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Understanding clusters dynamics in evolutionary economic geography

Essays on the structure of networks and clusters life cycle

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Summary

Introduction

Economic activity is unevenly distributed in space (World Bank, 2009). In this sense, a particularly important phenomenon is the spatial clustering of activities in the same industry. Clusters are said to boost productivity, innovation, employment and growth, and consequently they have come to occupy a prominent position in policy agendas during the last two decades. OECD (1999, 2007a) reports promote the development of cluster policies and suggest basic recipes for policy makers on how to set favorable local conditions for innovation. Similarly, the Lisbon Strategy considers clusters as one of the main tools to transform European economy in "*the most competitive and dynamic knowledge-based economy in the world*" (European Commission, 2009), one of the key political ambitions of the European Union. At the national level, many countries have launched cluster-based policies and programs with different approaches and articulations but with similar objectives: Pôle de Competitivité in France, Industrial Cluster Program and Knowledge Cluster Program in Japan, the Norwegian Centers of Expertise in Norway or the Kompetenznetze Deutschland Initiative in Germany to mention some of them.

The spatial clustering of innovation and actors in the same industry has been one of the main concerns of economic geography literature. For conventional theories, clusters existence and location stand on the interplay among natural factor endowment, transport costs, internal scale economies and, particularly important, agglomeration externalities of different nature (Krugman, 1991b; Fujita et al., 2001). Alfred Marshall (1890) identified three types of externalities: labour market pooling, proximity to specialized customers and suppliers, and localized knowledge spillovers. These agglomeration externalities, now known as localization economies, were completed later on by jacobian externalities (Jacobs, 1969), referring to the advantages of diversity rather than specialization, and urbanization externalities associated with city size. Thus, cluster advantages arise from the capacity to generate traded and untraded interdependencies, i.e. cumulative positive feedbacks.

Among these factors, the nature of knowledge spillovers has given rise to numerous debates and speculations. There is consensus on the positive impact of knowledge spillovers on productivity and growth, but while some authors underline the importance of specialization and intra-industry spillovers (Marshall-Arrow-Romer externalities) (Marshall, 1890; Romer, 1986), others contend that variety and inter-industry spillovers are an additional source of growth (Jacobs, 1969; Glaeser et al., 1992). A second relevant issue concerns the interplay between different conceptions of knowledge and the geographical area of diffusion. The tacit vs. codified distinction results in a knowledge spillovers conception as local public good, where tacit knowledge is highly contextual and diffuses only locally, while codified knowledge can easily travel across long distances (Audretsch, 1998). However, following the critical survey of Breschi and Lissoni (2001), attempts to open the knowledge spillovers black box multiplied. By studying the particular mechanisms of knowledge exchange, a common conclusion seems to arise: geographical proximity is neither a necessary nor a sufficient condition for knowledge flows, but it eases them (Boschma, 2005). Thus, the distinction tacit-local/codified-global is broken.

Beyond the debates on knowledge spillovers, cluster theories have been criticized because they isolate the cluster, leave no room for agency and are static. Firstly, clusters do not exist in a vacuum space, they are embedded in a larger economic landscape (Martin and Sunley, 2003). Thus, cluster growth does not only result of an endogenous mechanical movement, transformations on the environment affect clusters functioning. On the one hand, an industry has a global scale with multiple locations, a particular cluster is only one of the possible locations of industrial actors (Bathelt et al., 2004; Owen-Smith and Powell, 2004). Industrial transformations, even if originated elsewhere, will affect the cluster. On the other hand, a location contains activities and actors not in the cluster, but their action and transformation will also affect the cluster (Asheim et al., 2007).

Secondly, conception on clustered actors is often over-socialized, and their deliberate actions are usually passed over. However, actors in clusters are heterogeneous in their aims and capabilities, so agency behaviors referring to the purposive initiatives to adapt and change with the environment should be integrated in the analysis (Hervás-Oliver and Albors, 2012).

Thirdly, the traditional view has seen clusters as never ending stories. Nevertheless, clusters do not exist *per se* and they may disappear. On the one hand, the factors and mechanisms at play in functioning clusters cannot explain cluster emergence (Bresnahan et al., 2001; Orsenigo, 2001). On the other hand, the economic advantages of clusters are not infinite, and the motors of the growth process may become source of decline (Pouder and John, 1996; Bresnahan et al., 2001). First attempts to introduce dynamics on the study of clusters make a strong association between clusters life cycle and industrial life cycle, clusters growth and decline being the spatial manifestation of the industry life cycle (Klepper, 1996; Duranton and Puga, 2001). However, empirical evidence has shown that clusters active in the same industry may experience different trajectories (Suire and Vicente, 2009). On the one hand, only certain locations emerge as a cluster, and industrial expansion stages may see how certain clusters decline. On the other hand, in a phase of industrial decline, there may be clusters that decline while others manage to transform and renew themselves to start a new growth period. The integration of these disparate evolutions overcomes the deterministic flavor of "life cycle" concept as natural succession of stages (Martin and Sunley, 2011), clusters may have their own mechanisms of renewal to switch back to earlier stages of the cluster life cycle.

Innovation is basic for economic change, and knowledge is a key input for innovation. Consequently, the study of knowledge flows has become fundamental to understand clusters evolution. While specialization and intra-industry knowledge flows seem to be important for clusters' growth, diversification and inter-industry knowledge fertilization seem to matter for renewal (Menzel and Fornahl, 2010; Neffke et al., 2011b). As discussed above, the study of knowledge flows requires to focus on the particular mechanisms of knowledge exchange and the diffusion process through space. In this sense, much attention has been devoted to the study of (local and non local) relations of different nature and the emerging network resulting from the relational behavior of clustered actors (Giuliani and Bell, 2005; Cantner and Graf, 2006; Balland, 2012). The relational set constructed by clustered organizations may affect the cluster capacity to enter new growing industries, and to exit from declining ones by constructing novelty. The underlying hypothesis is that different network structures may exhibit heterogeneous capacities to sustain growth and renewal of clusters.

Following this literature, the aim of this dissertation is the study of the dynamic performance of clusters. That is, the capacity of clusters to associate and dissociate the evolution of the cluster and the industry at the right moment. They should associate the cycles to benefit of growth periods, and dissociate by shifting towards a new related growing industry to avoid decline when the industry reaches maturity. Consequently, this thesis focuses on the mechanisms and processes enhancing clusters viability or resilience in the long term. In particular, we focus on the structural properties of networks in clusters to explain the disparate trajectories of clusters.

To do so, we adopt an evolutionary approach to economic geography. Evolutionary economics, inspired by the Darwinian framework of mutation, inheritance and selection, seeks to understand how economy evolves through time, going beyond the movement of the economy towards an abstract ex-ante equilibrium state (Nelson and Winter, 1982). Consequently, evolutionary economic geography deals with the historical processes that produce the current distribution of economic activities in space, or in terms of Boschma and Martin: "*the basic concern of evolutionary economic geography is with the process* *by which the economic landscape (spatial organization of economic production, circulation, exchange, distribution and consumption) is transformed from within overtime*" (Boschma and Martin, 2010, p.6). This stresses two issues. On the one hand, it looks at how economic change continuously reshapes geography. On the other hand, it focuses on how the existing spatial structures progressively transform the economic system.

At least three reasons support the adoption of the evolutionary economic geography approach to study cluster life cycles. Firstly, evolutionary economic geography takes explicitly a dynamic perspective. Its main concerns are economic transformations on space through processes of birth and death of organizations and industries. Moreover, this space is not neutral but constructed over time through interaction of actors at different levels (network and/or industry), i.e. it is a path dependent process. Finally, as in clusters, the basic unit of analysis are organizations and their individual and collective routines (competencies) (Boschma and Frenken, 2006).

Since we are interested in network structural properties of clusters, we combine this evolutionary approach of economic geography with network theory. The applications of networks theories to clusters let us focus on interactions among clustered (and non-clustered) actors taking the relation as the elementary unit of analysis, and assuming that the behavior of specific actors affects and is affected by other actors' behavior. The aggregation of relations between different actors makes emerge a network with particular features, i.e. a structure composed by a set of actors and a set of relations defined on them. One of the main efforts of network theorists has been the definition of new concepts and measures to characterize the topology of real networks (Wasserman and Faust, 1994; Jackson, 2008). Thus, they have shown that the functioning of networks is contingent on the structural properties exhibited by the network (Strogatz, 2001). Network studies have progressively added the network dynamics dimension to identify basic mechanisms of network change and how they affect the structural properties observed (Ahuja et al., 2012).

The adoption of network perspective to study clusters has become quite popular in the last decade (Giuliani and Bell, 2005; ter Wal, 2011; Vicente et al., 2011). Such a success steams from several factors. Firstly, interactions among clustered actors are one of the defining features of clusters. Secondly, environmental fluidity and uncertainty push organizations to collaborate in order to access the needed complementary pieces of knowledge in sufficient short time. Finally, developments on network theories have widened the potential fields of application, and cluster studies have benefited from them. This growing interest on interactions has been called the "relational turn" of economic geography (Bathelt and Glücker, 2003) and has gone with a broader movement towards research on complex systems that has reached economic geography too (Martin and Sunley, 2007).

Research question

In this thesis we study clusters' evolution. Clusters are said to favor productivity, innovation and efficiency of clustered organizations, and thus employment and growth of the regions that home them. Our concern is to study how these positive effects hold over time. Clusters are embedded in larger economic landscapes in permanent transformation and clusters long term viability depends on their capacities to deal with these transformations. Our thesis aims at identifying the determinants of dynamic performance of clusters, i.e. why some clusters decline while others keep working by continuous renewal.

In knowledge based economies, knowledge creation and innovation processes are motors of change and adaptation. However, innovation and knowledge creation are complex processes that go through the combination of different but complementary pieces of knowledge. Complexity and environment volatility have progressively pushed to interaction, i.e. innovation as a collective process. In this sense, we adopt a relational perspective to place relations between actors and the emerging relational structures at the center of the analysis. Thus, we focus on the structural properties of networks to identify which ones matter for cluster long term viability or dynamic performance. We extend the analysis by integrating the relational mechanisms at play in network change, giving rise to such properties.

This thesis contends that networks of clusters have heterogeneous structures exhibiting different capacities to avoid negative lock-in leading to failure, or favoring lock-out to enhance cluster continuation. The literature has largely discussed network properties favoring production of innovation, creativity and efficient diffusion. We contribute to this literature by identifying which structural properties of networks favor network dynamic performance in the cluster context to assure their long term viability, i.e. extend the life of the cluster.

Thesis outline

Our discussion on the properties of the network structure for cluster long term viability is organized in five chapters. The first two chapters are single authored while chapters three to five result from scientific collaborations. The chapter 1 makes a survey of the literature on organizational networks applied to the cluster context. The chapter 2 makes a theoretical reflexion on the cluster life cycle framework to argue that the cluster long term viability goes through the association and dissociation of cluster and industrial/technological cycles. This is contingent on several factors, networks being one of them. Chapter 3 focuses on networks and defines two network properties enhancing cluster dynamic performance and proposes two network measures. Chapters 4 and 5 apply our theoretical reflections to two different contexts. The chapter 4 aims at testing the effects of hierarchy and assortativity properties on several mobile phone clusters in Europe. Finally, the chapter 5 analyses the relations between the cheese producers in Aculco (Mexico) to show how the relational behavior of actors may hamper the cluster development by blocking collective action initiatives.

Chapter 1 makes an interpretative survey of the main findings in literature, linking organizational networks and performance, and applying them to the cluster context. We first discuss the long list of concepts referring to spatial clustering and find that in spite of their diversity, they converge to underline the importance of (traded or untraded) local interactions as an explicative factor for territorial concentration existence and evolution. Then, we examine the main findings in network theories concerning organizational context and their effects on performance. To do so, we classify the literature in three levels of analysis based on their focal unit, and we discuss their interplay. The dyadic level takes the relation as unit of analysis and studies both: factors affecting their performance and factors affecting their formation, maintenance and disruption. The ego level focuses on the structure relations of a focal organization. The whole network level studies the properties of the structure arising from the aggregation of all nodes and relations in the network. The main objective of the chapter is to justify the network approach of clusters and underline the importance of the whole network level of analysis to study competitiveness (static performance) and adaptability (dynamic performance) of clusters.

Chapter 2 aims at building a theoretical framework in order to analyze cluster life cycles. We adopt a dynamic view from which clusters are neither pre-established structures nor never-ending success stories. On the one hand, the strength of a functioning cluster may not be present in the emergence stage. On the other hand, the success conditions may become unadapted for cluster change. We argue that clusters change with the join evolution of two dynamics that are mutually influencing each other: regional dynamics and industrial/technological dynamics. The different mechanisms at play in the emergence stage produce clusters with heterogeneous structures, and those heterogenous structures exhibit different capacities to deal with threats and opportunities. The strength of the regional and industrial/technological dynamics define the capacity to associate the cluster to the growth stage of industrial/technological cycle, and dissociate it when the industry/technology declines.

Chapter 3 combines the network approach of clusters from chapter 1 with the cluster life cycle framework from chapter 2. Among the wide range of parameters influencing cluster evolution, our purpose is to theoretically identify the structural properties of local knowledge networks that favor cluster long term viability. After presenting the network-based rationales of growth and structuring of clusters, we analyze under which structural conditions a cluster can achieve short run competitiveness without compromising long run resilience capabilities. We show that the level of hierarchy and the level of structural homophily (assortativity vs. disassortativity) of local knowledge networks should be studied in order to understand how clusters succeed in combining technological lock-in, in the growth stage of the industrial/technological cycle, with cluster lock-out, in the decline stage of the industrial/technological cycle. We propose degree distribution and degree correlation as two simple statistics to measure these properties. We conclude with a policy-oriented analysis showing that policies for cluster resilience should focus on *ex-ante* diagnosis and targeted interventions on particular missing links, rather than *ex-post* myopic applications of policies based on an unconditional increase of network relational density.

