

Grenoble 2004-2010. In 2005 the Minalogic cluster of Grenoble-Isère has been designated as one of seven “global clusters” in France because of its strong international renown. Collaborative research projects among firms and research organisations in the cluster are financed under the “pôles de compétitivité” programme by the Business Competitiveness Fund (FCE) of the central government’s Directorate-General for Enterprise. This budget is drawn from a pool of finance provided by the government’s Single Inter-ministerial Fund, a number of public agencies (the National Research Agency, the Industrial Innovation Agency and OSEO, the French innovation and SME agency) and the Caisse des Dépôts et Consignations, the government’s investment bank, and is supported by tax exemptions and reductions in social security contributions for R&D activities.

Minalogic is co-managed by a grouping of the key enterprises, research and education institutions and public authorities in the cluster. Schneider Electric chairs its governance structure. Minalogic had 78 members as of January 2007, including 48 businesses (33 SMEs), 10 research centres and universities, 14 territorial authorities, six economic development organisations and one associated private investor. In addition, LyonBiopole and Tenerrdis have been set up as clusters based on biotechnologies and energy research. Actors of Minalogic (both in academia and firms) are providers of the two clusters dedicated to biotechnologies and energy.

In addition, Minalogic renewed itself. The Nano 2012 R&D programme was officially launched in 2008, bringing together IBM’s research centres at Fishkill and Albany, New York state, STMicroelectronics and CEA-Leti. Nano 2012 is a cooperation program which aims to boost the technological lead and competitive position of the Grenoble area in the changing conditions of the global semiconductor industry and consolidate its leadership position in the development of (32 and 22 nm) CMOS technologies and derivative technologies for system-on-chips (embedded memory, analog/RF devices, etc.). Over the next five years Nano 2012 will be allocated a €2.3bn R&D budget with a further \$1.25bn for capital investment, making it one of France’s biggest industrial projects. National and local government are providing substantial support for the project, contributing some €457m. Realization of this project will make Grenoble- Isere a global centre for tomorrow’s nanoelectronics, with potential for creating about 650 jobs in the Grenoble area.

Table 3: Catania and Grenoble clusters: The decline/rejuvenation phase

Clusters	Catania (2004- 2010)	Grenoble (2004-2010)
Actors	STM declines New actors emerge (e.g., Etna HiTech) No private investors	Minatec and Cea Leti STM and Schneider Private Investors
Technology	Solar Energy	Nano 2012
Networks	JV STM-Sharp-Enel Etna Hitech Consortium Technological District	Multi-thematic clusters i.e. Minalogic, Lyonbiopole, Tenerrdis Several large multinational firms competing to benefit from the cluster

In the challenge phase, the cluster is institutionalized and its relations with public authorities and policy makers are established. Both actors and relationships are identified. Actors exploited the results of the first technological discontinuity. Technological pre-adaptation allows clusters to renew their knowledge base and to enter into a new phase of exploration based on new technological breakthroughs. When actors and relationships have been frozen, pre-adaptation is not possible and the cluster slows down and becomes less attractive.

The analysis of the two illustrative cases of Catania (Italia) and Grenoble (France) conducted so far has revealed that, while the starting situation of the two nanoelectronics clusters share the same anchor firm, technological pre-adaptation have shaped different patterns. Grenoble nanocluster is experiencing rejuvenation while Catana is still striving to cope lock-in effects and inertia processes, which negatively affects its international competitiveness.

4. DISCUSSION AND CONCLUSIONS

The comparison of Catania (Italy) and Grenoble (France) nanoclusters have highlighted the cluster dynamics as a result of anchor firms strategies and cluster-specific factors enabling firms to exploit their knowledge base in several market domains. Our findings support the idea that clusters own themselves inner forces to sustain their rejuvenation by leveraging prior knowledge base. The final section of the paper discusses first the conditions of pre-adaptation at the cluster level and the rejuvenation of clusters. It then draws implications for policy makers and large firms.

