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## Clusters for life or life cycles of clusters: Critical factors for resilience

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# CLUSTERS FOR LIFE OR LIFE CYCLES OF CLUSTERS

## *Critical factors for resilience*

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### *Abstract:*

*This paper aims to contribute to the identification of the key parameters of cluster life cycles. We assume that clusters are embedded in larger technological fields, so that the search for these parameters focuses on the way by which clusters could disconnect their cycle from the cycle of technologies, in order to insure their long term viability. For that, we set out 6 propositions concerning (i) the nature of location decision externalities that prevail in the co-location process; (ii) the particular diffusion process of composite technologies and the positioning of clusters along this process; (iii) the structural properties of clusters and the particular role and position some organizations play in their evolution. Through a cross-synthesis of the whole of these propositions, we discuss 4 basic scenarios of the structural and evolutionary pathways of clusters. We show that clusters succeed in disconnecting their cycle from the cycle of technologies if and only if they display resilience properties.*

Key-words : cluster, cycle, location externalities, knowledge, structural properties, resilience

JEL code: D85, L14, O31, R12

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## *From declining to resilient clusters*

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### **1. Introduction**

After a decade of a growing literature on clusters by regional scientists and a growing attention of the European Commission for cluster policies, the question of cluster viability (Menzel, Fornahl, 2007; Vicente & al, 2007; Suire, Vicente, 2009) has to be at the heart of the scientific community agenda as well as the policy makers debates. For the former, the researches on cluster success stories do not have to hide the fact that some clusters also decline, or at least, exhibit fluctuations in their development. The reasons of such a chronic instability have to be investigated in order to go beyond the image of cluster as a *panacea* of regional development (Martin, Sunley, 2003). For the later, the financial effort that supports the cluster policies requires understanding why some clusters succeed when others decline, in order to improve the cluster policy platform.

To understand cluster dynamics, it calls for starting with a more precise definition as possible of the concept. Clusters are more than the simple spatial aggregation of firms and other institutions in a same place. Clusters can be identified since this co-location process is correlative to an emerging structure of knowledge interactions. In a systemic and network approach, a cluster can be viewed as a more or less cohesive local network, part of a larger network representing a technological field (Owen Smith, Powell, 2004).

This definition has two major implications for our purpose:

- Cluster viability is not independent of the one of the technological field as a whole.
- Cluster viability depends on the ability of its collective organization to impose and maintain whole or part of a technological standard.

The paper investigates these two implications by developing a theoretical framework introducing the question of clusters instability and viability into the question of the knowledge dynamics at work in a particular technological field. The basic idea is that the cluster local viability depends on the global viability of the technological standard partly or totally coming from this cluster. Thus, there is a strong

parallel to do between cluster dynamics and technological dynamics since (i) cluster life cycles could be the result of technological standard emergence and diffusion (rather than product life cycles *per se*), (ii) cluster stability could be the consequence of the collective effort to insure the stability and the evolution of a technological standard in time and space.

In order to highlight this (not strict) parallel between “competing technologies” and “competing clusters”, the paper discusses a set of parameters that influence the growth and performance of clusters. These parameters are related to (i) the individual motives to locate close to others and the resulting co-location dynamics; (ii) the complex links between the composite technologies and their mass-market diffusion; (iii) the evolving structural properties of knowledge networks. Clusters life cycles will result therefore from the singular combinations of these critical parameters.

Section 2 starts by proposing two central hypothesis that outline the search for cluster life cycles key parameters. Section 3 investigates the cluster viability and stability as regard as the nature of location decision externalities that prevail in the co-location process. Section 4 studies cluster life cycles as regard as the diffusion process of composite technologies and the positioning of clusters along this process. Section 5 associates cluster life cycles to their structural properties, their resulting capacity to impose standards on markets, and their degree of resilience. Section 6 proposes a cross-synthesis of the whole of previous propositions, and sets out the key scenarios that correspond to the different patterns of clusters life cycles

## **2. Overview on cluster aggregate efficiency: two basic hypothesis**

To understand clusters life cycle requires having an overview on the critical parameters of clusters aggregate efficiency. Since Porter ideas, an abounding literature emerged focusing on the geographical, cognitive, institutional and relational dimensions of clusters, and stressing on how these dimensions interplay efficiently (Torre, Gilly, 2000; Boschma, 2005). Others works have tried to understand how clusters emerge and grow according to evolutionary paths which depend on the nature of location decision externalities, giving rise to peculiar co-location dynamics (Suire, Vicente, 2009). From these considerations, one can admit that clusters can be identified since these co-location processes are correlative to emerging structures of knowledge interactions, more or less cohesive, and part of larger networks which represent technological fields (Owen-Smith, Powell, 2004).

This definition has two major implications for our purpose, which can be stated as two basic hypothesis

*H1: Cluster viability depends on the viability of the technological field as a whole.*

Biotech clusters, IT clusters, nano clusters... are meso-structures that cannot be studied without investigating their embeddedness in the dedicated technological field dynamics. The cluster viability will obviously depends on the internal ties but either on (i) its connections with the whole of the technological field, (ii) the centrality of the considered cluster in the technological field, and (iii) the viability of the technological field itself in the market dynamics.

Firstly, starting from the later, the viability of a cluster will be even more likely to be strong that the emerging technologies will face an increasing demand along the product life cycle, whatever the form of the product diffusion at this preliminary stage. Secondly, the viability of the cluster will depend on the competition and/or strategic differentiation between clusters in the same technological field. A cluster which exhibits more centrality than another will be more likely to be viable due to a traditional effect of increasing returns to adoption, whatever the internal organization of the cluster at this preliminary stage. Thirdly, the connections of the cluster to the technological field represent a critical parameter of its viability. As a matter of fact, they condition the way by which firms will succeed to insure all the phases of the knowledge value chain, from the exploration phase to the phases of knowledge integration/combination, before an exploitation on markets, whatever the dominant phase of the cluster at this preliminary stage.

Considering these complex interactions between clusters and technological fields, clusters can grow according to multiple co-location motives and contexts. First of all, clusters can grow through the regional identity and the reputation capital (Romanelli, Khessina, 2005; 2005; Suire, Vicente, 2009) some of them can exhibit in the technological field. Clusters can also grow through the attraction of firms developing complementary and related knowledge assets. Clusters can also grow endogenously by spin-offs. The combination of these co-location motives will engender differentiated clusters concerning their internal organization and the management of local knowledge spillovers.

*H2: Cluster viability depends on the ability of its collective organization to impose and maintain a technological standard.*

If we admit that the viability of a cluster is the corollary of its evolving position into a range of competing clusters, it will depend, *ceteris paribus*, on how its interactions structure permits to impose and extend over time successive technological standards. This idea is not new and can be found in the analogy between the two analytic models of competing technology and Silicon Valley of B. Arthur (1989, 1990). He clearly displayed the fact that technological standards and location standards emerge from the same economic mechanisms of increasing returns to adoption. Nevertheless, the analogy between technology and location dynamics is not sufficient to understand cluster dynamics. For instance, a technological standard can diffuse while the cluster producing this standard can decline, and reciprocally, a cluster can still grow while the technological standard at the origin of its development declines. It would be thus more relevant to identify and understand how these two dynamics interplay and under what critical parameters.

The technological diffusion depends strongly on the consumers adoption behaviors. From the early adopters who research novelty and performance to the pragmatic adopters who research a convenient solution and service (Rogers, 1962), the innovation has to be transformed from a disruptive technology into a dominant design. The network effects which permit to increase the satisfaction of consumers and reach their willingness to pay (Katz, Shapiro, 1994; Liebowitz, Margolis, 1995), and the contagion effects which lead to conformity in a wide range of the population (Geroski, 2000), are the salient properties which allow to understand how a technology establishes itself as a leading one or does not overstep the stage of the early adopters.

The question is thus to understand how the cluster collective organization could support and favor this technological diffusion process. The basic idea is that clusters are more viable and attractive in time that their collective organization is able to cover the phases of the knowledge value chain by which the technology becomes a dominant design. Knowledge production and diffusion is a complex process covering different dimensions from the analytic to the marketing dimensions which cross different knowledge phases (Asheim, 2007, Cooke, 2007). A dominant design could emerge from a peculiar cluster only if its network-based collective organization is structured in such a way that fragmented knowledge inputs coming from different organizations are combined along each phase of the knowledge process. In addition, as the diffusion of technologies depend on the “chasm” between the earlier adopters and the mass population loving cheap prices, socioeconomic network effects and convenience (Moore, 1991), this collective knowledge dynamics between the emerging analytic “idea” and the exploitation on global markets appears as the key structural process of clusters viability and cycles.

These two hypothesis – clusters are embedded in technological fields and their viability depends on their ability to diffuse technological standards – form the general framework of a more complete as possible study of the critical parameters of the cluster life cycles. The first of them refers to the very nature of the location decision externalities. From the regional “identity effect” to the “knowledge accessibility effects”, differentiated location individual motives can engender different trajectories of clusters. The second one refers to the complex process of technology adoption by consumers and therefore to the economic vitality of the technological field, which can have strong consequences on clusters dedicated to this field. The third one refers to the structural and non structural clusters properties (Owen-Smith, Powell, 2004). These ones permit to examine how clusters covers (or not) each phase of the knowledge value chain, and thus to discuss their evolving efficiency in the

knowledge creation/diffusion process. In a first step, the complexity of these parameters requires to extract and discuss separated propositions. But the former are strongly related and necessitate in a second step to link them in an appreciative theory of evolving clusters.