Chapter 4 aims at empirically testing the effects of the network properties identified in chapter 3. We analyze the effects of hierarchy (degree distribution) and structural homophily (degree correlation) on cluster resilience measures through their innovative capacity. The underlying assumption is that resilient clusters have the capacity to remain innovative along the industry life cycle. To do so, we analyze the mobile phone industry in Europe from 1988 to 2008. We construct local and non-local knowledge networks from R&D collaborations, co-funded by European Framework Programs. Innovative capacity of clusters is measured by a regionalization of patent applications to the European Patent Office (using EPO PATSTAT and OECD REGPAT). Data availability constrains us to define clusters at regional NUTS 2 level. The main outcome of this chapter is that while assortative networks are less performant, the effect of hierarchy is ambivalent, depending on the industrial stage.

Finally, in **chapter 5** we empirically discuss the framework developed in chapter 2 by focusing on the regional dynamics behind cluster evolution. We use social network analysis to examine how the relational behavior of actors may hamper the success of collective action and compromise cluster development and viability. To do so, we move to a completely different context of low-tech nature. We analyze the Aculco (Mexico) cheese producers case and their project to establish a collective trademark to differentiate their products and increase competitiveness. This challenge is the target of collective action based programs aiming at framing the cooperation context that would enable a local community to turn inherited resources and know-how into new market opportunities. Literature acknowledges that social capital is a crucial local resource for successful collective actions since it is a source of trust and collective commitment within a community (Coleman, 1988). Focusing on the connectedness dimension of social capital and on the multiplexity of relations, we disentangle the opposite and ambivalent effects of social capital on the ability of a community to reach the goals assigned by the collective action program. Our empirical study shows that these critical properties can work in favor of adherence to the collective action but can also create elite capture, clannish behaviors and entry barriers, thus showing a failure of collective action. Such failure, revealing a weak regional dynamic, may undermine cluster long term evolution.

Chapter 1

Clusters and networks: a survey

This chapter is single authored and intends to make a survey on the literature on organizational networks applied to clusters. It justifies the adoption of network approaches to study clusters functioning and evolution. It discusses the main results for the three levels of network analysis. Our thesis aims to identify network structure properties for cluster long term dynamics, so this network approach will be used along this thesis and in particular from chapters 3 to 5.

1.1. Introduction

The studies about clusters are relatively young. Although strongly inspired by the old works of Alfred Marshall (1890), the cluster concept as spatial phenomenon was developed during the 90s. Nevertheless, it gained rapid success, and during the last two decades cluster theory has progressed considerably. This literature has primarily focused in the identification of different types of external effects to explain *why clusters exist* and their effects (Porter, 1998; Maskell and Malmberg, 1999; Maskell, 2001). Additionally, several authors have studied *how clusters work*. They try to identify which cluster properties and structures matter to explain differences in clusters performance (Markusen, 1996; Gordon and McCann, 2000). Finally, researchers have tried to integrate clusters and time to understand *how clusters evolve*, i.e. how they born, grow and decline or renew (Feldman and Francis, 2004; Dalum et al., 2005; Buenstorf and Klepper, 2009; Suire and Vicente, 2009; Menzel and Fornahl, 2010). The evolution of clusters has always been associated with industrial dynamics.

One of the main elements used to understand differences in clusters functioning and evolution are interactions among local (and non-local) firms and institutions. These interactions become channels trough which valuable resources circulate. In this sense, the study of knowledge flows has received particular attention. Knowledge spillovers are not just a matter of co-location. In fact, opening the black box of interaction lets us better understand how knowledge circulates (Breschi and Lissoni, 2001), and how one of the most important positive feedbacks for cluster existence effectively works. Moreover, interactions have also been acknowledged to be important for trust formation and the emergence of a common set of values and rules (Coleman, 1988; Gulati, 1995). The importance of the relational dimension has sustained the network approach of clusters. Methods of network analysis are used not only by physics or biology, but also by different social science such as economy, management, sociology or geography enhancing scientific cross-fertilization. Their popularity is based on their adequacy to study complex system properties, formation and change, articulating micro, meso and macro levels (Tichy et al., 1979).

This chapter adopts this network approach and makes a review of the main findings of the literature on inter-organizational networks and clusters. In section 1.2 we shortly discuss the different concepts developed to refer to local business agglomerations. In spite of their richness they are quite similar in their main components, and the "cluster" has become the most often used. In section 1.3 we accurately define what networks are and justify why they are a useful perspective to study clusters performance and evolution. Section 1.4 distinguishes the three levels of network analysis and their interplay. At dyadic level we discuss why organizations need to construct relations and how they select their partners. At ego level we focus on the way organizations use their relational capabilities to construct individual valuable positions. Finally, at whole network level we analyze the features favoring (or hampering) its aggregated performance. The last section concludes with a discussion about contribution of network approach to cluster understanding, and defending why structural level is appropriate to study clusters.

1.2. The *brotherhood* of "industrial agglomeration" concepts

"*Location matters*" (Porter, 1998). This assertion lies behind the observed fact that similar and dissimilar economic activities tend to concentrate in certain locations. Although unexpected, globalization process and transport costs reductions have made location decisions increasingly important rather than irrelevant. In fact, spatial clustering and regional economic heterogeneity have continued, even accelerated, over the last decades. This agglomeration phenomenon has periodically attracted the attention of economists, and since the 70s, a renewed interest in spatial concentration and localized growth has come from a variety of disciplines: economics, business and management, sociology, and geography and planning. Such revitalization was motivated by the development of formal methods to analyze the impact of increasing returns (Krugman, 1995), the transformation of the economic environment with the end of the Fordist era (Scott, 1988), and the inadequacy of the conventional spatial policies (Gordon and McCann, 2000).

This growing interest is at the origin of a whole set of neologisms developed by different schools of thought to refer to the spatial form and nature of local business concentrations such as industrial districts, innovative milieux, new industrial spaces, learning regions, local productive systems or clusters, among others. Each of these concepts has its own particularity, but they share as a common inspiration the "industrial district" of Alfred Marshall (1890).

The notion of industrial districts in the marshallian thought arises from his positions on the nascent theory of production. Marshall considers that the large scale factory system, i.e. the spatial concentration of all productive activities in a vertical integrated unit, is not systematically the most efficient solution. The concentration in the same location of several small companies specialized in different phases of the process may be an equally efficient alternative. Thus, concentration gains may be generated either by economies of scale internal to the firm or by external economies of localization. External economies are said to reduce long run factor prices and rise factor productivities through *i)* the reproduction of skills, *ii)* the circulation of knowledge, *iii)* the development of subsidiary activities in both manufacturing and services, *iv)* the use of specialized machinery, *v)* the development of a specialized labour market and *vi)* the development of complementary industries (Sforzi, 2002; Pyke et al., 1990). With time and the development of these factors, emerges what Marshall coined as special *atmosphere*, something intangible *in the air*.

Consequently, the Marshallian industrial district is a local system composed by small firms within a dominant industry. They are specialized in different phases of the production process (local division of labour), but have substantial intra-district trade among buyers and suppliers often entitling long term commitments. There is a vibrant labour market characterized by high skilled workers, high flexibility and high commitment to the district rather than to the firm. This is supported by a strong system of shared values and norms, i.e. a social culture, that enhances transaction and increases the efficiency of exchanges (Markusen, 1996).

However, the success of the Fordist system left these Marshalian contributions forgotten during more than fifty years. It was not until the end of the 70s that external economies and industrial districts were re-discovered. By this time, some economists leaded by Becattini observed in the North-East and Center of Italy the development of highly efficient and competitive small and medium firms in the same area, the district. Their production was (almost) entirely done in the district, but not in a single factory. They configure flexible integrated systems with many specialized firms (Piore and Sabel, 1984; Pyke et al., 1990). These "*empirical observations in search of a theory*" (Sforzi, 2002, p.439) brought back the Marshallian ideas on external economies and industrial districts. However, the Italian version of industrial districts draws particular attention to the role of social culture. Consequently, in order to go beyond external economies and opening the black box of the *atmosphere*, cooperation among competitive firms, construction of local governance structures and institutions, trust formation, local culture or social embeddedness of productive relations have received much more attention as explicative factors for the district success (Harrison, 1992; Markusen, 1996). In the early 1980s, some North American geographers coincided on the observation of a deep transformation on the organization of production, "*these changes consist primarily in a relative decline in the importance of Fordist mass production and an enormous expansion of manufacturing activities based on less rigid and more highly adaptable (i.e., flexible) technological and institutional structures*" (Scott, 1988, p.171). The spatial consequence was the emergence of new industrial spaces better adapted to the new production conditions and not attached to the old Fordist centers. They support Italian cases with an economic model of agglomeration via the analysis of transaction costs associated with inter firm linkages. They argue that agglomeration is the outcome of interdependence advantages maximization (flexibility, risk minimization, specialization) and transaction costs minimization (number, frequency, predictability and complexity of relation) (Storper, 1997). In the same vein, the French regulationist school develops the notion of local productive system to designate this concentration phenomenon but in a more general way. A local productive system is a set of proximate productive units defined in a broad sense, with relations of variable intensity and type among them (Colletis-Wahl and Pecqueur, 2001; Courlet, 2002). The main concern of these authors is the integration of non-purely economic factors, going beyond market mechanisms of coordination. The three schools place the region at the center of the analysis, but they are criticized by the limited capacity of their analytical tools to distinguish between high wage and technologically dynamic agglomerations, and the low wage and stagnant ones (Storper, 1997).

The growing importance of the globalization process and the shifts towards a knowledge-based economy have introduced new nuances in the development of industrial agglomeration literature. Knowledge becomes the most strategic resource, learning the most important process, and innovative capacity is seen as a fundamental source for the agglomeration durability. Neo-Marshallian nodes concept takes the industrial districts as point of departure, but updates it by considering globalization consequences and the role of multinational firms. Amin and Thrift (1992) recognize the importance of the local context in industrial districts, but they balance it by integrating the role of non-local linkages. From this perspective, industrial districts become nodes of a global network. Concerned by the effects of knowledge, the innovative milieu school emerged in the mid 80s. It takes innovation rather than production as main concern. Aydalot and the GREMI group point to the contextual character of innovation to explain the development of certain regions. They consider that innovation is not produced by the unique relation between the firm and his market; the *milieu* where the firm is located conditions his economic behavior and success too (Aydalot, 1986). This milieu is made-up of a set of relations within a geographical area that gather together a productive system, a technical culture and a group of actors that progressively learn through their interactions (Maillat et al., 1993). Consequently, firms' location decisions are much more than the juxtaposition of new activities independently from the other ones. They depend on systemic considerations, i.e. the nature of economic relations and the synergy effects structuring the milieu. However, research on innovative milieu has been criticized for their focus on the identification of milieux properties, while ignoring the functioning mechanisms and economic logics behind them (Storper, 1997). Few years later, the innovative system approach (national, regional or sectoral) developed. It also pays attention to innovation processes and points in the same direction: innovation is not achieved in isolation, but in collaboration and interdependence with other organizations. Thus, it emphasizes the systemic nature of innovation, composed by organizations (firms and non-firms), the multiple kinds of interactions among them, the central role of the institutional context as source of incentives and obstacles, and the complex interdependencies existing between these elements (Lundvall, 1992; Cooke, 2001, 2008). Edquist defined it as "*all important economic, social, political, organization, institutional and other factors that influence the development, diffusion and use of innovations*" (Edquist, 1997, p.14), and Freeman clarified "*the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies*" (Freeman, 1987, p.1)[1]. Innovative milieu and system of innovation approaches differ in their unit of analysis. While the first focuses on the influence of the milieu in organizational innovative performance, the second approach focuses on the whole system innovative performance (development, diffusion and use). Moreover, while the first has created the impression that there exists an ideal organization to maximize innovation and growth (Gordon and McCann, 2000), the second stresses differences between systems rather than optimality (Edquist and Hommen, 1999). However, innovative milieu and system of innovation approaches coincide by their disregard of the sectoral dimension present in industrial districts[2].

In the early 90s, the cluster concept enters the "industrial agglomeration" *brotherhood*. In a short time it becomes the most popular of all these neologisms, receiving most of the attention from academia and policy spheres. Michael Porter developed the concept from his previous work on competitive advantage of nations and competitiveness. He defines clusters as "*geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities*" (Porter, 1998, p.78). Such definition embrace the basic ingredients of the concepts above. The spatial dimension, because clusters are geographically proximate groups of interlinked organizations. The industrial dimension, because clustered organizations belong to the same (or related) field(s). The relational dimension among the constituent units, because organizations tie horizontal and vertical relations to access complementary resources. These linkages often involve social relationships that produce benefits for the organizations involved. The cumulation and repetition of local relations produce region specific assets in the form of untraded interdependencies, i.e. conventions, informal rules, and habits enhancing coordination in an uncertain context. Thus, clusters are not radically different from a conceptual point of view. However, it gains wide diffusion and rapidly becomes the standard concept in the field. According to Martin and Sunley (2003) there are several reasons behind the popularity of clusters. The most important one is the competitiveness framework constructed around it. On the one hand, Porter makes much more explicit the importance of competition

[1] This systemic view is also present in learning regions concept which, in spite of this success in policy spheres, is much more vaguely defined. In fact, Hassink (2005) defines it as a regional innovation strategy rather than as an agglomeration phenomenon.

[2] Malerba (2004) fill this gap by analyzing sectoral systems of innovation.

within the cluster; clustered organizations cooperate but, most importantly, they also compete. Indeed, "*without vigorous competition a cluster will fail*" (Porter, 1998, p.79). On the other hand, Porter develops an appealing framework in which regional competitive advantage depends on the interaction between four sets of factors composing the *competitive diamond*: *i)* firm strategy, structure and rivalry, *ii)* factor conditions, *iii)* demand conditions and *iv)* related and supporting industries. The interaction intensity among these factors is enhanced if firms are geographically close (Porter, 1990). A second factor of cluster success is the way the concept is framed, with a business and policy friendly writing and in terms of economics of business strategy rather than general theoretical debates and concepts. Finally, and more fundamentally, Martin and Sunley (2003) argue that cluster success lies on high generality and vague conceptualization, its definition is elastic enough to admit a wide range of applications.