Cluster pre-adaptation

The notion of technological pre-adaptation has been developed for firms (Cattani, 2005) to describe that part of a firm's technological knowledge base that is accumulated without anticipation of sub-sequent uses (foresight), but might later prove to be functionally "pre-adapted" (i.e., valuable) for alternative, as yet unknown, applications. In a cluster, pre-adaptation describes the part of the cluster knowledge base that is accumulated and recognized even it is not main stream and can be used as a seed of knowledge to hybridize with existing technologies or to initiate or participate to the new technological wave.

Our analysis reveals that clusters are developing pre-adaptation mechanisms in four ways. First of all, knowledge and scientific variety, measured by the breath of the knowledge base of the cluster (Mangematin *et al.*, 2010), is a way to nurture pre-adaptation. It maintains exploration relatively high and allows actors to hybridize with their existing knowledge based. Geographic proximity enhances opportunities for such hybridization as scientists (from academia or firms) may share research facilities (Robinson *et al.*, 2007) or exchange tacit information during seminars and informal meetings (Von Hippel, 1994). The second way to enhance scientific and technological variety is the coexistence of actors who are pursuing different non coordinated strategies within the cluster. As they do not co-ordinate but compete, different technological trajectories are explored so as to nurture pre-adaptation. Collaboration with other actors is the third way to increase pre-adaptation capabilities. When actors within clusters are collaborating on a dyadic basis with actors elsewhere, they are bridging capabilities, creating space for pre-adaptation even if it is not co-located pre-adaptation. Organizational proximity (Boschma, 2005) built through long-term dyadic collaboration enhances pre-adaptation capabilities of the collaborating members. The last way is very similar. Usually, anchor tenant firms are large multinational corporations which have multilocalized research facilities (Birkinshaw, 2002). In that case, because of organizational proximities, tacit knowledge circulates within multilocalized organizations, enhancing pre-adaptation within the cluster as multinationals bridge the different locations.

The comparative analysis of the two clusters and the respective role of anchor tenant firms which change overtime helped us to characterize pre-adaptation capabilities of clusters. The characterization of cluster pre-adaptation highlights the process to respond to technological change, supporting the first proposition.

Cluster rejuvenation

The role of cluster and of actors within clusters change as technology matures, and scientific fields and the organization of the geographic area are institutionalized. The two cases (Catania and Grenoble) exhibited similar historical conditions in terms of anchor firms R&D strategies. In both of them, STMicroelectronics played a key role, mainly investing in nanoelectronics, interacting with public research organizations and small firms which are technological suppliers, shaping the cluster and the relations with the local and national public authorities.

In particular, in Catania currently STMicroelectronics is managing the transition from nanoelectronics to photovoltaic solar energy, while in Grenoble the company is boosting cluster international visibility by using its integrative capabilities to bridge its own network and the other regional and international clusters (e.g. Tenerrdis, Lyon Bio Pôle, Dresden, Singapore). In each of these international clusters, one of the multinational firms is collocated between Grenoble and one of the foreign locations. These findings reveal that the dominance by STMicroelectronics in the Catania regional area increased the cluster growth in the short term, while negatively affected the cluster performance in the long term. Catania cluster seems frozen and deeply embedded in institutionalized networks. Grenoble cluster has benefited from the increasing technology diversity generated by STMicroelectronics, Minatec and other 'sleeping' anchors (like Schneider, HP, BioMerieux, etc.) which focus on different markets. These differing evolutionary paths unfolded through three distinct phases, i.e., emergence, growth and challenge.