### 3. Co-location processes and cluster viability

First of all, to understand why these clusters exist and perform, it is necessary to understand through what aggregation mechanisms of location strategies some clusters dominate a major part of the innovation and the demography of the technological fields. From the initial conditions and the small historical events (Arthur, 1990; Krugman, 1991) to the geographical charisma of clusters (Appold, 2005; Romanelli, Khessina, 2005), different kinds of location motives can drive the co-location process, each of them leading to different stability properties of the aggregate structure. One of the key criterion of these properties is the knowledge related/unrelated variety (Ashiem & al, 2007) the co-location process creates in the course of the clustering process.

*Proposition 1: cluster viability depends on the decision externalities governing the sequential co-location process*

The evolutionary way of thinking in Economic Geography (Boschma, Frenken, 2006) invites to invest the question of cluster viability in a dynamical micro-macro approach (Suire, Vicente, 2009). To appraise the cycles of clusters in the future, their success, their decline, their cyclic growth, it would be appropriate to discuss the evolving aggregate efficiency in respect with the nature of the sequential process of location decision making. Basically, the idea is that the individual motives of location decision making at each step of time of the cluster life influence the performance of the aggregate structure, while in return the evolving aggregate structure can influence and change the nature of these individual motives.

Suire and Vicente (2009) had shown that two kinds of co-location mechanisms prevail in clustering processes and engender differentiated evolutionary pathways. These mechanisms are based on location decision externalities in that location decision of predecessors influence decision of followers, but according to different motives or different constraints in the decision algorithms. For instance, Microsoft decided to locate a research plant in the Silicon Valley, even belatedly in 2001, for motives that can be supposed to be ambivalent and in some extents contradictory. On one hand, the convergence between Internet and mobile phone industry and “webservices” has required for this major company to re-locate part of its research activity. The re-location has been done close to the research activities of the major companies with which knowledge complementarities and integration permit to Microsoft to enlarge its consumer “installed base” (Katz, Shapiro, 1994). That is the so-called location *network effect*. On the other hand, it could be supposed that the Seattle company was incited to locate its plant in Silicon Valley in order to benefit from the geographical charisma and the audience (Appold, 2005; Romanelli, Khessina, 2005) the Silicon Valley displayed in this technological field. Obviously, that is due to the success some firms have acquired in this place, as Google, its main competitor. To claim to be one of the market leader and to be located out of the leading place could be a miscalculation. That is the location *audience and legitimacy effect*.

These two effects, which can interplay or not at the level of a single organization, display different cluster trajectories according to the prevalence of one of the effect on the other along the sequence of the location decision making. If the legitimacy effect prevails, Suire and Vicente (2009), using a informational cascades approach, showed that clusters can emerge and grow fast, in particular when the first adopters are perceived as having a strong reputation and economic success that they reduce uncertainty on the right place where to locate. This legitimacy can create a mimetic isomorphism (Di Maggio, Powell, 1983) and a growing cluster geographical charisma (Appold, 2005). The metaphor with financial markets and speculative bubbles can be used to explain how a place reaches to attract firms and investments. But the stability of the locational norm, as for stock market indexes, is fragile and not solidly founded on a real appreciation of the benefits of the co-location, but on the followers expectations that this place will be successful because the pioneers were successful. If the network

effect prevails, the trajectory will display a different pathway. In this case, the co-location process rests on location strategies based on voluntary connections with predecessors, for the goal of systemic production and reciprocal knowledge accessibility. Each follower gains from his connection to the network, so that the co-location process is path dependant and engenders an evolutionary stability of the aggregate structure.

Empirical literature is rather poor concerning clusters declines or cycles. Nevertheless one can notice the study of Longhi (1999) on the case of the European high-tech cluster of Sophia-Antipolis. Longhi showed that the cluster entered in a down period of the cycle at the beginning of the nineties, after a vigorous period of exogenous attraction of international plants based on a policy of territorial marketing which focused on the reputation of the first adopters. The emerging satellite platform (Markusen, 1996) stopped its growth, for reasons that Longhi imputed to the specific properties of the interaction networks of this kind of meso-structures. This example is emblematic of many high tech clusters for which the success at a moment of time can be explained by a sort of geographical charisma. This later rests on a location imitative behavior that Appold (2005) summarizes by the idea that “[Each] manager could conclude that the number of successful laboratories at a particular site is an indicator of its productivity” (p.21), without any kind of direct interactions that could insure the stability of the aggregate structure. Dalla Pria and Vicente (2006) and Vicente & al (2007) observed a more radical cluster cycle in the French Silicon Sentier. They show that the 1997-2003’ bell-shaped curve of location of dotcoms in this central place of Paris resulted from two periods. The signal sent by Yahoo and Lycos to the followers characterized the growth period. While the sudden decline and dispersed relocation phenomenon were correlative to the Internet Bubble crash and the lack of interactions between firms which would have permitted to collectively organize a new standard of e-business models. They concluded recognizing the role of the legitimacy effect on the “velocity” of the clustering process – Romanelli and Khessina (2005) speak of the weight of the external “audience” –, and stressing on the network effect for enforcing the structure beyond the standard life cycle.

Obviously, these two types of location decision externalities interplay at different moments and at different degrees in clustering processes. Cluster life cycles could result in some extents on the way and with the weight these two effects influence the clusters trajectories.

*Proposition 2: cluster viability depends on the related/unrelated knowledge variety resulting from the sequential co-location process*

Knowledge variety, which is a central concept of evolutionary economics (Dosi, 1982; Saviotti, 1996), has been recently recognized as one the key parameters of cluster long term aggregate efficiency (Frenken & al, 2007, Asheim & al, 2007).

Knowledge variety is related when cognitively distant knowledge assets are effectively combined. Indeed, technological fields, in which clusters succeed to establish themselves as leading places, could deeply differs according to the degree of heterogeneity of capabilities that are combined. For instance, some eco-innovations or “cleantech” in the agricultural sector (water-saving in irrigation, efficient land treatment, ...) are the result of the combination of strongly distant knowledge assets stemming from sectors such as satellite industry, GIS software and agricultural machinery. The foremost innovations in the tourism industry emanate from the conjunction between knowledge coming from different sectors such as travel agencies, new web medias, agro-food industry, which clearly do not share digits in industrial standard classification. Examples can be easily multiplied and the main characteristics of the clusters from which emerge these innovations concern the peculiar structural organization of knowledge relations (Owen-Smith, Powell, 2004), which permits to explore new technological windows and exploit new markets. Indeed, knowledge variety would be more related due to the complex structural properties of the network through which knowledge inputs are combined<sup>1</sup> than due to the simple co-location of *a priori* optimally and intermediary distant knowledge

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<sup>1</sup> These structural properties are developed section 5.

assets. Clusters have more chance to open new technological windows and develop new technological fields that they connect core capabilities in general purpose technologies (software, telecommunications, transport, energy, ...) with capabilities in other sectors that have to evolve according to expanding market paradigms, such as mobility or sustainability. For instance, some successful places had emerged from the cross-connection between software, media and mobile phone industry during the rising of demand for mobile media. Others has emerged from agricultural and food sectors, healthcare and energy sectors when the awareness of the risks of the climate change had reached a critical threshold in the population (Cooke, 2008).

Following our definition, knowledge variety will be unrelated, not for reasons of an excess of cognitive distance, but due to lack of structural organization that prevents the potential combination of distant pieces of knowledge to be turned into innovations. Related or unrelated variety in clusters at a given period will depend on the evolutionary location trajectories which result from the above-discussed types of location decision externalities.

Indeed, if the legitimacy and reputation effect prevails along the history of the co-location process, two scenarios could be expected. Firstly, the growing place could exhibit a strong “external audience” (Romanelli, Khessina, 2005) that attracts firms or other organizations, especially when one or the few first adopters are perceived outside to be the leading firms of a given sector (Suire, Vicente, 2009). Nevertheless, this process could engender a strong homophily in knowledge because this external audience, which is reinforced by medias, professional organizations or external links, focuses mainly on outsiders that share close knowledge resources. In this case, a cluster can grow and be identified as a key place of a particular technology development, by aggregating competitors and favoring spinoffs. This process might be also strengthened by the attraction of complementary organizations that work along the knowledge value chain, such as universities and research units, design centers or dedicated financial or marketing services. The place becomes associated to the technological field, which is generally strongly associated to a specific sector so that knowledge variety is weak. One of the most famous example is Akron, Ohio (Sull, 2001; Romanelli, Khessina, 2005; Buenstorf, Klepper, 2009), which has historically gathered a large part of tire manufacturers and the essential part of the knowledge value chain of tire industry. This historical process fits with the marshallian externalities, but also with the weight of the geographical charisma that played on the location decision of “outsiders” who search for legitimacy rather than to connect to variety. Considering the French Silicon Sentier again (Vicente & al, 2007), the fast agglomeration of e-business dotcoms, and associated venture capitalists and digital rights lawyers, had been focused on a very narrow segment of the Internet industry. That is precisely this lack of variety which slows up the innovation rate and could stop the co-location process. It could provoke a loss of legitimacy and a decrease of the external audience of the place, with, sooner or later, a reverse of the previous locational cascade. This extreme situation is typically the one observed by Vicente & al (2007) in the Silicon Sentier. They showed that the financial crash of the Internet bubble in 2000, and its consequences on dotcoms demography, had suddenly substituted denigration to legitimacy in the web entrepreneurs’ community.