At the same time vagueness and elasticity of geographical and industrial boundaries are the two main limitations of cluster theory. They have enhanced the construction of an universal concept that pools under the same umbrella quite different processes, scales and types transforming the cluster in a chaotic concept blurring the analysis. Additionally, clusters have been often treated from a static perspective, considering them as a isolated, pre-established and always-successful structures (Bresnahan et al., 2001; Martin and Sunley, 2003). Most of these limitations are not exclusive of clusters. They are shared, at least partially, by the other concepts of the brotherhood[3]. Consequently, we recognize the richness and variety of nuances of each concept, as because they refer to the same phenomenon and they common limitations, in the reminder we will refer to clusters and take the other concepts as interchangeable. Moreover, we take the interactive dimension seriously (Breschi and Lissoni, 2001). We look at clusters from a network perspective, so instead of postulating relations, we place them at the center of the analysis to study clusters emergence and evolution.

1.3. Network approach of clusters

Social network analysis studies the linkages among social entities or actors. Actors, or nodes in network jargon, may be defined in a flexible way either as discrete individuals or as collective social units. According to the cluster definition, nodes represent organizations that share a common location, are active in the same field and with different institutional forms (firms, universities, government agencies...)[4]. Indeed, the field of

[3]Industrial districts or local productive systems face similar problems in the definition of geographical and industrial boundaries. For innovation systems the industrial dimension does not exist, and the geographical one often is associated to administrative frontiers (region or nation). The insights on dynamics of the concentration are also rare

[4]In some cases and depending on the research question the nodal definition has been individuals in clusters: entrepreneurs, researchers/inventors and workers.

activity and the location of the organization are used as both, selection criteria and nodes' attributes. Similarly, the definition of a tie between two actors may be quite open too. The only defining feature of a tie is that it establishes a linkage between a pair of nodes. In a cluster context, organizations may have linkages of very different nature. Thus, several relational sets concerning productive, commercial, cognitive, financial or social linkages may co-exist (multiplexity). Consequently, a network can be defined as the union of a finite set of actors and the set or sets of ties defined on them (Wasserman and Faust, 1994).

There are several powerful arguments backing the adoption of network perspective to study clusters' structure, evolution and performance. Firstly, it seems to be a coherent approach based on the own definition of cluster. Network analysis is based on the assumption that relationships among interacting units are important; it goes beyond individual characteristics to consider the way relations between actors are organized (Tichy et al., 1979; Rivera et al., 2010). Consequently, its application to study clusters lets open the interactions black box to analyze the emerging relational patterns and their implications. Interactions are not just postulated, they became the main focus of the analysis. As explained in section 1.2, one of the key elements of the cluster definition is the fact that co-located organizations are *interconnected*. It is through competitive and cooperative relations of clustered organizations with their clients, suppliers, supporting services and rivals that the virtuous cycle of the diamond becomes possible and the intangible environment that favors productivity and innovation emerges (Storper, 1997). This conception may help to go beyond traditional arguments of cost advantages, low transportation and transaction costs and close material linkages, to emphasizes the fact that social and economic life is relational: organizations have relations with other organizations, and each of them has its own relations, and so on.

Moreover, the end of the Fordist era, the globalization process and the emergence of the knowledge-based economy have transformed the economic environment and the organization of production and innovation. Higher uncertainty and instability, shorter product life-cycles and increased competition based on cost reduction and differentiation have converted knowledge in a key input, and innovation in a fundamental source of competitive advantage. To deal with these transformations, new forms of production organization and innovation based on flexible specialization and organizational interaction become more and more important. They are characterized by externalization in order to reduce the risk of overcapacity, minimize the danger of technological lock-in and maximize the benefits of specialization. With externalization, organizations concentrate on their own core competencies and get the required complementary competences through interaction in loose, rapidly, shifting coalitions (Storper, 1997).

The increasingly complex process of knowledge creation[5] and the short delays imposed by the volatile environment push organizations to construct external relations in order to obtain the complementary pieces of the knowledge they miss. This growing importance of external relations and the spatial implications in their formation and structuring justify the adoption of the network perspective to study clusters.

Both prior arguments converge in the development of a new theoretical orientation termed the "relational turn in economic geography" (Boggs and Rantisi, 2003)[6]. Instead of describing spatial categories, process and regularities, these analysis draw attention to organizations and to the dynamic processes of change caused by their interaction in space (Bathelt and Glücker, 2003). The "relational turn" coincides with the growing interest that evolutionary economic geography is giving to networks. Evolutionary approaches to spatial networks contribute to understand the uneven distribution of economic activity in three ways. Firstly, they study the effect of networks on economic performance. Secondly, they analyze the drivers of network formation and change at organizational level. Last (but not least for our concern) they improve our understanding of working clusters (Boschma and Martin, 2010).

Finally, the recent development of appropriate analytical tools encourages the adoption of the network perspective to study clusters in order to open the interactive black box. These advances concern three main dimensions. The first dimension refers to the development of theoretical measures and mathematical methods to capture network properties and their implications. Secondly, the development of appropriate software for network analysis and the development of computing capacities for algebraic calculations with big matrix have enhanced calculations of network measures. Finally, network analysis requires relational data, so besides the information on the actors, network data include measurements on the relationships between actors. This additional information is often difficult to acquire, but progresses have been done by refining primary collection methods (interviews, questionnaires...) and particularly through the exploitation of secondary data (one-mode and two-mode data) such as collaborative projects, patents, strategic alliances and labour mobility.

1.4. Networks: three levels of analysis

Since the invention of the sociogram (Moreno, 1934), social network analysis has been applied to numerous and varied fields such as sociology, political science, economics, management, physics or biology, where the nature of nodes has great variety. As we are interested on clusters, we confine our discussion to inter-organizational networks. The study of these networks can be can be conceptualized on three primitives: *i)* the

[5]Transition from the linear to the interactive model of innovation (Kline and Rosenberg, 1986).
[6]See Sunley (2008) for a critic.

node of the network, *ii)* the ties connecting the nodes, and *iii)* the resulting structure from the aggregation of these connections (Ahuja et al., 2012). Depending on the level of aggregation of these primitives we classify the literature on networks in three levels: the dyadic level, the ego level and the whole network level. This section discusses the main aims and scope of each level as well as their mutual interplay.

1.4.1. Dyadic level

A relation does not pertain to a single node (organization); it is established between two organizations, so it is inherently defined in a pair. Thus, a dyad is composed by a pair of organizations and the possible ties existing between them. Network researches at dyadic level focus on the characteristics of this relationship. Two interconnected issues have drawn the attention of scholars. Firstly, the study of the outcome of relations depending on their nature and characteristics. Secondly, the study of how organizations create, maintain (renew) or disrupt relations, i.e. the selection of partners and the longevity of the relation. The first question often adopts a static approach taking the relation as existing and with fixed characteristics[7]. The second question is basically of dynamic nature because creation/disruption of relations, together with entry/exit of organizations and changes in organizational features, are basic units of network change. However, both question are not independent. Positive or negative outcomes will influence the decision of maintaing or disrupting a relation. Or to say it in a stronger way: the decision of maintaining or disrupting a relation is a measure of the outcome of the relation in itself. At the opposite, for new relations, there is no previous outcome to refer to, so different considerations are at play.

1.4.1.1. Performance of dyads

The rationale behind the construction of external ties is the access of relevant complementary resources to remain competitive. However, the a priori advantages of external relations are counterbalanced by the fact that they are not costless and without risk (Gulati, 1995). Organizations should face the costs of searching, storming and monitoring, and the risk of suffering unintended spillovers and opportunisms. Organizations will consider relations as performing or satisfactory if the benefits compensate the costs and risks. Durability of the relation is the simplest indicator of a satisfying relation, but others such as knowledge access and efficiency of transfer (Uzzi, 1997; Sorenson et al., 2006), organizational survival rates (Mitchell and Singh, 1996) or revenue (In-

[7]Few researches exist on the dynamics of dyad performance. Nevertheless, on the one hand, trust formation may take time, and so the benefits of a relation evolve as trust strengthens. On the other hand, since the resources and knowledge of our partner are not unlimited the gain of the relation may reduce with time. Remarkable exception mixing dyad and ego levels is Baum et al. (2012) who concluded that when the age of the tie increases the performance of closure ties increases, but the performance of bridging ties decreases.

gram and Roberts, 2000) have been used too. The benefits, costs and risks of relations depend on their characteristics and nature.

The analysis of a relation between two organizations has several dimensions. Firstly, clustered organizations interact to access to different types of resources and competences. Thus, depending on the contents circulating in the relation it can be classified as exchange of influence or power, exchange of information or knowledge, and exchange of goods or services in a broad sense (Tichy et al., 1979). However, this distinction is more operational than conceptual. On the one hand, organizations are often connected through several relations of different type, i.e. production, financial and knowledge relations may co-exist. On the other hand, these three categories are often overlapping, particularly because financial and production relations often involve voluntary or involuntary knowledge exchanges.

Inter-organizational relations can also be classified by their degree of formalization. The most common categorization distinguishes formal and informal relations. Formal relations refer to organizational exchanges whose content has been established in a more or less complete and complex formal contract: joint-ventures, buyer-supplier relations, strategic alliances broadly defined (Haunschild, 1994; Rosenkopf and Padula, 2008). Concerning informal relations explicit contracts do not exist (Schrader, 1991). Friendship and kinship contribute to build mutual trust as a substitute of formal contracts to define the terms of the exchange and avoid the risk of opportunism. The distinction between formal and informal relations may be often complicated because reciprocity and repetition may generate exchanges of informal nature in an initially formal relation, these informal exchanges will be done by individuals belonging to the same or different organizations.

The integration of social and economic dimensions of relations is the main focus of the embeddedness literature (Granovetter, 1985), which tries to understand how social relations affect economic outcomes. They found significant differences on the performance of arm's length ties and embedded ties (Uzzi, 1996), the two extremes of the exchange continuum. Both extremes represent the Granovetter's distinction between weak ties and strong ties, where the strength is related with "*the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie*" (Granovetter, 1973, p.1361). Arm's length ties match the idea of neoclassical organizational relation. Organizations have self-interest, profit-seeking behavior, the exchanges are non-specific and based on price, which it is supposed to contain complete information for efficient decisions. Embedded ties are socially constructed, they integrate a personal dimension on a business relation, so motivations shift away of narrow pursuit of self profit. From this extreme price is an incomplete source of information, then trust and complementary information obtained through social relations become important. The main findings suggests that embedded relations benefit from higher level of trust than arm's length ties. Trusted relations benefit from lower transaction costs, more flexibility, richer opportunities and advanced access to a set of assets not available with arm's length ties (Uzzi, 1996). Moreover, embedded ties are more powerful channels for information circulation and knowledge exchange. Uzzi (1997), Uzzi and Lancaster (2003) and Sorenson et al. (2006) conclude that embedded ties convey richer messages than arm's length relations. Finally, embedded relations are said to be more effective as mechanisms for joint problem solving due to the generation of common routines of negotiation and mutual adjustment (Uzzi, 1996).

Level of embeddedness is not the unique feature of the relation influencing performance of dyads. Geographical proximity (co-location) between two organizations increases the probabilities of their meeting and improves the efficiency of their communication thanks to face-to-face contacts (Storper and Venables, 2004). Institutional proximity, i.e. the fact that the two organizations of the dyad share common language, rules, laws and values, enhances coordination by reducing uncertainty and transaction costs (Kirat and Lung, 1999). Similar effects has the strength of organizational arrangement between organizations (Boschma, 2005). Finally, when organizational relations concern knowledge exchanges, a minimal cognitive proximity between organizations is necessary, otherwise the gap is too big and the communication, understanding and processing of new knowledge fail (Boschma and Lambooy, 1999; Nooteboom, 2000). These different proximity dimensions do not work independently from each other, but they are partially substitute and partially complementary (Boschma, 2005; Bell and Zaheer, 2007). Additionally, the positive effects of proximity on dyadic performance do not linearly grow ad infinitum. There are thresholds beyond which the positive effects of proximity (in its different dimension) becomes harmful. Too much proximity produces redundancy on knowledge flows, lack of novelty, inertia and lock-in hampering organizational actions to take advantage of new opportunities. Broekel and Boschma (2012) referred to this as the "proximity paradox" and Uzzi (1997) talked about the risks of over embeddedness.

1.4.1.2. Creation and disruption of dyads

Dyadic formation and disruption have received great attention as two of the elementary units through which networks change[8] operates over time. The costs, risks and strategic value of external linkages impose the need to select partners carefully. However, such process is characterized by the uncertainty that steams from incomplete and asymmetric information. Information on competencies, needs and behavior of partners

[8]The other elementary units of network change are entry and exit of nodes, which are usually associated with tie creation and disruption, and change in the nature or content of tie.

are rare and difficult to obtain. To deal with this, organizations with heterogeneous characteristics use the relational environment as source of information. We can classify the mechanism behind partners selection in three main categories: individual characteristics, proximity mechanisms and structural mechanisms.

Individual characteristics

The literature has argued that individual characteristics of organizations may influence their likelihood to collaborate, i.e. their evolvement in a relation. Contrary to the neoclassical view based on the representative agent, evolutionary economists argue that what organizations do is not only determined by the conditions they face (Kirman, 1992). They will pursue different paths because they differ in their strategy, structure and capabilities, including relational capabilities (Nelson and Winter, 1982; Nelson, 1991). In fact, this organizational diversity is the base for the selection process (Boschma and Frenken, 2006). There are several organizational characteristics that, in absolute terms, influence the relational choices of organizations.