At the emergence phase, in both Catania and Grenoble clusters, STMicroelectronics played the role of dominant anchor firm, and contributed to create a critical mass - both in scientific (patents and publications) and industrial terms (infrastructure and new fabs) -, which positioned the respective clusters within the international competition. STMicroelectronics, local universities and research centers have developed dyadic collaborations. For most of the local firms, STMicroelectronics is representing an important partner or clients. Specifically, STMicroelectronics Catania site strengthened its collaboration with University of Catania by means of the Co.Ri.M.Me Consortium, while STMicroelectronics Grenoble site launched a cutting-edge R&D and manufacturing pôle (Crolles 1) thanks to the equity joint venture with LÉTI-CEA and France Telecom. In that phase, technology remains generic as well as investment and patterns of collaboration. The introduction of breakthrough technology created technological, collaborative and organizational discontinuities.

The growth phase witnessed the development of specialized assets, the speciation of the technology as the dominant design had emerged (Teece, 1986). Firms became more specialized as the market grew. Actors within the clusters are involved in given scientific and technological trajectories. They entered in the exploitation phase and the whole cluster is more specialized and dedicated. Pre-adaptation is key to renew the scientific technological knowledge base. In Catania, the process of specialization followed STMicroelectronics' one. In Grenoble, competition to orchestrate the cluster and the CEA's involvement in both local (Minatec) and international networks challenged the existing trajectories. Unlike Catania cluster, whose growth relied upon STMicroelectronics investments on nanoelectronics, Grenoble cluster experienced the competition between the dominant anchor firm (STMicroelectronics) and Minatec-CEA (academic anchor highly involved in technology transfer), promoting actor variety. It first develops towards academia (Minatec, INPG, CEA-Leti), and then has been enlarged to wider applications of nanotechnologies (i.e. nanobiotechnology, solar energy, nanoelectronics) and additional actors from global networks, like Schneider, Biomerieux etc. In addition, Tenerrdis as an institutionalized cluster (pole de compétitivité) is developing, involving new actors. It has reinforced technological diversity and competition for cluster influence and orchestration. Different anchor tenant firms are currently disputing the orchestration of the clusters. They influence technological trajectories and induce alternative ones, based on their existing, not yet exploited, knowledge base. As the whole, pre-adaptation of the clusters and competition for orchestration stimulate cluster rejuvenation.

Finally, during the challenging phase, rejuvenation is based on competition amongst firms that appeared before as sleeping anchors. They exploit technologies from the pre-adaptation capabilities to launch new technological trajectories within the cluster. Doing that, they rejuvenate it, initiating new collaborations, new firms and addressing new markets.

To conclude, cluster rejuvenation comes from pre-adaptation of actors, competition amongst anchor tenant firms, competition and overlap amongst networks and the mobilization of sleeping anchors tenant organizations to renew actors and technologies. As soon as the process of specialization (asset specificity, network specificity, technology speciation) starts, it is important to stimulate pre-adaptation to avoid cluster lock-in on one technological trajectory. Our findings support our idea that competition amongst multiple anchors sustains cluster growth and lays the foundations for cluster rejuvenation. We retain that competition is a key mechanism to leverage technological pre-adaptation. In this respect, we observed similar

levels of technological pre-adaptation, at least at the first phase, even though the two clusters exhibited heterogeneous dynamics. It follows that simply looking at cluster's stock of knowledge is misleading and does not fully explain how anchor firms may use it. Therefore, while we emphasized technological pre-adaptation, we do not underestimate the relevance of anchor strategies searching for broadening technology variety and global network. These strategies coupled with policy maker initiatives to support actors' variety, forge technological pre-adaptation and promote cluster rejuvenation.

Several implications for policy makers emerge as well. First, to develop sustainable clusters, policy makers should integrate the cluster life cycle in the policy design and identify the 'right' phase. Additionally, policy makers should strengthen diversity within the cluster both at the organizational and scientific levels. It implies not to reinforce existing anchor, but to detect and invest in multiple anchors (potential and 'sleeping' anchors). Second, policy makers should support knowledge circulation within the cluster and between anchor tenant firm and other clustered members. To this end, public initiatives should encourage collaboration outside the cluster and collaboration amongst different divisions of the anchor tenant organization. Third, since multiple networks emerge when the cluster matures, policy makers should pay attention to actors who are central not locally but within global networks.

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