Secondly, legitimacy and reputation effects in location decision making could lead to knowledge unrelated variety – at the opposite of knowledge homophily just above-discussed – when the co-location mimetic process is based on the belief that some places symbolize the “ideal-type” of intensive and efficient R&D places, whatever the industrial sector. The presence of a famous university, modern facilities, the support of local and sometimes national elites, a certain way of life fitting with the creative labor force expectations, are the main features which are generally captured in the initial conditions of the more successful science parks (Longhi, 1999; Appold, 2005). This form of clustering process corresponds to a social influence process (Appold, 2005, Watts, 2007; Suire, Vicente, 2009): firms decide to locate on a particular place by arbitrating between the weakness of information on each alternatives and the signal of the research productivity of the predecessors. This “be and be seen” attitude (Appold, 2005) played a key role in the development of science parks and technopole in the eighties. In these structures, knowledge variety can be strong, because the signal refers to a general assessment of the research productivity and the world-wide identification of the place, rather than a particular knowledge specialization of the predecessors. Nevertheless, this variety



is unrelated, because social influences and legitimacy effects play at the level of the *ex ante* observation of location decision of others, without any assurance of *ex post* direct knowledge interactions. The aggregate structures are close to the “satellite platform” model that Markusen (1996) observed and described, *Research Triangle Park* being one of the most famous examples (Appold, 2005). Satellite platforms emerged generally from the willingness of local or national elites to create legitimacy effect by a fitted territorial marketing strategy, and subsidies, designed to attract research plants of knowledge-based companies. First movers can set in motion followers so that the cluster grows by the attraction of unrelated branches of externally based multiplant firms. The key feature of the resulting regional structure is “*the absence of any connections of networks within the region and the predominance of links to the parent corporation and other branch plants elsewhere*” (Markusen, 1996, p. 304). But according to her, and confirmed by the specific case of Sophia-Antipolis investigated by Longhi (1999), this type of cluster could exhibit a chronic instability. Indeed, the effect of reputation and legitimacy of the place on the attraction of plants, which is a strong contribution to the regional development, could not counteract the observed weakness of endogenous growth of spinoffs and render vulnerable in the long term the success observed at a given period. The only way to reduce this growth vulnerability is that spinoffs broke knowledge in order to turn unrelated knowledge variety into related one, but the particular features of satellite platforms restrains the probability of such a crossed-knowledge process, due to the fact that strategies and decisions are made mainly externally (Longhi, 1999).

At the opposite, related variety has more chance to be the feature of clusters when location decision externalities based on networks effects prevail along the evolutionary trajectory of the co-location process. The pure legitimacy and reputation effects imply a wide spectrum of scenario between a great knowledge variety and a strong knowledge homophily. Conversely, network effects play at the level of the *ex ante* observation of the followers on the possibility to connect their knowledge with the one of the predecessors and thus can imply an *ex post* high level of relatedness since followers search for knowledge complementarities. In this case, clusters grow by endogenous and exogenous effects. (i) Spinoffs emerge, connect separated knowledge, and explore new knowledge combinations. (ii) Outsiders are attracted by the accessibility of knowledge, whereas insiders find opportunities to connect to new entrants due to the diversification of applications in which their knowledge can be introduced in. Variety will thus be even more related that the individual motives for location refer to the search for network effects in technological integration. This proposition converges with Saxenian idea for who “*Silicon Valley is a regional network-based industrial system that promotes collective learning and flexible adjustment among specialist producers of a complex of related technologies*”, putting the network effects on related technologies at the core of the aggregate structure stability and viability (Suire, Vicente, 2009).

#### **4. Composite Technology Life Cycle (CTLIC) and clusters viability**

In parallel to the location decision externalities, cluster viability and life cycles maintain complex relations with the cycles of technological fields, even if the dynamics of the former cannot be reduced to the one of the later. Literature on these relations is well-documented (Audretsch, Feldman, 1996; Klepper, 1996; Menzel, Fornahl, 2007). A cluster can go through a long period of stability and growth while the technological field at the origin of its development declines. At the opposite, a cluster can enter into a decline period even before the technological field reaches its maturity, due to the competing and selection pressures between clusters along the cycle of the technological field. Moreover, product cycles depend on consumers demand conditions, so that the links between cluster and technological field life cycles cannot be studied without any considerations and feedbacks from market dynamics. Indeed, market conditions and the level of the consumers demand for a technology influence the chances of the technological field and the dedicated clusters to reach maturity. But conversely, the demand conditions will be even more conducive to the technology diffusion that the structural and geographical organization of the technological field permits to turn new ideas and very upstream knowledge into dominant designs, cheap and standardized technologies.

*Proposition 3: clusters viability depends on the way that organizations succeed in crossing over the chasm between the early and the mass-market.*

Product life cycle (PLC) is a well-documented topic in the economics literature (Rink, Swan, 1979). Based on the well known work of Everett Rogers (1962), most of the technological products tend to follow a sigmoid diffusion trajectory. The model of Rogers implicitly supposes a technological determinism. As soon as the product begins to diffuse into the market at time 0, it passes through all categories of consumers (innovators, early adopters, early majority, late majority and laggards) such as at time T the product dies. In that way, the different stages of product life correspond to an introduction, growth, maturity and decline stages. But the characteristics of technological products do not perfectly fit within this framework, particularly due to the existence of a “chasm”, identified by Moore (1991), especially on technological markets. Geoffrey Moore has developed a convincing complementary approach of Rogers theory of diffusion. He proposes to differentiate two kinds of high tech markets, the early markets and the mass markets; between both, a chasm that a technological product does not cross over naturally. The main explanations rely on the type of consumers who demand some specific characteristics of their products. In the early market, (defined with a representative consumer of type  $\theta 1$ ) consumers are visionary in the sense that they would accept a non-zero default product, “*they want to start out with a pilot project which makes sense because they are going where no man has gone before*” (Moore, 1991). Products are defined by many characteristics: functionalities, design, ergonomic and more generally symbolic features such as mobility, bio-health, wired life style for instance. Most of the time, the product is an on-development product and co-evolve with the feedback of consumers. Concerning the industry, there is a high uncertainty on the level of demand and profitability leading to highly volatile profits. Many products did not succeed to cross this chasm. For example, at the level of a single organization, at the beginning of the 1990’s, the Compact Disc format is the dominant standard for digital music. Sony tried to impose a new and portable device with mini disc players. The features were original in the sense that mini discs allowed recording in a new compressive format favoring a new way for portability and mobility. But if the product diffused in local market of Japan through a  $\theta 1$  type of markets (musicians and audio enthusiasts), it did not succeed in crossing the chasm and did not dominate the market of portable and recording digital music in other countries. Excessively high price and a proprietary format and design are commonly accepted explanations. This typical situation at the level of an organization can be arise also at the level of the firms agglomerations. Vicente & al (2007), concerning the above-discussed case of the French Silicon Sentier, associated partly the sudden decline of the agglomeration of dotcoms to the disconnections between the expectations of consumers in terms of quality and security of electronic transactions and the unsettled models of pricing strategies and technological choices.

Conversely, on the mass market (defined with a representative consumer of type  $\theta 2$ ), consumers are pragmatists and “*care about the company they are buying from, the quality of the product they are buying, the infrastructure of supporting products and system interfaces, and the reliability of the service they are going to get*” (Moore, 1991). To put it differently, they just want zero-default products, well fitted with their needs and at the best price. By consequence, the internal dynamics of an industry would be different because of the nature of the market but also because of the characteristics of the demand. Klepper (1996) and Klepper and Simons (1997) have highlighted this point. The former suggests that the couple exit/entry and the intensity of R&D are no longer stable over the PLC. Precisely, at the beginning of a cycle, there is a high level of entries within the industry and these firms, small ones most of time, are responsible for innovative products or processes. Many of them will die before the product reaches the mass market. But, some of the successful vertical integrated firms who will dominate this cost oriented  $\theta 2$  market was most of the time present on the early market. At that time, the level of entries is rather low, as Klepper and Simons (1997) empirically showed for four industries.

These results are also particularly in accordance with PLC approach of Abernathy and Clark (1985) and Utterback and Abernathy (1975). Fundamentally, for them, there are three phases along the PLC.