Firstly, organizations are different in nature. Firms, universities or governmental agencies differ in the nature of goals accepted as legitimate, the norms of behavior and the features of the reward system (Dasgupta and David, 1994). Therefore, the perception of benefits, risks and costs of external relations is different and so their openness to collaboration will vary. Jaffe et al. (1993) or Owen-Smith and Powell (2004) find that knowledge flows out of universities and other public research organizations (PROs) more easily than from firms. Secondly, organizations have heterogeneous absorptive capacities. This cognitive property refers to the ability of organizations to recognize the value, and to assimilate and apply new external information and knowledge (Cohen and Levinthal, 1990). It is not possible to cooperate without understanding, so when organizations enlarge their absorptive capacity they enlarge their collaboration possibilities (Nooteboom, 2000). Organizational size is often related to it. Colombo (1995) argues that, *ceteris paribus*, cooperation agreements produce greater gains for big organizations than for small ones. On the one hand, big organizations are more attractive because they own a bigger range of specialized assets with competitive success. This same argument can be applied to reputation and/or market leadership of organizations. The positive perception of leaders makes them attractive to cooperate with in oder to take advantage of their image and supposed successful assets (DiMaggio and Powell, 1983; Powell et al., 2005). On the other hand, big organizations are able to build more, and more profitable external relations (Mitchell and Singh, 1996; Hervás-Oliver and Albors, 2009). Following Nooteboom (2000) larger firms have larger absorptive capacities. Additionally, they are in a better situation to deal with transaction costs of relational construction and maintenance, due to their higher internal resources and their advantageous bargain position. Finally, organizational experience on cooperation may also be important. On the one hand, cooperation management is a competence in itself that organizations acquire through learning by doing and so reduce transaction costs. On the other hand, as time goes by, the loyal, opportunistic and deterrence behaviors of organizations vis-a-vis of their partners may forge their own reputation as "good" or "bad" partner.

Proximity Mechanisms

The second category comprises proximity mechanisms. It refers to the individual features of organizations in relation to the features of the partner. For proximity mechanisms, what matters in tie creation, maintenance or disruption is not the attribute of the organization in itself, but the complementarity and compatibility of this attribute with the partner's attribute (Rivera et al., 2010). Therfore, proximity mechanisms depend on the organizational features defined in relative, not absolute, terms. Proximity mechanisms echoes sociological debates on the dynamics of homophily and dynamics of heterophily. Organizations are complex units with many defining attributes, so network ties may relate organizations that are simultaneously sharing similarities in some dimensions and differences in others. In this sense, the proximity framework has been quite useful (Boschma and Frenken, 2010). Section 1.4.1.1 showed that different proximity dimension influence dyad performance, and we have argued that dyads creation/disruption is contingent on performance, so organizations will integrate these proximity dimension in partners selection, i.e. organizations are more likely to interact with other proximate organizations. However, this is not linear, and organizations may look for heterogeneity in their relations to avoid lock-in and access novelty. In fact, homogeneity vs. heterogeneity or proximity vs. distance is a matter of degree with multiple dimensions (Blau, 1974).

New knowledge production goes through combination and integration of complementary pieces of knowledge dispersed among different organizations (Antonelli, 2005). When the cognitive gap exceeds the bridging power of absorptive capacities the knowledge transfer fails (Nooteboom, 2000). Consequently, cognitive proximity, makes interaction more likely due to the higher probabilities of success. Moreover, organizational proximity favors interaction because makes coordination easier, stronger arrangements reduce uncertainty and risk of opportunism (Hansen, 1999). Despite working in a different way, the effects of social proximity on ties formation are similar. Organizations are more likely to interact with socially proximate alters because they benefit from reduced uncertainty and risk of opportunism (Granovetter, 1985; Uzzi, 1997). Additionally, they may be source of relevant informations about other (potential) partners. However, social proximity is based on trust constructed by friendship, kinship and past common experiences instead of in formal contracts. The fourth dimension concerns institutional proximity. It refers to formal (rules and laws) and informal (social values and norms) institutions, source of stable conditions for economic activities (North, 1990). When two organizations share the same institutional set, the coordination process between them is more efficient (Edquist and Johnson, 1997). Consequently, institutional proximity makes collaboration more likely. Finally, geographical proximity, understood as physical separation, eases tie construction. Meeting the partners is easier with shorter commuting times and lower transport costs. Thus, face-to-face contacts are more common[9].

In spite of these advantages, proximity (Boschma, 2005; Broekel and Boschma, 2012) and management (Gulati, 1995; Uzzi, 1997; Powell et al., 2005) literature have pointed to the risks of too much proximity, and have argued that relational behavior often seeks heterogeneity. This is particularly evident for the cognitive dimension, because only dissimilar competences and bodies of knowledge make the relation valuable. The other forms of proximity are also concerned. The risks of inertia and lock-in in rigid and closed systems impeding new adjustments, limiting the access to new sources and underestimating opportunities push organizations towards heterogeneity in their partners research. Consequently, at proximity level there is a tension, or a balance, to find between proximity and distance factors, between the dynamics of homophily and the dynamics of heterophily, in order to explain how organizations find their partners.

Structural mechanisms

Finally, structural mechanisms refer to the creation or destruction of relations based on previous existing networks. We keep a dyadic level of analysis, the main focus is still tie formation (destruction), but we consider endogenous mechanisms, i.e. mechanisms through which the current network structure influences its future evolution. From this perspective, the literature has identified several relevant mechanisms.

The first of these mechanisms is reciprocity. Relations are often directional meaning, that an organization choses another who may or may not return[10]. Reciprocity mechanisms refers to this "return" choice, the existence of a relation from i to j influences the creation of a relation from j to i. Reciprocity occurs because of the desire of organizations of maintaining an ongoing relationship (Bock et al., 2005). Indeed, reciprocity is not only a mechanism affecting tie creation, but also reducing tie disruption, because non-reciprocity may reveal mistrust, abusing behaviors and non respect

[9] Recent developments of transport let us distinguish between geographical proximity and co-location. Two organizations can be geographically proximate without being co-located thanks to temporal meeting Torre and Rallet (2005).

[10] When relations are undirected reciprocity is not an issue and the analysis focus only on the existence of a link between both organizations.

of community rules (Breschi and Lissoni, 2001; Uzzi, 1996). Secondly, another basic mechanisms at play in network dynamics is repetition, i.e. the existence of a relation between two organizations in the past increases the probability of its existence in the present (Soda et al., 2004). Common past (positive) experiences of collaboration are the most important source of mutual trust, and a powerful indicator of previous satisfying relations. Moreover, repeated relations increases mutual knowledge, and so costs of relation construction reduce due to lower information asymmetries, lower risk of opportunism and lower uncertainty (Gulati, 1995). Both mechanism, reciprocity and repetition, are associated with network stability. They endogenously reproduce the existing structure. A third relevant structural mechanism of tie creation is triadic closure. It induces the creation of a relation between two organizations previously connected to a common third organization[11] (Davis, 1970; Gulati and Gargiulo, 1999), or in colloquial terms "friends of my friends become my friends". Network closure is one of the main structural differences between social and biological or technological networks (Simmel, 1908). Several explanations lie behind this tendency. Firstly, the common third increases the probability of meeting even without explicit introduction (Feld, 1997). Most importantly, the third organization is a fundamental source of information through referrals and gossip about capabilities, behavior and trustworthiness of the other. These additional reliable information reduces uncertainty and risk (Uzzi, 1996). Finally, once the relation has been established, organizations are less inclined to adopt opportunistic behaviors, because collective norms emerge, and so the risk of reputation lost and community exclusion prevent them (Coleman, 1988). Consequently, triadic closure not only favors relations creation but also prevents relations disruption.

The cumulative process of entry/exit and ties formation/disruption produces structural differentiation, this is a "*systemic property that captures the extent to which organizations come to occupy an identifiable set of network positions, each of them characterized by a distinctive relational profile*" (Gulati and Gargiulo, 1999, p.1450). Differentiated network positions may be used as competitive tools. Organizations exploit their relational profile to increase their performance, profits and control. Moreover, and from a dynamic perspective, the existence of differentiated network positions acts as a motor for continual network change (Ahuja et al., 2012), i.e. organizations create and disrupt relations in order to access organizations with interesting roles in the system, or to build their own advantageous network position. The heterogeneous features of organizations manifests, among others, in their unequal relational capabilities. Thus, in networks may co-exist highly and poorly connected organizations (Borgatti and Everett, 1999). Preferential attachment is an endogenous mechanism of relations creation

[11] The effect of sharing common third organizations is additive. Each additional common partner with a non partner organization increases our likelihood of connection (Newman, 2001).

and network expansion that reinforces this pattern. It posits that new organizations tend to form relations with existing organizations according to their degree distribution (Barabási and Albert, 1999). So in a "rich get richer" phenomenon, more central organizations have a higher probability of receiving new relations, so they are more attractive. New entrants have poor informational sources, so they use organizations degree as a proxy of fitness. More central organizations have higher visibility and this may indicate higher performance, higher competence and higher collaborative predisposition (Podolny, 1994; Balland et al., 2013b). Additionally, central organizations are attractive as a powerful source of information for future partners thanks to its many relations (Gulati and Gargiulo, 1999). However, some studies argue that this strong tendency in technological networks is attenuated in social networks by several factors, resulting in less skewed distributions. On the one hand, relations consume time and money, so organizations are limited by the number of relations they can meaningfully maintain. In this sense, Kogut et al. (2007) found that the more expensive relational construction is, the less skewed the degree distribution. On the other hand, there exist other mechanisms that may reduce the importance of preferential attachment. In addition to the mechanisms discussed above, preference for novelty mechanism is particularly important in inter-organizational networks, and it echoes the heterogeneity behavior discussed in proximity mechanisms. While closure and preferential attachment mechanisms contribute to reinforce the network structure, preference for novelty is source of more significant network changes. It refers to the creation of relations between disconnected network areas. Burt (1992) calls them "structural holes". The main rationales for this behavior are the access to much different knowledge, necessary for disruptive innovations, and the benefits associated with brokerage positions. On the one hand, they often bridge bigger cognitive gaps, so they need higher absorptive capacities. On the other hand, the construction of these relations have to deal with much higher uncertainty and risk due to missing information steaming from no previous experience, gossip and referrals.

1.4.2. Ego level

The aggregation of relations among the existing organizations results in a whole network with a structure. Each organization has a position in this structure defined by his relational set, i.e. egos' connections, egos' alters connections, their individual characteristics and the whole network features (Zaheer et al., 2010). Research at ego level runs away from the view of organizations as autonomous entities to study the effects of network position of organizations on their behavior and performance (Gulati et al., 2000). The analytical focus shifts from the features of a particular relationship in the dyadic level, to the features of network structures with ego as focal point in the ego level.

The study of the link between organizations' performance and their network position has concentrated the bulk of the literature on inter-organizational networks (Ozman, 2009; Zaheer et al., 2010)[12]. Consequently, a rich bunch of concepts and measures have been developed for both, performance and network positions. The measure of organizational performance vary significantly depending on the particular research question and the available data. Research interested on market or financial success have used revenue (Baum et al., 2000), profit (Tsai, 2001) or survival (Mitchell and Singh, 1996) of organizations as performance indicators. Innovation studies have constructed several indicators to measure organizational innovation output such as number of patents (Ahuja, 2000a), creativity (Cattani and Ferriani, 2008) or rate of new product development (Tsai, 2001). Finally, network measures, such as prestige or ephemeral structural hole position, can be also used as performance indicators of a network position.

Similarly, social network scholars have been quite productive in the development of measures to capture different dimensions of organizations network position and role. In this sense, one of the primary uses of network analysis is the identification of the most important and prominent organizations in the network. Following Knoke and Burt (1983), an organization is prominent if his relations make him particularly visible for the others. Visibility is often measured with different centrality indicators[13]. The simplest and more often used is degree centrality: the most active organizations have the most ties. More complex, Bonacich centrality computes a centrality score considering ego and ego's alters centralities. Closeness centrality do not consider the direct neighborhood but the whole network, and measures how close an organization is to all other actors in the network. The underlying idea is that central organizations can quickly reach all others in the networks. Finally, betweenness centrality is associated to the notion of control. Central organizations lie in the paths connecting others, i.e. between many of the organizations (Wasserman and Faust, 1994). Irrespective of the used measure, the main findings converge to suggest that centrality increases performance in terms of innovation output and financial or market success. Ahuja (2000a) found that the number of direct and indirect collaborations of chemical companies had a positive impact on their patenting activity. Soh (2003) analyzed the network of technological alliances of the computer networking market to find out that the quality of

[12]Although, most of the studies have treated networks as "pipes" through which resources, knowledge, opportunities... circulate, and set the bases for increased performance due to privileged positions, there may be an issue of causality. Podolny (2001) proposes a reverse view, that considers networks as "prisms", i.e. network position reveals organization status and so it works as a strong signal of quality. While for the "pipes" view network position influence performance, for the "prisms" view performance influence network position (status).

[13]They have been developed for both, directed and undirected networks.

the new product developments was positively affected by the central position of the organization. Tsai (2001) extended the conclusions towards profitability of the organization. In the same line but with a multi-level approach, Fershtman and Gandal (2011) found centrality of contributors influenced the market success of open source software.

Much more debate has been generated by the link between ego network structure and social capital. The apparent opposite views between structural holes and closure as determinants of social capital have been the source of numerous research efforts at this level of analysis. Coleman (1988) argues that closure, dense cohesive structures where egos' alters are mutually connected, strengthens social capital because it facilitates the emergence of effective norms, maintains trustworthiness, facilitates sanctions, and so avoids opportunisms. Contrary, Burt (1992) asserts that greater social capital benefits arise with sparse networks with non-redundancies. Organizations linking otherwise unconnected groups of actors, i.e. spanning structural holes, profit from a competitive advantage due to their early access to more diverse sources of information and the control of flows between both sides. Consequently, both authors claim that social capital is generated by two different mechanisms that are exactly opposed one to the other. Burt (2000), based on a long list of empirical studies, proposes an integration of both views. For him, they are two different complementary rather than competitive mechanism reflecting the need of groups to access to different information and share it within the group. Others have found that the importance of both mechanism is contingent on the context (Adler and Kwon, 2002). Gabbay and Zuckerman (1998), Walker et al. (1997) and ter Wal (2010) find that in early stages of an industry or network, structural holes are more important since tacit knowledge reduces the risk of unintended spillovers and exploration of new ideas is the priority. But, when the industry becomes more established, applied research and codified knowledge take the lead. In this context closure becomes more important.