There is a *fluid phase* where technological and market uncertainties prevail. It is almost a large experimentation game in the market place and many small firms base their advantage on differentiated product features. Companies have no clear ideas on potential applications for the innovation, nor on what direction the market might grow, but this is conform to what consumers of type  $\Theta 1$  want. In a sense, this is a very open structure where new entrants or new connections would play a crucial role. Then, there is a *transitional phase*. As producers start to learn more about the potential technology applications and about consumer's needs, standardization will emerge. Precisely, this phase is strongly featured by the appearance of a *dominant design* (Abernathy, Clark, 1985). In the words of Utterback (1994) "*the dominant design product has features that competitors and innovators must adhere if they hope to command significant market share following*". The product innovation is now incremental and firms will use strategies to consolidate their position in order to succeed in the battle of dominant design. They start increasing production capacity and process innovation in order to face the next phase, the *specific phase*, where consumers are  $\Theta 2$  type. Now the competition has shifted from differentiation to product performance and price competition. Firms have well identified the characteristics of consumers and have a clear picture of the market segments. The market moves toward an oligopoly and incumbents are able to secure their position through supplier relations, distribution channels and other complimentary assets that will create barriers to new entrants. In accordance with Klepper (1996), "*the number of producers grows initially and then reaches a peak, after which it declines steadily despite continued growth in industry output*".

The industrial dynamics within a particular technological field is partly the consequence of the position over the PLC but also, and it is a corollary, of the nature of the demand. Inevitably, this also means that the nature of the demand has impacts on the spatial organization of innovative firms. Audretsh & al (2008) have tested the proposition of a region life cycle. They show that a routinized phase where innovation takes place within top-performing incumbents succeeds to an initial entrepreneurial phase where Jacobs externalities and inter-industry start-ups prevail. From a certain point of view, this recent work is in line with an older one (Audretsh, Feldman, 1996). Indeed, the purpose was to understand the way an innovative activity tends to spatially cluster or not according to the stages of the industry life cycle. As tacit knowledge prevails in the early stage of an industry life cycle, the geographical proximity plays an important role to diffuse knowledge spillovers. On contrary, innovative activity tends to be more highly dispersed during the mature or declining phase. In such a framework, cluster life cycle could be even more shorter than the cluster collective organization does not cross over the chasm. Moreover, the cluster life cycle could be shorter than the product life cycle, even if the product reaches  $\Theta 2$  consumers, if its entrepreneurial dynamics does not match with an overlap of technological phases and market demand for new products (Menzel, Fornahl, 2007).

*Proposition 4: The cluster viability depends on the evolution of elementary bases of knowledge along the composite technology life cycle (CTLC)*

Technological products are fundamentally for most of them composite products combining knowledge coming from different organizations and knowledge environments (Antonelli, 2006). Indeed, successful technologies and new markets emerge frequently from the crossing of other previous separated technologies and markets. Beside the traditional phases of exploration and exploitation firms invested in their "isolated" innovation process, firms can also enlarge their technological market by forming partnerships based on a mutual knowledge accessibility. This intermediate phase requires additional R&D, a mutual understanding and engineers mobility (Nooteboom, 2000), due to the compatibility constraints and engineering processes these combinations imply. This additional phase has been invested by Cooke (2007), who proposes to separate knowledge production in three stages. Based on the classic distinction between exploration/exploitation phases (March, 1991), Cooke proposes to add a phase of examination between both. Thus, there is a necessary phase of exploration in order to innovate in some right ways on the market but a necessary phase of exploitation in order to be competitive on markets. Therefore, firms have to manage the way their internal resources are affected to these phases. The couple exploration/exploitation co-evolves along the PLC whit the characteristics of the demand and successful organizations are those who succeed in this ambidexterity

management (Raisc and Birkinshaw, 2008). Regarding composite goods, as many technological are, a phase of examination is always a necessary condition to cross the chasm. When the dominant design is not well defined and firms are on the early market, it appears very difficult to succeed without partnership. The technological product is supplied by a collection of firms and organizations or similarly by an opened cluster that permits for each organization to enlarge the potential tradability of its own technology by combining it with the one of the other(s). Many IT clusters respond to this examination phase in which each organization succeeds in extending its own market crossing digital technologies with media, phone industry, cleantech, biotech and so on (Cooke, 2002).

In order to have a better understanding of the knowledge value chain of the composite knowledge processes, one can split up the production of a technological composite good into 4 non independent sub-activities more or less present. Each one is related to a category of organizations and/or industrial strategies. Following Asheim (2007), we distinguish between 3 types of knowledge bases. The first one is analytical (a1) and concerns scientific knowledge often based on deductive processes and formal models, while the second is synthetic (a2) and refers to applied problems and engineering solutions often based on inductive cognitive processes. Put another way, the first phase tries to codify pieces of knowledge through patents or scientific publications, while the second one is more tacit and tries to combine these different pieces of knowledge in a more market oriented way. The third base helping to succeed in the market concerns symbolic features (a3) of technological products and requires a design and art approach of the technology. It helps making the technology friendly. Finally, we propose to add a fourth knowledge base: the price, cost and marketing strategies (a4), which have to fit with consumer preferences needs. This cost-oriented industrial configuration constitutes a fourth specialization. We then assume that regarding the degree of maturity of a product or the position along the CTLC, a technological field (T) is then structured by a previous activities pre-order and a convex combination of these fourth bases, such that  $T = \sum_{i=1}^4 \lambda_i a_i$ , where  $\sum_{i=1}^4 \lambda_i = 1$ . For instance, a technological field defined with the vector  $\{\lambda_1 = 0.6, \lambda_2 = 0.3, \lambda_3 = 0.1, \lambda_4 = 0\}$  is immature, composite technologies are beta-version and mostly supported by intensive fundamental research while marketing and/or price strategies are inexistent. Conversely, the following vector  $\{\lambda_1 = 0.1, \lambda_2 = 0.3, \lambda_3 = 0.2, \lambda_4 = 0.4\}$  defines a mature technological field which produces standardized products or services and most of all structured by price and cost saving strategies.

Following this definition, the  $\theta 1$  market type is then characterized with the following pre-order  $\lambda 2 > \lambda 1 > \lambda 3 > \lambda 4$  while the  $\theta 2$  market is defined by this pre-order  $\lambda 4 > \lambda 3 > \lambda 2 > \lambda 1$ .

The following figures resume our purpose.

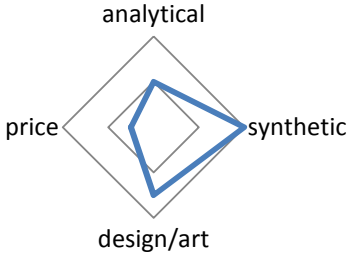


Figure 1 -  $\theta 1$  market

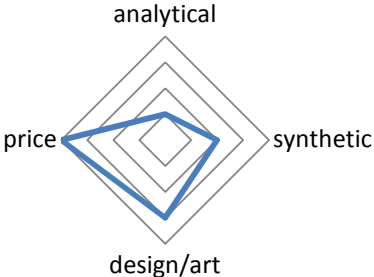


Figure 2 -  $\theta 2$  market

Table 1 summarizes the firm strategies and the degree of standardization behind the supply of composite technological products.

	$\theta 1$ : early market	$\theta 2$ : mass market
Analytical (a1)	Rather unstable, research and very upstream beta-tests, differentiation strategy	Stable, economics of scale
Synthetic (a2)	Rather Unstable / engineering and development of a beta-technology for an expected tradability	Stable / update version
Symbolic, design/art (a3)	Ergonomics and customization	Stable
Marketing and price strategy (a4)	Unstable or niche strategy	Price discrimination
Phase cycle	Fluid phase	Specific phase

table 1 - co-evolution of knowledge bases and market phases

This table calls for two further comments. It appears that the phase of examination or the necessity to integrate efficiently different pieces of knowledge is a necessary condition to cross the chasm in order to be competitive on the mass market. This corresponds to the transitional phase in the words of Utterback. The second one is that there is a market, or a “beta-test market” with a representative consumer named  $\theta 0$  where firms are in a highly intensive explorative phase. It also means that analytical knowledge base is the main activity which fuels the technological field, and price strategies as well as design activities are absent. Figure 3 represents this configuration.

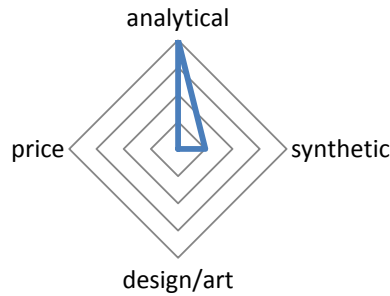


Figure 3 -  $\theta 0$  market

By consequence, along the CTLC, the dominant form of knowledge production (1 for dominant, 3 for dominated) determines the type of supplied products but also the features of the market to reach. *Table 2* summarizes our concerns.

	$\theta 0$	$\theta 1$	Chasm	$\theta 2$
Knowledge base				
Analytical	Unstable	Rather unstable	Standardization and dominant design	Stable
Synthetic	Unstable	Tradable beta version		Update version
Design/art	Unstable	Customization		Stable
Mkt and price strategies	Not established	Unstable		Price discrimination
Knowledge prod phase				
Exploration	1	2		3
Examination/integration	2	1		2
Exploitation	3	3		1

Table 2 - co-evolution of knowledge phases and CTLC

Individual characteristics of representative consumers are not stable along the CTLC, so that clusters have to organize themselves in order to provide a composite technology that fits well with the demand. In order to be competitive in the “beta-test market”, clusters have to be very open in order to maximize this relational exploration phase. This openness is defined by a high concentration of activities due to

the exchange of tacit (Audretsch, Feldman, 1996) and analytical knowledge (Asheim, 2007), and by weak ties with knowledge-intensive organizations (Owen-Smith, Powell 2004), ie, public research organization and inter-sectoral start-up and spinoffs. A necessary condition of a successful introduction of a composite technology in the early market is that a phase of integration has now to be dominant, even if explorative phase is still active, especially because business models and features of the technologies are not yet stabilized.

In synthesis, clusters which provide pieces of composite knowledge are defined by a “magic square”, in which the summits represent the elementary knowledge bases that shape the internal organization and the positioning of the cluster along the CTLC. By the way, the clockwise rotation appears as a critical feature of the viability of clusters.

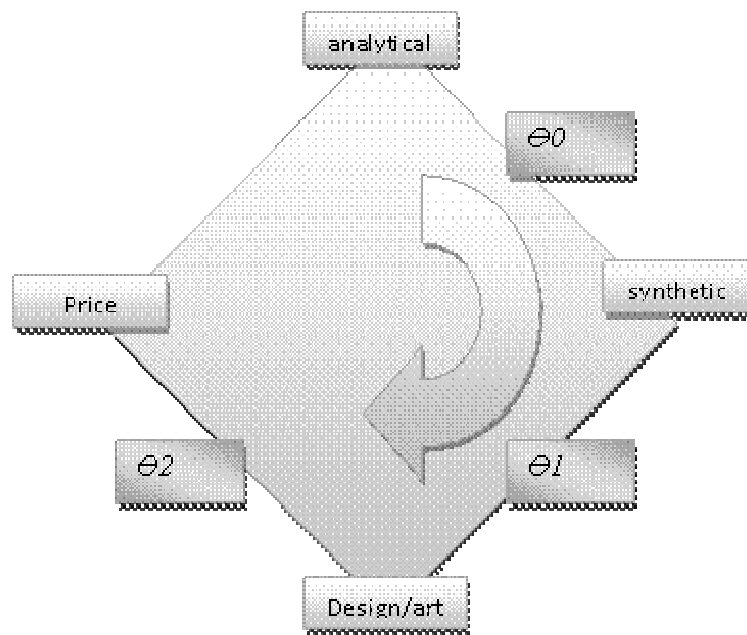


Figure 4 - Co-evolution of markets and knowledge bases

As for the individual motives that govern the location decision making, the case of Microsoft, once again, is an interesting stylized illustration of the way by which the CTLC interplays with knowledge relations in evolving clusters. Microsoft decided to locate in Silicon Valley in 2001. Dan’L Lewin is the former vice president for .NET business development strategy within Microsoft. At this time, Microsoft is a leader on the mass market for software but encounters some difficulties with the market turning point of web services. Indeed, in 2001, web services are typically located on the very beginning of the CTLC (beta-test and early market). By opening a research lab in Silicon Valley, Microsoft tries to maximize its own explorative activities by managing efficiently its alliance with inter-sectoral start-ups as well as with public research organizations, in order to get access to the analytical knowledge of distributed computing. Microsoft wants to benefit from the local territorial resources in order to define and refine the open standard XML, the one which allows data portability between services and devices. One of the objectives for Microsoft is then an attempt to make software and services available whatever the platforms: PCs, handheld computers and cell phones. For that, Microsoft needs to embrace and absorb the knowledge on open standards that are developed in the valley. Lewin said at this time “ *I believe our commitment to these standards, and the complement of what goes on in the Valley, will create great opportunities*” and “ *have seen dozens of companies in*

*less than a year materialize a relationship with Microsoft. It's immensely satisfying to be part of identifying opportunities” (SeattlePI.com, 03/08/2002).*

Finally, and in order to cross the chasm and succeeding in introducing a composite product to the mass market, the exploitation phase has now to be dominant, even if a regular update process of the products engenders intra industry spinoffs, as shown empirically by Audretsh and al (2008). In that phase, the technological field has reached its maturity and could be geographically dispersed, even if clustered structures could co-exist and being organized according to the hub and spoke topology which is typical of mature industries (Markusen, 1996). In this framework, a particular cluster will reach its maturity since it succeeds in covering the integration of these knowledge bases in the knowledge value chain. Then its long term viability will depend on the one of the technological field as a whole, but also on its intrinsic resilience capabilities that appear in the transition from  $\Theta 2$  market to  $\Theta 0$  market and that are the necessary condition of the technological overlaps and of the cluster self-reinforcement mechanism.

## **5. Network structural properties and clusters viability**

Clusters are more or less cohesive localized structures that display interesting structural properties in terms of knowledge distribution, accessibility or appropriability in a particular technological field (Owen-Smith, Powell, 2004). The noteworthy researches of Storper and Harrison (1989) and Markusen (1996) previously emphasized the heterogeneous structuring of firms' agglomerations, using monographs and classifying each ones into aggregate categories. Network density, clusters inside/outside relations, are the main parameters that determines these categories, and give an overview of the coexistence of cluster structural forms. Recently, regional scientists went further on this topic by using Social Network Analysis (SNA) for the empirical treatment of relational data (Owen-Smith, Powell, 2004; Guiliani, Bell, 2005; Boschma, Ter Wal, 2007. Vicente & al, 2008). Using a set of quantitative structural indicators and efficiency criteria, this methodology permits to highlight how technological fields are organized and how pieces of knowledge flow and combine themselves along the knowledge value chain. Moreover, organizations display different role and position in a network and in the structuring of a technological field. In particular the embeddedness of a cluster in its technological field depends on the specific role of some geographical gatekeepers (Rychen, Zimmermann, 2008) that broke relation between clusters insiders and outsiders (Gould, Fernandez, 1989). Whereas the way by which the same cluster will be embedded in its local technological environment will depend on the specific knowledge gatekeeper organizations that broke local relations between organizations working in disconnected technological fields. Some of these structural properties can thus be particularly appropriate to study the viability of geographical clusters in relation to their innovation rate, their internal organization and their position (in) and connection (to) the whole of the technological field.

*Proposition 5: clusters viability depends both on the density of their internal knowledge relations and on the way by which there are connected or not to the whole of the technological field.*

The first hypothesis of this work stressed that clusters viability cannot be appraised without focusing on the technological field as a whole. And supposing that this latter can be represented by a network structure, thus, clusters appear as significant sub-networks that display a more or less cohesive structure in a same place and are connected to others in the field. One of the first critical parameter of network structures that permits to highlight this “embedded clusters” hypothesis is the density of relations. It is simply defined as the ratio of actual relations to the number possible relations and thus gives a good measurement and marker of the connectivity of the network. Obviously, a network with fully connected nodes is an extreme case that is far from the reality as well as from an efficient structure. Indeed, fully connected networks, geographically clustered or not, display redundancies in knowledge flows (and thus excessive transactions costs), and engender risks of knowledge under appropriability due to the absence of arms-length relations (Uzzi, 1997). At the opposite, a network with very few connections between nodes traduces the existence of a technological field in which knowledge flows through a limited number of pathways. In this extreme case, the network structure

implies a narrow range of knowledge inputs combination, and innovations, if they occur, come from more or less isolated organizations. Density of the network is thus a good indicator of how knowledge variety is connected and how knowledge spreads through different pathways in the structure. Moreover, the distribution of links in the whole technological field can display geographical features of denser local relations so that clusters can be identified as significant cliques in the aggregate structure. This cliquishness property, i.e groups of nodes that are more closely tied between themselves than with other nodes, reveals that geographical proximity matters for innovation since cliques are geographically localized. But non local relations can play either a central role in the global structure, as discussed by Bathelt & al (2004) and Rychen & Zimmermann (2008), so that clusters viability and cycles depends on their internal organization as well as their connectivity to the global network through a limited number of geographical “gatekeepers” (Gould, Fernandez, 1989).