The discussion on the importance of structural holes using only nodes and ties can be extended by adding nodal attributes as a base of group distinction. Thus, we integrate structural positions with homophily and heterophiliy behaviors. Consequently, we joins betweenness centrality and structural holes measures, but the additional information let us distinguish different brokerage roles, i.e. structural holes of different nature. Marsden defines brokerage as a "*process by which intermediary actors facilitate transactions between other actors lacking access to or trust in one another*" (Marsden, 1982, p.202). Gould and Fernandez (1989) identify five different brokerage roles based on the similarity or dissimilarity between ego and alters in certain attributes. They distinguish between coordinator, internal broker, representative, gatekeeper and liaison roles[14]. These roles are defined for each brokerage position, but organizations may have multiple relations and groups separation can be based in different criterions. Consequently, the same organization can have different brokerage roles simultaneously. In these cases, the use of proportions and external-internal index contribute to define their structural positions. In organizational research, the most important attributes used to distinguish groups of organizations have been location, knowledge bases, industry and organizational nature. According to the structural holes literature, the performance advantages are obtained thanks to their privileged access to network resources.

Finally, there are measures of ego network positions arising directly from the whole network structure. They are in essence measures of the whole network structure (see section 1.4.3), but they can be easily transposed to ego-network by exploiting the nodes classifications they produce. The two more common measures are main component and core/periphery. Main component is used as a measure of ego position by classifying nodes either as members or non members of the main component of the network. Empirical studies show a positive relation between the fact of being member of the main component and organization performance (Boschma and ter Wal, 2007; Owen-Smith and Powell, 2004). The basic rationale is that organizations have direct or indirect access to more information and resources. The same method can be used after running the core/periphery algorithm for the whole network, organizations are classified either binary as belonging to the core or to the periphery, or with a continuous score of the closeness to the core (Borgatti and Everett, 1999). In this sense, Cattani and Ferriani (2008) found a non linear effect of coreness on film creativity, the more creative individuals are in contact with both the core and the periphery.

1.4.3. Whole network level

The third level of analysis takes the whole network as a unit of analysis. Whole network level studies aggregate the existing relations among the different organizations, but they focus on the features of the resulting structure as an unique set, rather than in the positions of each organization. Thus, it takes a structural perspective to study how and why features of networks influence their performance as a whole. The focus on whole network properties has been an important issue in physics and other engineering sciences concerned by the study of technical networks such as energy, transports or world wide web networks. It is just recently that they have become a relevant research area for network scholars in social science in general (Zaheer et al., 2010), and clusters

[14]We can identify five different brokerage roles when relations are directed. However, when networks are undirected we have less information and so we cannot distinguish between gatekeepers and representatives.

in particular. Characterization of network anatomy is important because structures affect functioning (Strogatz, 2001)

Concerning the study of the relation between whole network structure and performance, there are two conceptions of performance: performance as efficiency and performance as adaptability. In a very general definition, performance, as efficiency, refers to the production of positive outcomes (innovation, profitability, employment, growth...). The effects of the whole network structure on performance can be measured either at organizational level or at the whole network level. In the first case, we focus on how the network structure influences innovation, survival or profitability of organizations. In the second case, we analyze the effect of the network structure on his aggregated outcomes. They are obviously not independent, because the performance at the whole network level is often obtained from the aggregation of individual performances. Research on clusters has often focused on innovation, and patents have been the most used measure of innovative outcomes. Patents can be assigned either to the corresponding applicant(s)/inventors(s) in the cluster, or to the cluster as a whole. However, the transposition of performance measures from the micro to the macro may be not that simple in all cases. The growth of the cluster by positive rations of entry over exit has only a partial counterpart in the form of survival analysis and start-up/spin-off processes. The use of profitability measures is somewhere in the middle, the micro macro transposition can only going through summary statistics such as the mean profit. In the opposite situation are GDP growth and employment measures of cluster performance. They are aggregated in nature and difficult to transpose from the macro (cluster) to the micro (organization), so they are only appropriated for studies of performance at cluster level.

On the other hand, performance, as adaptability, refers to the capacity to maintain the functioning features of the network over the succession of shock or endogenous transformations. Studies adopting an adaptability perspective have measured performance with network measures in itself. Performance analysis study how, after a certain event, the network architecture changes (or not) in comparison with the prior structure defined by these dimensions. According to Ahuja et al. (2012) five dimensions of network change can be identified: *i)* degree distribution of nodes, *ii)* network connectivity, *iii)* pattern of clustering in the network, *iv)* network density, and *v)* assortativity of the network. Others, like Madhavan et al. (1998), have used nodal indices but at an aggregated level to obtain a single group-level index[15]. The triggering event may be of very different nature too, going from regulation modification to technological innova-

[15]Studies on regional resilience, not necessarily concerned by networks, have measured this adaptability capacity as the laps of time necessary to reach the levels of GDP or employment existing prior to the shock, or the change in the growth rates prior and after the shock (Simmie and Martin, 2010).

tion, but the most often used (with simulation techniques) has been nodes exit (Albert et al., 2000).

Research on whole network properties has given particular attention to properties characterizing small world networks: high clustering and short average path length, two characteristics that usually operate against each other but simultaneously present in the same network. High clustering refers to the fact that, in average, organizations' connections are likely to be also connected to each other. Short average path length refers to the small number of steps separating, in average, any two organizations of the network. The original small-world idea comes from the field experiments of Milgram (1967), and has been then applied to very different social, biological, ecological and technological systems (Uzzi et al., 2007), particularly since Watts and Strogatz (1998) formalize it with two conventional network measures and a simple framework for baseline comparison.

The combination of high clustering and short path length is said to create unique performance benefits for interactive systems. Separate groups in the network enhance the incubation of diversity of specialized ideas, resources and opportunities, while the short path length favors their exit from the group to rapidly diffuse across the whole network (Cowan and Jonard, 2004). Empirical studies have shown that small world networks favor innovation. Verspagen and Duysters (2004) study network of strategic alliances on food and chemistry and electricals to find that small world networks are efficient for knowledge transfer compared to a theoretical benchmark. Schilling and Phelps (2007) found that the combination of clustering and reach in industrial strategic networks increased the number of patents of firms. Finally, Fleming et al. (2007) and Breschi and Lenzi (2012) take a regional rather than industrial perspective, to study how properties of networks of inventors impact regional innovation. While Breschi and Lenzi (2012) find support for the positive effects of small world networks, the results of Fleming et al. (2007) are less concluding [16]. Kogut and Walker (2001) study cross-ownership among German companies to demonstrate that, beyond the performance as efficiency features, small world networks exhibit also high adaptability. Small world properties of the network persisted through the substantial number of shocks of the 90s as the German economy internationalized. The conclusions of Davis et al. (2003) about corporate elites go in the same direction: we need massive restructuring to transform small world networks in another kind of structure.

However, the Watts and Strogatz (1998) small world model has some limitations to model real world networks. Barabási and Albert (1999) suggest two main weak points.

[16] Similar studies have also been applied to scientific co-authorship but the results are less consensual, not all disciplines seem to show small world properties (Uzzi et al., 2007). Studies on artistic networks join the conclusions of organizational networks (Uzzi and Spiro, 2005).

On the one hand, in the small world model the number of nodes is constant, while in real world networks may grow. On the other hand, in the small world model the probability to find nodes with large connectivity is almost zero, all nodes having quite similar number of ties. However, real world nodes exhibit heterogeneous relational capabilities, and so nodes with high and low degree co-exist[17]. Consequently, Barabási and Albert (1999) proposed a model to explain small world emergence by combining two simple rules: *i)* network growth by the entry of new nodes, and *ii)* new actors connections by preferential attachment. The combination of these two rules leads to scale-free networks with power law distribution in nodes connectivity. One of the prominent features of scale-free networks is their core/periphery structure, i.e. they have a cohesive subgroup of actors densely connected configuring the core (primary hubs), and a set of nodes loosely connected in the periphery (spokes) (Borgatti and Everett, 1999). Borgatti and Everett (1999) algorithm, centralization index and degree distribution shape have been used to account for the existence of a core/periphery structure and the identification of these two groups. Beyond the existence of core/periphery structures, literature has studied the influence of connections within and between organizations in the core and the periphery for whole network performance. Based on the correlation of degree, networks are said to be assortative when highly connected nodes interact with highly connected nodes, and poorly connected nodes interact with poorly connected nodes. Networks are classified as disassortative otherwise (Newman, 2002). Networks with core/periphery structures are argued to be performing from the efficiency perspective, while disassortative networks are said to be performing in the adaptability perspective (Brede and Vries, 2009).

Empirical studies analyzing the effects of core/periphery structures on whole network performance in the context of inter-organizational networks are scarce[18]. From the efficiency perspective, the literature has focused on the construction of technological systems where standardization and complementarity are fundamental competitive tools (Rullani and Haefliger, 2013). From the adaptability perspective, studies on resilience of technological and biological network have analyzed the changes in network connectivity after successive nodes removal (random or target) (Albert et al., 2000). They found that in core/periphery structures with few super-connector nodes target removal had a dramatic impact on connectivity, but on the contrary, with random removal the network maintained connectivity levels even with high removal rates. There are no systematic replications of such studies for inter-organizational networks, but

[17] In fact, this was also present in the Milgram (1967) experiment. Although less popular than the idea of small world he found that 66% of the transmissions passed through the same four people, the superconnectors.

[18] The impact of core/periphery structures (and positions) are often studied at the ego level (see section 1.4.2) and at the dyad level see section (1.4.1.2).

there are interesting similar attempts. Madhavan et al. (1998) studied the impact of a regulatory change and a technological innovation in the architecture of the network of strategic alliances in the global steel. Eisingerich et al. (2010) analyzed several high-tech clusters to find that when environmental uncertainty increases the relative importance of network openness increases too, while the relative importance of network strength decreases. Orsenigo et al. (1998) found that successive generations in biotech industries do not change the core/periphery structure of the collaborative network.

Table 1.1 recapitulates the main points of this discussion. When organizational networks are considered, it summarizes, for each level of analysis, the measures and determinants of performance most often used, as well as the associated network measures.

1.4.4. Levels interplay

Although each of the three levels of analysis focusses on different units of analysis they are not independent. The dyad focuses on the basic units of networks, i.e. the relation established between two organizations. The ego level focuses in particular subsets of the network, composed by a focal organization (the ego), and the set of direct and indirect relations it has with other organizations. The whole network level studies the structure as the aggregation of all organizations and their relations. To the extent that each analytical level represents an increasing level of aggregation, they are mutually interdependent. Therefore, events or changes at micro level, such as relations creation or disruption, affect and modify macro levels, such as ego and whole network. Reversely, architecture at macro level may influence decisions at lower levels (see Figure 1.1).

Section 1.4.1 has shown that the cumulative succession of dyad formation, renewal and disruption is one of the basic processes of network change[19]. Organizations construct their ego position in the network by exploiting their relational capabilities to manage their portfolio of relations, i.e. decisions of formation, renewal, and disruption of relations at dyadic level modifies simultaneously the network of the focal organization, the networks of the organizations around it, and the whole network. This interplay between levels of analysis can go even further. The dominance of certain mechanisms of tie creation may be associated with the emergence of certain network structures. For instance, preferential attachment tend to result in scale free networks with core and peripheral organizations, closure mechanisms tends to increase clustering coefficient and preference for novelty behavior results in networks with shorter path length. However, the co-existence of different mechanisms and their probabilistic nature prevents determinism. Additionally, it is worth to mention that, although any new or extinct tie

[19]Together with organizations entry/exit, and organizational change.

implies a network change, it does not mean that the ego or the whole network suffer a radical transformation in their properties. Some network structures have shown a high capacity to maintain their main properties face to shock of different nature producing network change (Orsenigo et al., 1998; Kogut and Walker, 2001).

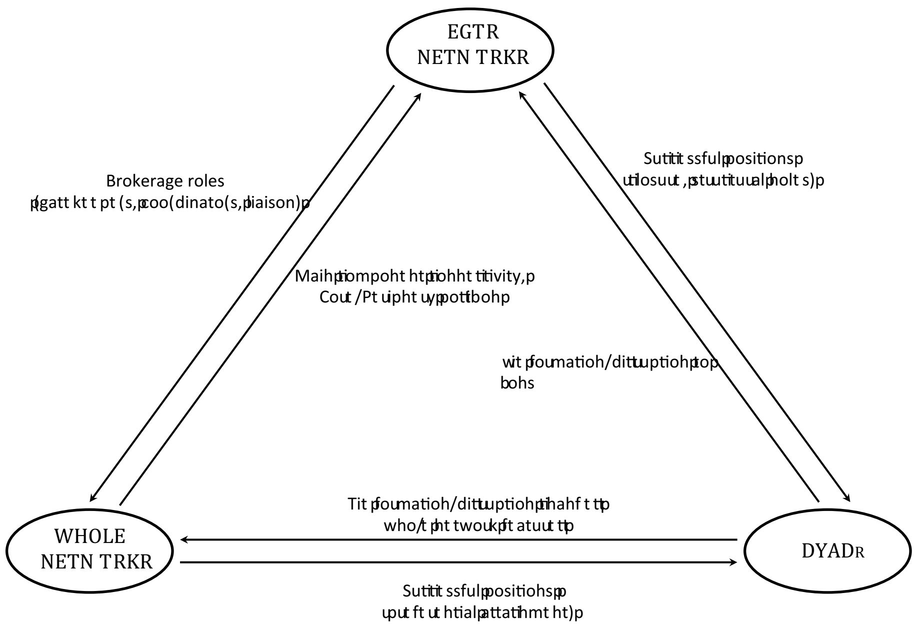
The interplay from dyad level to ego and whole network level can also be reversed. As we have discussed in section 1.4.1.2, structural mechanism influences relational behavior. Structural positions of organizations (ego and whole network level) are endogenous motors of network change (dyadic level). The features of the existing network and the set of relations each ego has influence future decisions of relation's construction and partner's selection for ego and for alters. Advantageous positions, such as structural holes, become attractive positions, so other organizations may modify their portfolio of relations to meet an equivalent advantageous position, and possibly extinguishing the previous advantage. Reciprocity, repetition, closure, preferential attachment and preference for novelty mechanisms are source of endogeneity in network evolution: dyad formation/disruption modify (ego and whole) network structure, and (ego and whole) network structure conditions formation and disruption of dyads. Network evolution is then a path dependent process where "*at each moment of time the suite of possible future evolutionary trajectories (paths) [...] is conditioned by (contingent on) both past and the current state, and some of the paths are more probable than others*" (Martin and Sunley, 2006, p.402).

Ego network and whole network levels of analysis are also interdependent. On the one hand, valuable network positions for an organization are often defined in the whole network. The corenness position of an organization not only depends on the direct and indirect relations of ego with first order alters, but also on the relations of his alters with the whole network. Similarly, the membership of an organization to the main component of the network, that increases egos reachability, goes beyond the organization direct network and depends on the the connections existing in the whole network. On the other hand, the performance of a whole network, from either efficiency or adaptability perspective, is often contingent on the existence of organizations in certain network positions, i.e. with particular ego-networks, assuring the connectivity and well functioning of the whole network.

1.5. Discussion: back to clusters

The application of network theory, in their diverse analytical levels, to clusters has produced positive strides in the understanding of clusters phenomenon and functioning. In cluster contexts, most of network studies deal with inter-organizational networks because firms, universities, research centers, government agencies... are the basic com-

Figure 1.1: Interplay among network analytical levels



ponents of clusters. However, some researches on clusters have done one additional step in disaggregation and have studied inter-personal networks on clusters. They look at labor mobility, inventors collaborations or entrepreneurs background to study knowledge flows and cluster growth. The most studied interactions in cluster context concern knowledge exchanges. On the one hand, it is evident that in knowledge-based economies knowledge is a fundamental input. On the other hand, the relation between geographical proximity and knowledge exchanges has revealed as particularly complex.

The literature on clusters has traditionally pointed to agglomeration externalities of different type as the principal reason of spatial clustering, the importance of *being there*. Among them, localization knowledge spillovers have been source of great debate. The common assumption is that being proximate to other firms and universities gives rapid access to new and relevant knowledge, and thus get innovative advantages over distant organizations (Jaffe, 1989; Jaffe et al., 1993; Audretsch and Feldman, 1996b). Knowledge is conceived as a local public good (Antonelli, 2005). However, during the last decade criticism has raised because localized knowledge spillovers literature does not consider knowledge channels (Breschi and Lissoni, 2001). These critical voices claim for opening the knowledge spillovers black box focusing on networks. From this perspective knowledge flows are much more complex. It is not (only) a matter of being in the right location, it is also a matter of being in the right network. For inter-organizational knowledge flows to happen, geographical proximity is neither necessary nor a sufficient condition. However, it is an easing condition (Boschma, 2005).

The adoption of dyadic level perspective to study clusters gives valuable insights on cluster evolution. Creation and disruption of relations by incumbent, new or exiting organizations represent elementary units of cluster change. Cluster's evolution depends on the balance between persisting intra-industry relations and inter-industry ones to enhance renewal by jumping from domain to domain. Equally important is the balance between formation of local and non local relations to keep local cohesion and embed the cluster in the global network. Section 1.4.1 discusses different mechanisms for relation creation and renewal. Geographical dimension is not always directly involved, and many empirical studies exists that neglect it (Gulati, 1995; Uzzi, 1996; Gulati and Gargiulo, 1999; Uzzi and Lancaster, 2003; Soda et al., 2004; Rosenkopf and Padula, 2008). However, it is very often indirectly influencing relational creation/disruption by stimulating other mechanisms such as social or institutional proximity. Cluster inward-looking relations (local) may directly or indirectly benefit of more efficient transmission technologies, and of lower formation and maintenance costs. This local bias is partially compensated by higher novelty of cluster outward-looking relations (non-local).

Several empirical studies show this interplay either for both, the efficiency of the relation and its formation/disruption. Bell and Zaheer (2007) consider geography of relations to understand transfers' efficiency through different types of ties. They study mutual fund Canadian companies and observe that more knowledge flows circulate through geographically proximate institutional ties and through geographically distant friendship ties, for organizational ties no evidence was found. Other authors explain the emergence of clusters on the base of the efficiency of local relations. Sorenson (2003) has used shoe manufacturing and biotechnology industries to show that entrepreneurs locate close to existing firms because they represent the largest pools of valuable knowledge and distance makes access more difficult. Similar argument is used by Boschma and Wenting (2007) and Buenstorf and Klepper (2009). When studying the British automobile industry or the Akron (Ohio) tire cluster, they show that the spin-off process was the source of agglomeration through heredity and reproduction of indigenous firms. Casper (2007) find the same results when reconstructing inter-firm labour mobility of managers between San Diego biotechnology firms. Finally, some authors explicitly focus on the mechanisms tie creation introducing geographical proximity as one of the several mechanisms at play. Autant-Bernard et al. (2007) and Balland (2012) applied it to R&D collaboration in European nanotechnologies and Midi-Pyrénées Global Navigation Satellite Systems sector respectively. They both found that geographical proximity between two organizations increases the probability of relation creation. Organizational and relational proximity have the same effect, but the effect of cognitive proximity was negative. Balland et al. (2013a) study how these different proximity dimension change their influence for tie creation along the life cycle of video game industry. They found that geographical proximity is more and more important when the industry becomes mature.

Since access to knowledge flows is a matter of location *and* a matter of connection, ego network level becomes relevant to study clusters and the behavior of clustered organizations. Abundant research exists to discern which network positions are more or less advantageous for organizations, but they rarely integrate the spatial dimension, i.e. studies focus on networks defined at the industrial level, but the spatial dimension of clusters is often missing. However, some notable exceptions exist. Ingram and Roberts (2000) combined friendship networks and organizational performance to show that Sydney hotels obtained better occupancy rates when their managers were central in the "friendship network of hotel managers". Boschma and ter Wal (2007) studied the Barletta footwear cluster in South Italy and found that more innovative organizations were those connecting local and non local organizations. Broekel and Boschma (2011), when studying more than 300 firms in different industries and regions in Europe, find that firms can increase their innovation performance by primarily linking to technologically related firms.

Much more common are the studies focusing on ego positions to explain performance of the cluster as a whole, either from efficiency or adaptability perspectives. An important bulk of case studies has analyzed the existence and behavior of organizations in certain network positions to explain cluster functioning and performance. Giuliani and Bell (2005) identified a core/periphery structure in a Chilean cluster of wine production. They showed how core firms drive the technological dynamics of the cluster. These studies have particularly underlined the existence and behavior of certain organizations in key network positions relevant for the performance of the cluster. Leading organizations often are gatekeepers too. Gatekeepers combine local relations with clustered organizations, and non-local relations with organizations located elsewhere in the world. They develop two fundamental functions. Firstly, they embed the cluster in the global network of the field. Secondly, they are the door through which new external knowledge may reach the cluster to avoid lock-in. However, their position can also increase the vulnerability of the cluster, because the development of the local knowledge network is dependent on the strategy of these dominant actors as showed Morrison (2008) and Hervás-Oliver and Albors (2012) in furniture district in Italy and tile cluster in Spain. Similarly, universities and other PROs are often acknowledged as key organizations for local knowledge diffusion and functioning as cognitive gatekeepers, i.e. organizations filling the gap between different technological fields. Owen-Smith and Powell (2004) show how PROs were critical for connectivity for biotechnology network in Boston. Vicente et al. (2011) underlined the function of universities and PROs as coordinators of knowledge exchanges between direct competitors in the GNSS cluster

Table 1.1: Network levels of analysis

	Dyadic level	Ego-network level	Whole-network level
Measure of performance	Resource access Relation renewal	Profitability Survival Innovation	Adaptability Efficiency Innovation
Determinants of performance	Social prox. (Embeddedness)	Structural holes	Hierarchy
	Organizational prox.	Closure	Dissassortative
	Institutional prox.	Connectivity	Connectivity
	Cognitive prox.		
	Geographical prox.		
Network measures	Relation creation	Centrality	Core/Periphery Average path length
	Relation maintenance	Brokerage	Clustering coef.
	Relation destruction	Coreness	Main component
		Main component connection	Degree distribution
			Degree correlation

in Toulouse. Universities and leading organizations have been identified as important organizations for renewal by their role as source of successful spin-offs. Young and innovative spin-offs lie behind the process of cluster renewal due to their path-breaking behavior, i.e. innovation in new areas Almeida and Kogut (1997).

Fleming et al. (2007), Breschi and Lenzi (2012) and Lobo and Strumsky (2008), focusing on small world properties, have tried to see the influence of whole network properties on cluster performance. These attempts integrate the network and spatial dimension of clusters, but no industrial frontier is defined; they work on regions rather than clusters. Further research in this systemic approach of clusters is still needed. Indeed, following Strogatz (2001) who says that structure always affect function, and Markusen (1996) who shows that clusters may have different structures, we get that the study of network structures of clusters becomes fundamental to understand differences in clusters' efficiency effects and adaptability or renewal capacities.

Chapter 2

How emergence conditions of technological clusters affect their viability? Theoretical perspectives on cluster life cycles

This chapter is based on a paper single authored in the early stages of the PhD, and published in European Planning Studies[1]. This chapter presents a general framework to study cluster evolution as interplay between a technological/industrial dynamics and a regional dynamics. This framework will be the base for the developments of chapter 3 concerning network properties. This framework also grounds the empirical test of chapter 4, combining networks and technological dynamics; and chapter 5, combining networks and regional dynamics.

[1] Crespo, J. (2011). How emergence conditions of technological clusters affect their viability? Theoretical perspectives on cluster life cycles. *European Planning Studies*, 19(12):2025-2046

2.1. Introduction

The uneven spatial distribution of economic activity has been, although marginal, an old concern for economists (Krugman, 1991a). Special attention has received the spatial concentration of firms in the same industry. Concepts such as industrial district, localized systems of production, innovative millieux... have multiplied. However, it is the porterian "cluster", defined as "*geographical concentration of interconnected firms and institutions in a particular field*" (Porter, 1998, p.78), which has gained most attention from the academia and the political spheres in the last two decades. Nevertheless this concept is problematic at different points (Martin and Sunley, 2003).

The literature has mostly focused on the comprehension of why clusters exist, how they can be characterized and which the reasons of success their are. But dynamic aspects have been neglected. In fact, clusters are usually considered as isolated, pre-defined, pre-established and successful structures (Martin and Sunley, 2003; Bresnahan et al., 2001) that enhance the competitive performance of firms, innovation and regional growth. Contrary, not many studies focus on when and where clusters come to exist (Orsenigo, 2001; Brenner, 2004), and what makes some clusters survive in the long-term while others decline after a while (Suire and Vicente, 2009; Belussi and Sedita, 2009; Menzel and Fornahl, 2010). This chapter aims to fill this gap. We focus on genesis conditions of technological clusters, the viability conditions that determine their long-term dynamics and the links existing between both.

The definition of clusters as interconnected structures goes beyond their spatial considerations. They have a knowledge dimension too. Their interactions conform a local knowledge structure that is embedded in a larger network representing the technological field (Owen-Smith and Powell, 2004). These relations between the cluster and the technological field go in both directions: the evolution of the cluster depends on the evolution the technological field, and the evolution of the technological field depends on the evolution of the several clusters specialized on it. This conforms the local-global embedding knowledge structure known as technological field.

This chapter particularly focuses on the evolution of technological clusters, i.e. clusters that are in the cutting-edge positions in the evolution of the technological field. They usually appear with windows of technological opportunity in emergent technological fields resulting of knowledge recombination. Technological clusters are mostly driven by knowledge and innovation and no so much by cost/price competition of productive clusters.

The aim of the chapter is to analyze how the mechanisms at play for the emergence of technological clusters, influence its long-term viability. We explain that the viability of clusters depends on the combined strength of the regional process and the technological process, which are linked to the emergence conditions.

To proceed in this theoretical construction, we ground our reflexion on a critical review of the literature. Our analysis advances by the discussion of these arguments and their reconsideration to insert them in our clusters lifecycle framework. Through these methodology we make several propositions whose articulation let us argue the validity of the initial hypothesis linking emergence and viability. Additionally, several case studies extracted from the literature illustrate these arguments. These case studies are selected on the base of their dynamic insights and their technological nature.

To do so, Section 2.2 defines the cluster as a combination of a regional and technological dynamics traversed by different networks. Section 2.3 is concerned by emergence and the double dynamics process. Section 2.4 focuses on the combination of regional and technological dynamics to ensure long-term viability. Section 2.5 links emergent and viability conditions to propose that both stages are interrelated.

2.2. Clusters: the cross-roads of double dynamics

We decompose the Porter's definition of cluster in its basic elements. The cluster's development from emergence to decline depends on the joint evolution of regional and technological dynamics. We firstly analyze the interplay between these dynamics, and secondly we identify the main factors influencing them.

2.2.1. The nature of a double dynamics

Michael Porter (1998) definition encompasses the basic frontiers of a cluster. They are technologically defined by the "particular field" on which "firms and institutions" develop their activities, and spatially by the "geographic concentration" of these actors in the same region. These two boundaries, although very elastic (Martin and Sunley, 2003), let us take the cluster out of its isolation and place it in the intersection of two dynamics: technological and regional. Moreover, actors in a cluster are "interconnected", then the evolution of these two dynamics is crossed by networks of different nature that affecting their evolution.

Actors develop their activities in different spheres, so they belong to different overlapping networks. Three types of networks with different structuring principles exist. Firstly, there are social networks of inter-personal nature (Grossetti and Bes, 2001). They account for the personal relations of human beings. Secondly, there are industrial networks. They are inter-organizational relations of productive nature on the production chain (Storper and Harrison, 1991). Finally, firms and institutions may be linked through knowledge networks, i.e. networks linking actors in their exploration/examination phases to construct new products or application (Vicente et al., 2011).

Since firms and institutions are characterized with respect a technology and a location, their decisions in each dimension are necessarily interdependent. This relation can be scaled up to the aggregate level, and reinforced by the transversal networks of different nature. Consequently, regional and technological evolutions are not independent: cluster's evolution is driven by the interplay of regional and technological dynamics.