For instance, Owen-Smith and Powell (2004), using SNA on a dataset of biotech patents and strategic alliances in Boston cluster, compared the same bio-technological field dynamics in two different geographical scales and showed that the cohesive structure in the Boston cluster rests on the active participation of public research organizations, whereas large companies and venture capitalists are the central nodes of the “Boston + network”, i.e the network including all organizations in any locations having a tie to an institution of the Boston sample. More precisely, in the Boston cluster, the public research organizations, which are preeminent in the upstream explorative phase, play a very “leakier” role and water the local structure by connecting non connected organizations. Moreover, when the technological field reached a certain level of maturity and knowledge diffused in the wide “Boston + network”, venture capitalists and integrative big companies became central in the market strategy and display a strong structural weight in the extended network by posit themselves as geographical gatekeepers. This result suggests that local explorative phases co-exist with wider phases of knowledge exploitation on markets, and strengthens the previous fieldwork-based observations of Storper & Harrison (1989) and Markusen (1996) concerning the *hub and spoke* structure of many clusters, and the importance of their outside connectivity. Vicente & al (2008), used a close empirical methodology on a dataset of collaborative projects in navigation satellite systems. Navigation Valley – the Midi-Pyrenean cluster of navigation satellite systems – is a clustered local structure that is embedded in a wider European (and world-wide) network and thus homes organizations that mix local and non-local knowledge relations. They found out that a strong local cliquishness between spinoffs, public research organizations and big companies of the satellite industry in Midi-Pyrenees region co-exist with a limited number of structural bridges between the later and other big European satellite companies. Results showed that the local density of relations are based on the combination of knowledge coming from different sectors (satellite, software, telecommunications, air fleet management, tourism, transport, ...) in explorative and integrative knowledge phases; whereas European “pipelines” between incumbents and public agencies of space industry rests on strategic alliances devoted to market exploitation and standardization constraints. Thus, the viability and development of the Midi-Pyrenean cluster depends on how the local interaction structure permits to connect knowledge variety but also on the ability of the geographical gatekeepers to cross over the chasm of the diffusion process and transform new ideas and knowledge into dominant designs and standards.

*Proposition 6: clusters viability depends on the existence of a core/periphery structure that favors resilience*

Beside the cliquishness property, the overall density of knowledge relations in a cluster can also display a core/periphery structure (Borgatti, Everett, 1999), in a structural rather than a geographical sense. For an average level of relational density in a cluster dedicated to a specific technological field, some organizations can have a high density of relations between themselves by sharing and combining knowledge intensively in the “core” of the cluster, while some other organizations having a low density of links between themselves and with the clustered organizations of the core can be located in the “periphery” of the relational structure. Barabasi (2005), focusing on the long term evolution of scientific networks, has shown that core/periphery structures are concomitant to the gradual



structuring of knowledge fields. Networks do not evolve at random. A network will evolve through a clustering process that enhances the coreness of the network (Cattani, Ferrina, 2008), while more marginal “players” remains weakly connected to the core, even if they could be weakly connected to another networks. The cohesive structure of the core leads their members to stabilize and share conventions and exploit efficiently their outputs, whereas peripheral members constitute a pool of new and fresh ideas. Then networks evolve and can grow through the particular role of organizations that connect the core and the periphery, strengthen the core and favor the existence of a permanent periphery, as observed by Uzzi and Spiro (2005) for the evolving network of Broadway artists.

Organizations that are embedded in the core of the structure are able to coordinate their action, exchange knowledge and favor its circulation, while the others located in the periphery are not. Core/periphery structures are rather efficient since they combine a level of cohesiveness that improve the knowledge seeking and matching in all the core, multiplying pathways and reducing distance, with the necessary openings towards “distant” knowledge in the periphery. Organizations in the core have a greater cumulative experience and a strong embeddedness in the technological domain, but may find it difficult to renew their knowledge and explore ideas that do not conform to the established standards. A clustered network without periphery can suffer the consequence of a lock-in when market conditions evolve more or less suddenly.

Then, this structure fits well on one side with the composite knowledge value chain of technologies which requires performing the integration and exploitation of technologies in conformity with the current consumers demand. On the other side, when current markets enter in a phase of decline, they permit to strengthen few but strategic explorative ties with well-targeted organizations that operate in related technological fields. A core/periphery is thus suited to overlap knowledge processes and knowledge phases while a pure cohesive structure is not. Organizations that broke relations between the core and the periphery play thus an important role in the structure. In particular, when organizations at the periphery of a cluster dedicated to a particular technological field are also connected to another technological domain, the organizations in the core that are tied with the periphery are the essential players of the cluster evolution due to their knowledge gatekeeper role. Romanelli and Khessina (2005) observed the role that plays this overlapping process in the evolution of places. They showed that the places strengthen all the more their regional identity and their innovative performance that, at each step of time, the dominant technological field of the place is related to smaller ones. In a same way, Cooke (2008) observed that cleantech clusters arise from the overlapping process of originally disconnect Jacobian clusters, through the peculiar role of entrepreneurs that posit themselves locally as vehicles by which capabilities in one sector mutate into another.

## 6. Discussion

Cluster viability and cycles are thus strongly correlated to three categories of critical parameters: (i) the nature of location decision externalities and the resulting knowledge variety the co-location process engenders (*propositions 1 and 2*); (ii) the particular diffusion process of composite technologies from the beta test market to the mass market (*propositions 3 and 4*); (iii) the structural properties of clusters and the role of geographical and knowledge gatekeepers (*propositions 5 and 6*). All these critical parameters interplay in the long term cluster dynamics. A first overview considering competing clusters in a technological field gives an overall explanation of how they interplay. A more precise analysis based on scenarios displays the main evolutionary and structural pathways along the market phases of composite technologies.

### 6.1. A first overview on cluster life cycles

The viability of a technological field ( $T$ ) can be appreciated according to the linear convex combination of the four knowledge bases developed in section 4 (analytic, synthetic, symbolic/art/design, marketing/price strategy). In this framework, each cluster  $C$  represents a sub-

network of this technological field, so that their respective viability depends partly on the way with which these knowledge bases are combined inside them. If we consider that  $T=f(C1, C2, \dots Cn)$ , the set of clusters  $C$  that belong to the technological field  $T$ , then, following *proposition 4*, each cluster can be defined by a vector of knowledge  $Cn(\lambda_{n1}, \lambda_{n2}, \lambda_{n3}, \lambda_{n4})$  where  $n_i$  is the contribution of cluster  $n$  to the knowledge base  $i$ . Following this definition,  $\lambda_1$  can be written as  $\lambda_1 = \sum_{j=1}^n \lambda_j 1$  where  $j$  labels each cluster. Due to the structural and historical heterogeneity, clusters differ according to their peculiar combination of knowledge bases. Suppose 3 clusters ( $C1, C2, C3$ ) that are contributors to a technological field  $T$  on the beta test market  $\Theta_0$ , and suppose that  $C1=C1(0;0;0.5;0.5)$ ,  $C2=(0.6;0.4;0;0)$  and  $C3=(0.3;0.4;0.3,0)$ .  $C2$  and  $C3$  are very active contributors to the very upstream phase of the technological field value chain while  $C1$  is not. Conversely, if we reach the mass market  $\Theta_2$ , then  $C1$  is now well positioned due to its capabilities on more cost-oriented activities, while  $C2$  is not. Obviously, these parameters are not static and their combination evolves according both to the nature of location decision externalities (*proposition 1*) and the relational structure of the embedded organizations (*propositions 5 and 6*). For each cluster, the vector of knowledge bases can evolve through an endogenous and an exogenous process. Related spinoffs and network effects as well as audience and legitimacy effects can reshape these combinations along the knowledge value chain as well as the size and the relational structure of each cluster. But the most important question at this stage refers to the links between the CTLC and the dedicated clusters one. The dynamics of the later depends on the dynamics of the former. If the technological field exhibits a weak level of compositeness, that is to say that technologies do not tend to cross many applications in many sectors in a phase of knowledge integration that require engineering and synthetic knowledge, then the product life cycle will be shortened as well as the dedicated clusters *per se*. This technological phase is typical to the  $\Theta_1$  early market in which technologies have to be set up as standards that integrate themselves in various technological systems. Conversely, in this  $\Theta_1$  phase, if the technological field is more opened and find integration opportunities in larger technological systems leading consumers to increase their willingness to pay for the standard, then the product life cycle will be time extended and the clusters that managed these integration phase in the  $\Theta_1$  market succeeded in crossing the chasm, while the others declined. At last, even for clusters that have succeeded to go through the chasm from the beta test market  $\Theta_0$  to the mass market  $\Theta_2$  by positioning themselves as dominant clusters in the technological field, they could not pursue their development without a strong capability of resilience once market demand decreases and technological standards decline in long term. In that case, clusters can exhibit longer cycles than technologies if they home entrepreneurs – the local knowledge gatekeepers – in upstream phases of knowledge processes (mainly  $\lambda_1$  and  $\lambda_2$  knowledge bases) that are able to redirect their basic competencies and tacit knowledge in a overlapping process with an emergent technological field (Cooke, 2008). Clusters which exhibit an excess of specialization in the downstream phases of the knowledge value chain are excluded of this resilience mechanism – the cluster  $C1$  in our example –. For the others, the structural properties of clusters and the particular broker role of some embedded organizations could play in favor of this resilience. The resilience of clusters, which can be defined as the endogenous process by which a relational structure prevents lock-in effects in a technological field, constitutes the *missing link* between the  $\Theta_2$  and  $\Theta_0$  markets of the figure 4.

## 6.2. Scenarios of cluster life cycles

Considering this overview on cluster life cycles, *figure 5* furnishes a highlight of various scenarios that rest on a particular combination of the above-discussed propositions. These scenarios appear in the five black boxes of the figure. Each one corresponds to a particular trajectory in which location decision externalities (Suire, Vicente, 2009) and evolving network structures (Barabasi, 2005; Boschma, Frenken, 2009) interplay along the composite technologies diffusion and cycles from  $\Theta_0$  to  $\Theta_2$  markets.