Networks and dynamics do not exist on their own, they become to exist and evolve through a sequential process of multiple decisions taken by heterogeneous actors (ter Wal and Boschma, 2011). This creates particular regional and technological dynamics mutually interplaying. Consequently, clusters cannot be pre-defined and pre-established structures, but they appear as aggregation of individual actions of actors. From the long-term perspective, cluster's evolution is continuously exposed to the occurrence of endogenous and exogenous transformations affecting the regional and/or technological dynamics. Therefore, clusters are not always never-ending success stories.

Most of the works about clusters evolution make a unidirectional association between the industry or technology life cycle and the cluster life cycle. Based on industry life cycle (Klepper, 1996) and technological cycles models (Abernathy and Utterback, 1978; Anderson and Tushman, 1990) the evolution of the cluster is supposed to run parallel to that of the industry/technology. There is a unidirectional link between the evolutionary pattern of the industry/technology and that of clusters. In this sense, Arthur (1989, 1990) modeled how a technological and a regional monopoly can independently emerge by the generation of externalities. However, if technological and regional dimensions are bi-directionally interlinked, the cyclical outcomes of clusters are not so straightforward. The technological evolution depends on what happens at regional level in the several locations where the activity is present. Similarly what happens at regional level depends on the technological dynamics. But due to the local-global articulation of the technological field with respect regions, the symmetry between both dynamics is not perfect. Consequently, not all clusters in the same technological field will experiment the same evolution, neither will do all the activities in the same region.

H1: Conditions for cluster viability depend on its emergence conditions.

The success from the emergence perspective requires the capacity to generate the right synergies between technological and regional dynamics in order to succeed in the double competitive process generated after a technological shift. While the aeronautics/aerospace in Toulouse region may illustrate the success (Dupuy and Gilly, 1999), the case of biotechnological activities in Lombardy illustrates the failure (Orsenigo, 2001). From the long-term perspective, what matters is the cluster's capacity to maintain the regional conditions to follow the growth of the technology (Suire and Vicente, 2011), and be able to dissociate from it when the technology declines. The sustaining and dissociation capacities depend on cluster's structure which is mostly defined at the emergent stage. At this moment, different emergence mechanisms create networks, technological and regional processes of dissimilar strength. Although regional and technological dynamics are interlinked they are neither symmetric nor influenced by the same determinants. That is why some clusters, such as Silicon Valley, maintain their innovative nature when the technology enters their mature stage (Saxenian, 1994), while others, such as Silicon Sentier (Paris), decline while the technology is still growing (Vicente and Suire, 2007).

From this perspective successful clusters have the capacity to maintain as a location norm and overcome the different threats and opportunities they face. Hence, Silicon Valley is successful not only because of its current innovative performance, but also by dynamic performance, i.e. its viability. This explains its successive shifts from defense to integrated circuit, personal computer, Internet and clean-tech. Each wave, responding to different external shocks such as cutbacks of defense spending or price competitive challenges, has created a growth period transforming the Valley (Saxenian, 1994).

Consequently, clusters, composed by several interactive actors, appear in the cross-roads of technological and regional dynamics. However, these two dimensions are not independent. It is the interplay among them, produced by individual actors and their networks, that defines the evolution of clusters from the emergence to the eventual renewal or decline.

2.2.2. Factors influencing the regional and techno-industrial dynamics

We review here the static and dynamic factors that influence the regional and technological dynamics as well as their interconnection through different networks.

The static views of location underline the relevance of geographical endowment, transport possibilities and firms' needs, to explain the resulting industrial spatial pattern. More recent approaches have nuanced these deterministic views by introducing indeterminacy generated by endogenous agglomeration forces (Krugman, 1991b; Arthur, 1990), and adaptive instead of static environment (Scott and Storper, 1987). Although they point to chance, locational capabilities and externalities to explain agglomerations, initial conditions cannot be completely ignored as trigger of cluster development.

Firstly, the very early entrants do not profit of external effects and take their location decisions on the base of existing initial conditions. Secondly, the dependence on a particular resource only accessible in certain locations can make emerge a cluster by pure necessity. From the long-term perspective, the nature of resources influences viability by locking-in the choices of actors due to their non-contestability and alternative potential uses. The technological counterpart of deterministic analysis takes the form of intrinsic performance. The users adopt a technology based on its performance without considering the potential feedbacks. Similarly, viability depends on the relative better intrinsic performance of a technology compared to new and old alternatives, and the size of switching costs.

With positive feedbacks chance becomes important and path dependency trajectories may appear (Arthur, 1989). Chance is conceptualized as random small-events that probabilistically occur in a sequence of time. However, not everything can happen because the probability to occur it is not the same for all events (Martin and Sunley, 2006). Admitting the importance of chance does not mean that each actor takes its own adoption or location decision regardless of parameters such as performance, regional conditions or available information. Arthur (1989, 1990) synthesizes it in two variables: private preferences and externalities imposed by previous decision-makers. This combination of chance and externalities magnifies early small-events and make location and adoption processes path-dependent and unpredictable.

Externalities can adopt the form of informational signals, agglomeration economies or network externalities. Informational signals are important in uncertain contexts with incomplete information about technological and regional features. They create a particular process of location and adoption influencing viability of clusters. Adoption and location decisions are subject to uncertainty and incomplete information because some relevant particular features are only observable a posteriori. In such contexts, early decision makers generate several externalities. They produce additional information about the properties of their chosen technology (region), and so reduce the informational problem. As epidemic models show, information is more easily available for more popular technologies (regions) (Geroski, 2000). Additionally, uncertain contexts incite actors to adopt mimetic behaviors by imitating the decisions made by similar actors in similar situations. They cause bandwagon effects (Bikhchandani et al., 1998). Although mimesis and bandwagon effects drive to convergent decisions, they do not generate any additional return for co-adopters or co-located firms (Vicente and Suire, 2007).

Agglomeration externalities are defined as "*advantages (or disadvantages) that local firms draw from a concentration of economic actors and activities in their close vicinity*" (Neffke, 2009, p.22). These effects, external to the firm but spatially constrained, are usually classified in three categories. Localization externalities involve the formation of pools of skilled labour, specialized inputs and services and specialized knowledge spillovers. Jacobian externalities refer to the benefits (or costs) of the agglomeration diversity, potential source of inter-industry spillovers. Urbanization externalities, associated with the size of the city, involve market access, public utilities and common infrastructures, but also congestion costs. Assuming that positive externalities are bigger than negative ones co-location becomes more attractive than isolation.

This account about agglomeration externalities has two shortcomings. Firstly, their rise as co-location goes may not be so straightforward. Hanson and Pratt (1992) argue that places are not just the containers where labour market processes take place, but it is through place-based interactions that local labour markets emerge. Similarly, the emergence of specialized suppliers and service providers requires interaction to identify the specialized needs and define the nature of linkages. The generation of knowledge spillovers has received large attention. It is argued that geographical proximity is neither a necessary nor a sufficient condition to observe them, because knowledge spillovers may be grounded on other forms of proximity (Boschma, 2005). Knowledge flows, to be effective, need a minimal cognitive proximity (Nooteboom, 2000). Consequently, diversity is not enough to boost innovation, what it is important is related variety defined as industrial sectors that are related in terms of shared complementary competences (Frenken et al., 2007). Secondly, the above account assumes passive firms in the defense of their choices. However, given the strategic character of locational decisions, previous entrants engage in explicit strategies to defend their choice rather than wait for later entrants to follow them. Both nuances claim for the relevance of interaction, i.e. the existence and structure of underlying networks, to explain regional and technological dynamics.

From the technological point of view, increasing returns externalities are known as network externalities: the user's utility obtained by adopting a technology is positively dependent on the number of adopters. The private decision of an actor adopting a technology creates direct physical effects on size, indirect effects on quantity, quality and variety of complementary goods, and induced effects on quantity, quality and variety of complementary services (Katz and Shapiro, 1985). However, network externalities may not arise automatically. The demand side induces them, but they require the adoption of certain behaviors from the supply side in order to be generated: pre-emption, construction of complementarity and compatibility. In technological competition, network externalities are fundamental to establish and maintain a technology on the long-term (Arthur, 1989), and so it is co-operative behavior to gain early advantage and build up complementarity and compatibility. Since both strategies cannot be achieved in isolation, they depend on the existence and structure of networks. Consequently they are linked to regional dynamics.

The literature has identified several forms to organize this "battle". They range from market-mediated for a de facto standard to politically-mediated for de jure standards (David and Greenstein, 1990). They reflect the need to develop collective strategies of co-operation and interaction among supply actors, because proprietary control and risk of wrong choices create incentives for firms to act and defend their technology. Pre-emption, pricing strategies and the construction of compatibility and compatibility are the basic competitive tools (Katz and Shapiro, 1994). Compatibility decisions are done to allow different technologies to be interchangeable either vertically (successive generations) or horizontally (alternative new technologies) (Katz and Shapiro, 1985). Complementarity means to wide the range of attachable goods and potential uses to a certain technology (Katz and Shapiro, 1994).

All the three externalities considered insist on the role of interactions for their generation and the need to overcome quantitative accounts to introduce also qualitative aspects. Either for enhancing the size of informational, agglomeration and network externalities, or for cluster lifecycle, it is not just matter of how many links and actors there are, but also the context of interaction, the ego/alter attributes of heterogeneous actors and the aggregated resulting structure.

We can conclude that the technological and regional processes underlying the cluster's evolution results from the combined effect of chance, necessity and external effects generated by interactive heterogeneous actors. In the following sections we focus on the particular form these factors take at each stage of the lifecycle and the interplay among them (Look at Figure 2.1 for a summary of the main arguments).

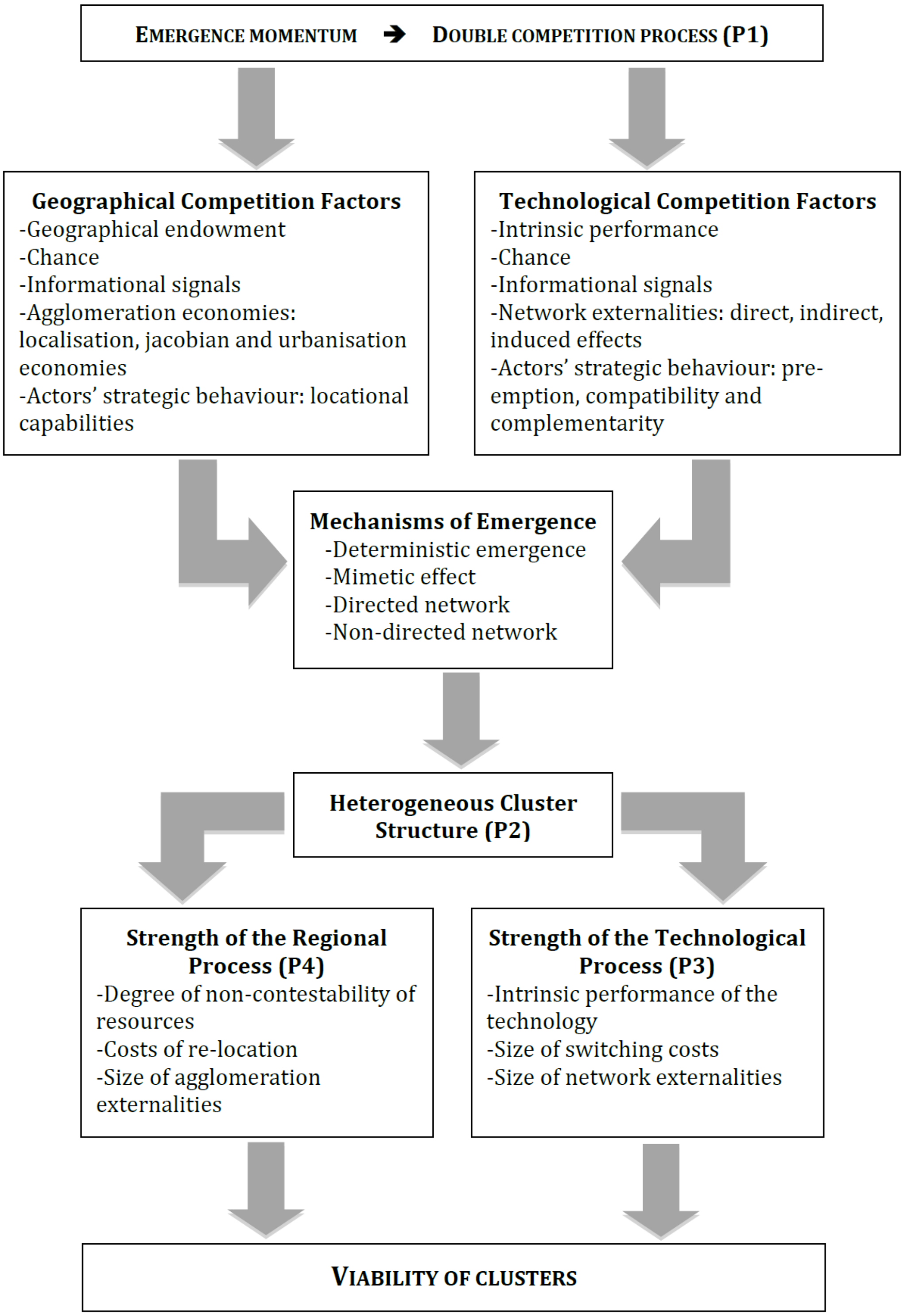
2.3. Regional and technological dynamics in the cluster emergence

Contrary to what is usually assumed, clusters are not established *per se*. The current success of Silicon Valley or Toulouse aeronautics/aerospace cluster has gone through a previous stage of emergence where the conditions were different. In this section we first analyze the conditions required for a new cluster to emerge, and later we turn to study the double competitive process in itself.

2.3.1. Conditions for the emergence of clusters

A cluster's emergence implies a break with the existing spatial pattern. This break can be triggered by an increase in demand, a change in regional conditions or a technological

Figure 2.1: Schematic summary of chapter 1 propositions



shift (Brenner, 2004). Increases in demand are acknowledged to have the potential to create new clusters through dispersal dynamics (Storper and Walker, 1989). They increase the production capacity of existing clusters; they are clusters of productive nature. A change on regional conditions can result on a technological or productive cluster depending on complementary conditions. However, since we are talking about technological clusters, the main momentum of emergence is linked to the windows of technological opportunity in the form of technological shift or need of technological evolution. The advent of a breakthrough innovation generates a double indeterminacy, technological on the one hand, and regional on the other hand. Consequently, a double competitive process is launched.