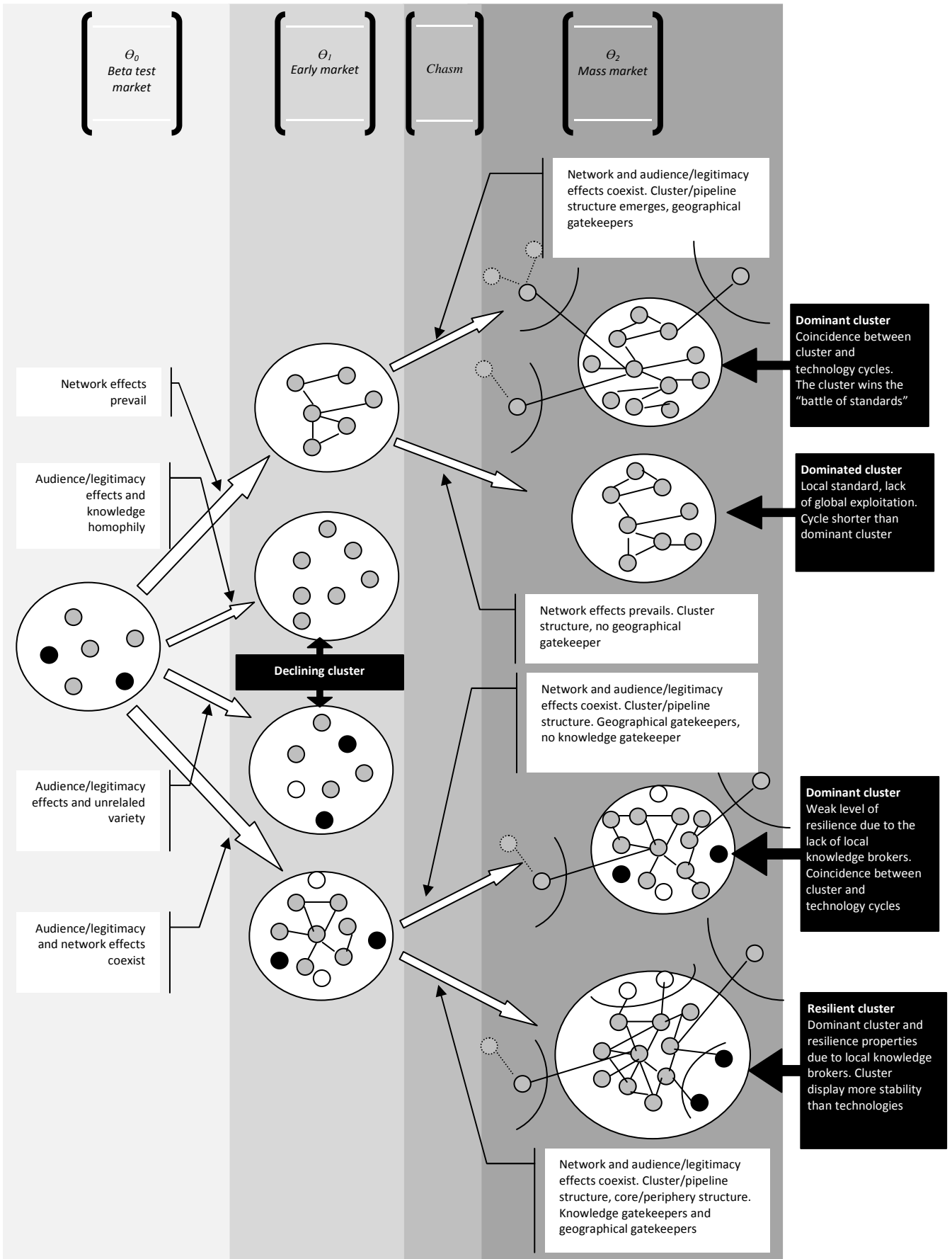


Figure 5 – life cycle of clusters

- *The declining clusters*

Figure 5 displays two typical situations of declining clusters, i.e clusters that for different reasons do not cross the chasm between the early market in which technologies exist and the expected mass market. Literature is poor concerning the clusters failures even if some cases presented in section 3 give interesting explanations. Starting from a  $\Theta_0$  beta-test market in which an emerging technological field is mainly supported by analytic knowledge in a very scattered network (a high value of  $\lambda_1$  in the  $\Theta_0$  market), declining clusters, among the clusters that are involved in this field, are the ones that grow only through an external audience and legitimacy effect. In the first case (the upper one), the external audience and legitimacy effect plays on the belief that some of the leaders of the emerging technological field are located there (*proposition 1*), so that a locational cascade occurs associated to a strong knowledge homophily in the place and a lack of knowledge interactions. The aggregate structure enters thus in the  $\Theta_1$  early market with a deficient interaction structure: the core of interactions between analytic, synthetic and engineering knowledge that defines and stabilizes a technological standard does not emerge. A lack of  $\lambda_2$  knowledge can explain such a situation. Conversely, an excess of knowledge homophily engenders for organizations a risk of under appropriation of their internal knowledge (*proposition 2*). This risk prevents the strengthening of the network and prevents the analytical solutions to be turned into practical and tradable ones. Following *proposition 1*, the aggregate structure displays fragility, in particular when another cluster succeeds in setting a competing standard (the *dominant cluster* in the following scenarios), or when the “first leader mover” at the origin of the locational cascade decides to relocate elsewhere. The short success story of the French Silicon Sentier developed previously (Vicente & al, 2007) corresponds to this scenario. The second case occurs when audience and legitimacy effect plays at the regional level rather than the organizational level (Romanelli, Khessina, 2005, Appold, 2005). A particular place which symbolizes the “ideal type” of intensive and efficient R&D places, whatever the industrial sector, will attract organizations that focus on  $\lambda_1$  and  $\lambda_2$  knowledge bases in a decentralized and “jacobian” process. Following *proposition 2*, in spite of the intensive effort of research, the excess of knowledge variety and non-coordinated activities among organizations impede the expected clustering process to emerge and, as in the previous case, isolated knowledge strategies do not benefit from the critical mass of connected organizations that permits to cross the chasm that follows the early market (*proposition 3*). The decline of the Sofia Antipolis platform (Longhi, 1999) at the middle of the nineties corresponds to this situation.

The external audience and the capital of reputation some places exhibit at a moment of time do not constitute a sufficient condition of a stable evolutionary pattern of clusters. This result converges with the one of Romanelli and Khessina (2005). Here, the two opposite cases of knowledge homophily and unrelated variety developed in *proposition 2*, and the resulting lack of cohesiveness in the aggregate structure, explain these trends.

- *The dominated clusters*

Starting now from the right of the *figure 5*, dominated clusters correspond to a particular case of clusters that succeeded in crossing the chasm from the  $\Theta_1$  early market to the  $\Theta_2$  mass market (*proposition 3*), but with a risk of instability and decline due to a weakness in  $\lambda_4$  knowledge bases. These clusters reached their maturity by a strong prevalence of network effects in the co-location process along the phases of the development of the technology (*propositions 1* and *2*). These clusters gain in cohesiveness as far as external organizations and endogenous spinoffs make connections and relate variety with the core of initial innovators, in order to bring complementary pieces of knowledge and enlarge the spectrum of tradable applications. This growing process based on an active phase of knowledge integration & engineering ( $\lambda_2$  knowledge bases) allows to set up a viable local standard on the mass market (*proposition 3*), due to the increasing satisfaction the pragmatic consumers gain from the effort of the core organizations of the cluster to propose a reliable and well designed product ( $\lambda_3$  knowledge bases). Nevertheless, this type of cluster could exhibit fragility when their structural properties go far from the efficient cluster/pipeline structures developed in *proposition 5*. Indeed, considering that exists a strong parallel between competing technologies and competing clusters, the

battle of standards can have its counterpart in the battle of clusters. In this context, even if a cluster succeed in crossing the chasm, its long term viability depends on the way by which some of these core organizations manage the exploitation phase of technologies. Without a world-wide networks of relations that permits to match the incremental innovations ( $\lambda 3$  knowledge bases) with an appropriate cost-oriented strategy ( $\lambda 4$  knowledge bases), dominated clusters are the ones for which the cycle will be shorter than the cycle of the competing clusters that succeed in setting up this matching (the dominant clusters).

- *The dominant clusters*

The dominant clusters follow the evolutionary trend of the dominated clusters (*propositions 1 to 4*), but the former achieves to construct the global pipelines while the later does not (*proposition 5*). Notice that in this case the network effect plays longer in the  $\Theta_2$  mass market phase, whatever it comes from “outsiders” or insiders (spinoffs). These clusters won the battle of standards in their technological field and display thus more attractiveness and creativity. Dominant clusters are featured by an efficient matching of all the  $\lambda$ -knowledge bases (*proposition 4*), each one explaining the overall structural properties of these clusters. The emerging cohesive structure in the  $\Theta_1$  early market is confirmed and strengthened in  $\Theta_2$  mass market. This structure exhibits on one side a high level of local cohesiveness that insures the combination of analytic, synthetic and design and art knowledge. On the other side, a limited number of hub organizations coordinate this combination process as the same as they make connections with outsiders. Indeed, these hubs posit themselves as the geographical gatekeepers between the local structure and some outward organizations (*proposition 5*). Their gatekeeping strategies consist either in extending the market once the technology is mature, and reinforcing the standard diffusion by forming strategic alliances in world-wide markets, or developing cost-oriented strategies ( $\lambda 4$  knowledge base) with farther partners that have a good position in low-cost production and incremental innovations. The Midi-Pyrenean cluster of navigation satellite systems in one example among many others (Vicente & al, 2008). This cluster is a central one in the European satellite industry due to its endogenous capabilities to innovate and to ensure a standardization process in the European technological alternatives of the U.S GPS technologies. The two local incumbents of satellite industry are locally embedded in a cohesive structure with SMEs and public research organizations that develop and improve the navigation and positioning technologies and explore new services and applications in many sectors (tourism, telecommunications, transport, agriculture, ...). On the other side, beside their strategy of local coordination, these hubs form alliances with other incumbents in Europe, since the diffusion of these technologies and applications rests on the necessity for consumers that technologies are convenient and services are in-between compatible and interoperable, as for the mobile phone industry.

The life cycle of dominant clusters follows thus the life cycle of technologies. Their cycle will be even more longer that the clusters will succeed in maintaining as long as possible their structural properties that match a local cohesiveness with geographical gatekeepers, and their efficient combination of  $\lambda$ -knowledge bases that permits to control the process from  $\Theta_0$  market to the  $\Theta_2$  mass market. Nevertheless, dominant clusters can decline since the technological field reaches its maturity and enters on a decline period. An excess of specialization in a declining technological field locks-in the cluster, as observed for instance by Klepper (1996) in the Akron district. The network effect that plays in the co-location process and the efficient matching of knowledge bases are not then sufficient conditions for clusters to disconnect their cycle to the CTLC.

- *The resilient clusters*

Resilient clusters are the ones that succeed in disconnecting their cycle to the cycle of the technologies. Clusters will be even more resilient that they maintain the appropriate technological, structural and attractiveness conditions that permit to overlap technological fields in the continuum of the market phases. This overlapping process arises in the “shadow zone” between the  $\Theta_2$  mass market phase of a mature technological field and the  $\Theta_0$  beta test market of an emerging one. A cluster that achieves to be dominant in a particular technological field will be furthermore resilient if and only if

its position on this mature field coexists with an endogenous capability to invest the emerging phase of another related one.

Some conditions summarized in *figure 5* have to be fulfilled in order that such a process occurs. Firstly, following *propositions 1* and *2*, clusters will be resilient if the network effects highlighted for the dominated and dominant ones coexist with a certain amount of external audience of the place, even if this external audience does not engender a fully connected network for clusters at the first stage of their growth. A local cohesive structure emerges in the  $\Theta_1$  early market phase of a particular technological field, whereas a disconnected technological periphery composed by other organizations producing various kinds of knowledge assets “(knowledge heterophily)” constitutes a latent base of related variety. As previously exposed by Vicente and Suire (2007), network effects and cascades effects in location decision making do not produce long term viability of clusters if one of the both plays without the other. If the network effects favor the development of a cohesive structure that strengthens the production of a standard, audience and legitimacy effects favor its resilience, i.e its ability to avoid the territorial lock-in and turn unrelated variety into related one once the technological field starts to decline. Secondly, following *propositions 3* and *4*, clusters will be resilient if the upstream bases of knowledge process ( $\lambda_1$  knowledge base and  $\lambda_2$  in a less extent) are still active even if the main technological field of the considered cluster is on the mass market phase which requires a strong activeness of the  $\lambda_3$  and  $\lambda_4$  knowledge bases. Indeed, at the end of the composite technology life cycle when the  $\Theta_2$  mass market is saturated, a cluster  $j$  should decline as far as the technology declines if  $\lambda_{j1}$  and  $\lambda_{j2}$  are under of a critical level. Under this level, the mechanisms of endogenous growth are inactive due to the lack of exploration capabilities, and a resulting lack of creative and entrepreneurial activities supporting a cross-sectoral spinoff regime (Cooke, 2008). In these situations, the technological overlapping process does not work. Thirdly, following *propositions 5* and *6*, clusters will be resilient if they exhibit particular structural properties. On the one hand, as for the dominant clusters model, the existence of geographical gatekeepers is required in order to strengthen the position of the technological standard on the  $\Theta_2$  mass market (*proposition 5*). Moreover, the resulting cluster/pipelines structure reinforces the external audience of the cluster (Romanelli and Khessina, 2005) so that audience and legitimacy effects keep playing with network effects and maintain a certain amount of knowledge heterophily in the local aggregate structure. On the other hand, resilience requires that knowledge gatekeepers connect the disconnected organizations of the periphery in order that the core of the network moves as far as the cycle of the technology on the market moves (*proposition 6*). Indeed, during the transition between the  $\Theta_1$  early market and the  $\Theta_2$  mass market, the core of the dominant cluster had been reinforced, being able to impose a dominant design and standard though a strong activeness of the  $\lambda_3$  and  $\lambda_4$  knowledge bases and a structuring around a core of integrated and hub organizations (Markusen, 1996). But a cluster that evolves toward a pure core structure will take the form of a dominant cluster and will decline as far as the composite technology declines. Nevertheless, if some organizations of the core connect the disconnected organizations of the periphery, the technological overlapping process between peripheral members and the core-embedded organizations occurs, and the structure evolves by resilience toward a new analytic and engineering phase. Cattani and Ferriani (2008) provide a good illustration of such a knowledge gatekeeping strategy in their study of the creative performance of the Hollywood motion picture industry. They show that the most creative organizations are the ones that posit themselves as intermediaries between the core and the periphery. The core represents a cohesive structure of relations between traditional majors with their well-established practices and conventions of “mass-media” movies ( $\Theta_2$  mass market), whereas periphery gathers organizations with disruptive and creative technologies ( $\Theta_0$  beta test market) that are developed off the beaten path of the dominant conventions. The Hollywood motion picture industry is thus resilient thanks to the intermediary organizations that connect disconnected players and escape the pressures to conform to the established norms when the later begin to decline. To put it differently, the long term viability of this place in this industry results from its collective organization which matches efficiently the exploitation and the exploration phases along the life cycle of products. Knowledge gatekeepers are then a necessary condition for the resilience of clusters, since they permit to the periphery of  $\lambda_1$  and  $\lambda_2$  knowledge bases to be connected to the core of design and market strategies and refresh them when saturation effects occur on the mass-market. Following our abstracted representation, a resilient cluster  $j$  is thus the one that benefits from a good

position on the upstream phase of the knowledge value chain ( $\lambda_{j1}>0, \lambda_{j2}>0, \lambda_{j3}>0, \lambda_{j4}>0$ ), but also a position in the technological field which favors the resilience ( $\lambda_{j1}>\lambda_{i1}, \lambda_{j2}>\lambda_{i2}, \lambda_{j3}>0, \lambda_{j4}>0$ ) where  $i$  represents a competing dominant or dominated cluster in the field. The examples furnished by Cooke (2008) concerning the network-based entrepreneurial process by which the Silicon Valley and the North Jutland clusters moved toward clean and green technologies are very illustrative of such a process of cluster resilience.

## 6. Conclusion

How clusters evolve, grow and decline is nowadays one of the most essential issues on clusters after a decade of researches on how they work and perform. One of the main results of this paper has been to highlight and explain the differentiated patterns of cluster development, each of them being featured by a more or less great disconnection from the cycle of their dedicated technological field. We have put forward that these patterns depends on the locational decision externalities that govern the co-location process. The resulting structural properties and the consequences on the cluster's ability to deal with the phases of the knowledge value chain, are also the key criteria to cross the chasm between creativity and market performance. The life cycle of a cluster will be longer than the cycle of the technology if its structural and attractiveness properties permit to impose a technological standard and maintain resilience conditions when the standard declines. The resilience of the clusters is therefore the critical property that permits to positively disconnect the cycle of clusters from the cycle of the technologies. To sum-up, (i) clusters will be resilient if they combine network effects and audience and legitimacy effects in the co-location process. The former participates to the structuring of the technological field, while the later maintains the conditions for clusters to go from a particular mass-market to another related early one. (ii) Clusters will be resilient if the knowledge bases from the analytic knowledge to the marketing and price ones are present and connected in a structure that permits to technologies to be locally developed and widely diffused on markets. (iii) At last, clusters will be resilient if they display an evolving core/periphery structure, in which the standard is reinforced and exploited in the cohesive structure, while entrepreneurial connections to the disconnected periphery allow knowledge gatekeepers to turn new ideas into new mass-market technologies before the previous standard starts to decline.

Obviously, from the resilient to the declining scenarios of our evolutionary approach of cluster life cycles, the former constitutes the ideal-type to reach in terms of regional development policies, so that resilience properties of clusters should be further developed in order to renew the catalysts of cluster policy platforms.

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