> P1: Clusters emerge in those regions that manage to be successful in the regional and technological competition process created after a technological shift.

The technological indeterminacy originates because the technological shift generates multiple technological forms. So, through a process of variation and selection different technological alternatives compete to become the dominant or standardized one (retention) during an era of ferment (Anderson and Tushman, 1990). The initial form of the new technology is progressively shaped through this competition. As the battle VHS vs. Beta or the Minitel vs. Internet illustrated, this competitive context is characterized by high uncertainty, incomplete information and heterogeneous actors voluntary and/or involuntary interacting.

The spatial indeterminacy appears because a gap is formed between the new locational specifications[2], of the emergent technology and the regional conditions accumulated along the past trajectories (Boschma, 1997). Regions may be locked-in in a production environment defined by the productive conditions accumulated in the past but which are unfitted to answer the needs associated with the new technology. Although Scott and Storper (1987) established the concept Window of Locational Opportunity (WLO) to refer to the "*moments of enhanced locational freedom*" enjoyed by an industry, it equally applies for contexts in which the location of actors entering a new technological field does not depend on past conditions. This indeterminacy launches a competition among regions to become the location norm.

From that perspective local environment is not a static selection mechanism. Grounded on location capabilities (Storper and Walker, 1989) or creativity (Boschma, 1997) of actors the environment is dynamically shaped to close the mentioned gap. However,

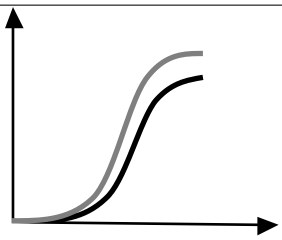
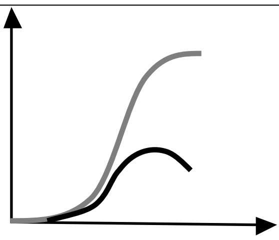
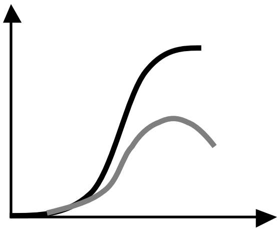
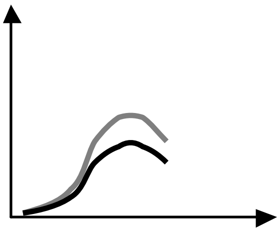
[2]Locational specifications refers to the labour, natural resources and consumers as well as the complex vertical and horizontal linkages that define the technology input-output conditions (Storper and Walker, 1989)

space does not become irrelevant. Technological change is not exogenous to space. Innovations are triggered by spatial structures and practices revealing problems and opportunities (Storper and Walker, 1989). Moreover, spatial conditions differ among regions due to their different histories and mixtures of advantages, constrains and capabilities (Boschma, 1997). This nuances the vision of Storper and Walker (1989), who only consider the role of chance in the formation of the industrial spatial pattern. Boschma (1997) defends that since new spaces are built on the base of existing spatial conditions chance is not enough. Chance matters when the particular conditions to stimulate the attraction and creation of localisation specifications are widely available on space. Feldman and Francis (2003) show this by underlining the role of entrepreneurs. The pursuit of their own interest contributes to shape the environment, spark regional transformation and overcome the constraints of initial conditions to close the WLO. The shock caused by a regulatory change on the transfer of publicly funded intellectual property to individual firms triggered the transformation from latent to active entrepreneurship due to higher incentives, and launches the formation of a biotech cluster in US Capitol region. Pria (2008) insisted on the relevance of policy decisions to foster cluster emergence by altering the initial conditions and constructing regional advantages (Cooke, 2007). Photonics cluster near Bordeaux relies on the implantation of the military equipment LMJ decided by the French Atomic Energy Commission, which launched an endogenous process of spin-off creation and technological transfer to create a pool of specialized SMEs (Carrincazeaux et al., 2009). Bresnahan et al. (2001) talk about the role of large firms to nurture technical and managerial competences, as it was done in Silicon Valley by Stanford University and Fairchild Company (Saxenian, 1994).

With these indeterminacies a double competition begins (Table 2.1). According to proposition 1, with a failure in the technological competition the demand for the technology is too weak to sustain the growth of a cluster. Similarly, a failure in the regional competitions implies that the region was not able to generate the conditions to attract new entrants and agglomerate, the cluster will neither exist. Since both indeterminacies have the same origin, and most of the actors are involved in both competitive processes, the regional and technological competitions are interdependent. The resulting techno-spatial pattern is a dynamic process that depends on the individual evolution of each process and the interplay among them.

In the upper-left case a cluster emerges. The region is able to take advantage of the WLO by meeting the new locational specifications required before alternative locations. Moreover, the regional dynamics is able to strengthen the competitive performance of the technology to become the standard. This is the case of biotech in San Diego, where entrepreneurs have profited of region's scientific capabilities to, firstly, set biomedical

Table 2.1: The double competitive process at emergence

		Regional Competition	
		Competitive Success	Competitive Failure
Technological Competition	Competitive Success		
	Competitive Failure		

X-axis : time ; Y-axis : cumulated employment in a technological field in the same region (black). Technological adoption (grey).

research centres, then lobbying for the establishment of university in their proximity and finally, creating and attracting biotech firms leaded by Hybridtech since late 70s (Casper, 2007). Contrary, the upper-right case represents a failed emergent process. Early co-located actors were engaged in good technological dynamics. However, the regional process stopped in the creation of proper environment for the technology. New entrants decide to locate elsewhere and the cluster does not emerge. This illustrates the fail of a biotechnology cluster in Lombardy due to the "*structural weakness in the [regional] industrial base, in the research system and at the institutional level*" (Orsenigo, 2001, p.77). The lower-left case represents the figure in which the cluster may emerge because of the strength of its regional dynamics. However, its effective development is compromised by its weak capacity to impose in the technological competition. Two outcomes are possible here. Firstly, a small cluster focused on a local standard may appear. Secondly, based on the strength of its regional dynamics the cluster manages to shift and integer a more performing technology to emerge. This reflects what happens in Rennes Atalante. The cluster managed to locally impose temporary its technology: in France the Minitel was initially more successful than Internet. But the global "victory" of Internet forced the cluster to abandon the Minitel (Pria, 2008). Finally, the lower-right case illustrates the case in which no cluster emerges because of the fragility of the regional and technological dynamics on it.

2.3.2. Emergence: a double competition process

This section explains how the factors identified in section 2.2.1 drive the regional and technological dynamics for cluster's emergence. According to the literature the double competitive process goes by two phases with different logics. The first refers to the initial stage where no externalities exist; each actor decides individually. In the second phase external effects become important and decisions made by previous entrants influence latecomers. We argue that different mechanisms are at play in each phase, and each dynamics explains the location and structure of the cluster.

The emergence of a cluster is necessarily nurtured by the arrival of firms into the region[3]. The particular mechanisms at play, guiding the decisions of co-location of new entrants, drive the potential cluster through the different emergent phases, and produce different cluster structures.

Regionally, the first phase, the pioneering phase (Bresnahan et al., 2001), is characterized by the existence of particular specifications and the transformation of local private/public actors from latent to active in response to an exogenous shock opening the WLO. The actions of these first entrants, shaping the environment to meet the new locational specifications, are fundamental to the cluster development (Feldman and Francis, 2003). The second phase, the agglomeration phase (Pria, 2008), refers to the emergence of a location norm. The eventual generation of agglomeration externalities by early entrants influence the location decisions of new entrants. Consequently, regional competition success depends on the existing geographical endowment, chance and the interactive behavior of co-located actors.

From a deterministic approach, the cluster emerges by a resource effect. In a strict sense, no spatial indeterminacy is created. This emergence mechanism stands for those clusters grounded on a particular natural resource that seriously conditions the location choice. However, perfect determinacy is rare, deterministic views are too narrow to entirely explain emergence in a world where externalities exist and the environment can be shaped, especially for technological clusters where the fundamental input is knowledge.

In non-ergodic contexts what matter is to close the gap between the existing and required locational specifications sooner and better than alternatives regions. The pioneering phase depends on chance because the triggers and the place where pioneering new entrants become active and/or chose to locate are uncertain and unpredictable. Moreover, although some environments may be better fit than others, the static and dynamic capabilities or creativity of actors manage to progressively shape the envi-

[3]Following Klepper (2002), these new entrants can be classified in three categories depending on their founder's background: diversifiers, entrepreneurial or parent spinoffs and inexperienced firms.

ronment by transforming generic resources widely available in space into specific ones. At this stage, individual features such as creativity or learning capacity of public and private actors are important.

As the demand for technology progresses, the number of entrants, taking location decisions, rises (Klepper, 1996). The independent actions and eventual collaborations that progressively develop among co-located actors may transform regional dynamics in self-sustaining. Externalities guiding the agglomeration phase appear. The location decisions of previous entrants influence new ones. Eventually, the region becomes the location norm.

When externalities are caused by informational signals, an informational cascade is launched and the cluster emerges by a mimetic effect. The reputation capital of first movers influences positively the speed of the agglomeration phase. Since mimesis is founded over similarity, the co-located actors have very similar knowledge bases. Although focussing favors the agglomeration phase (Menzel and Fornahl, 2010), it reduces local exchanges in order to avoid involuntary flows of knowledge towards direct competitors. With weak localization externalities, due to homogeneity and lack of interactions, the size of agglomeration externalities depends on the previous existence of related variety in the region and the particular balance between city-amenities and congestion effects. Such was the story of Silicon Sentier in the late 90s. The arrival of Yahoo and other leaders in the emerging e-business caused a locational cascade. The early entrants were followed in order to reduce uncertainty and gain legitimacy. In spite of the endogenous creation of collective identity, no relevant network was formed due to their homogeneity and competition (Pria, 2008).

Alternatively, if the agglomeration phase is guided by interactive motivations two related phenomenon develop. Firstly, the environment is permanently re-shaped because collective action boosts locational capabilities. Secondly, agglomeration externalities increase with the number of co-located actors. While the localization economies will appear as the co-location goes by a focussing process, jacobian externalities depend on the existence of a diversified industrial base. Both combined effects increase regional attractiveness, locks-in the process and effaces the initial heterogeneous locational preferences.

Interactive mechanisms are not unique because clusters are composed of different overlapping networks. The individual motives for interaction and the nature of the industry may influence the interactive behaviors. If laggards enter to interact with a main actor due to its market position or reputation, the agglomeration goes through a directed network effect (preferential attachment (Barabási and Albert, 1999)). This explains the Toulouse aeronautics/aerospace cluster's consolidation where Airbus and the main French research institutions in aeronautics and space become the focal point for latecomers. Contrary, non-directed network effect exists when new entrants locate in the emergent cluster by the attractiveness of the local network in itself rather than by individual attractiveness (Owen-Smith and Powell, 2004). The individual and aggregated success of Silicon Valley is grounded on the networking and collaborative practices that have created a "*complex mix of social solidarity and individualistic competition*" (Saxenian, 1994).

The original technological shift should be followed by an increase of demand in order to nurture the agglomeration process and the technological cycle. It is through this increase in demand that technological competition develops. The first phase, or ferment era without dominant design or standard (Anderson and Tushman, 1990; Utterback and Suárez, 1993), is characterized by the uncertainty in technology and market. No certainty about the potential applications of the technology exists, so the opportunities for successful innovations are abundant (Abernathy and Utterback, 1978; Anderson and Tushman, 1990). The innovation intensity and experimentation is high (Klepper, 1996). The second phase, or era of incremental change, refers to the cumulative effects succeeding the appearance of a dominant design or standard (Anderson and Tushman, 1990). Uncertainties about the technology are reduced, product innovations decline and the generation of network externalities in the demand side modifies the supply side organization. The success in that technological competition process depends on the nature of the technology, chance and the strategic behavior of actors in the technological field.

Deterministic views on technology explain competitive success by the exogenous users' preferences and intrinsic performance. Each new adopter makes its choice regardless of what previous adopters have done; the demand side does not influence the supply side organization. However, since network externalities exist what matter is to gain quick diffusion in order to rapidly go trough the early markets, cross the chasm and enter the mass market (Moore, 1991; Suire and Vicente, 2011). In these circumstances pre-emption strategies, constructed through early entrance and pricing strategies, reputation and expectations management, are very important (Shapiro and Varian, 1999).

In ferment era, chance may be important as a favorable sequence of adoptions, or as a favorable political decision to establish a technology as a de jure standard. As the number of adopters increases information and network externalities become important. Informational signals may generate informational cascades of adoptions. This can be accelerated by the reputation and market power of early entrants. Moreover, the rise of number of users potentially increases network externalities and push to supply side re-organization.

In fact, the size of network externalities depends on the strategies adopted by supply actors. Constructing vertical compatibility reduces sunk costs and so enhances the transition from old technologies to new ones. Enhancing horizontal compatibility let adopters (and producers) avoid lock-in into loser technologies. However, sponsors of technological varieties may avoid full compatibility to control network ownership and appropriate additional rents (Katz and Shapiro, 1994). This is the case of the video game industry where, Sony, Microsoft and Nintendo keep their captive networks incompatible. Complementarity raises the impact of indirect effects and enlarges the set of potential users. Consequently, the higher the compatibility and complementarity are, the higher the possibilities of a technology to become a standard.

The success in each of the two processes is progressively interlinked. On the hand, the development of the location specifications influences the capacity of local actors to generate and defend a potential dominant design. Complementarity and compatibility require the combination of different pieces of knowledge, so they depend on the quantity, diversity and nature of resources and interactions regionally available. On the other hand, the location capabilities of successful actors on the technological activity are stronger. So the success of local firms to impose their standard influences the co-location process at different levels. Firstly, it reinforces the need of collaboration. Secondly, the regional structure of the cluster will be influenced by the organization of the technological field. Finally it reinforces the region's external identity (Romanelli and Khessina, 2005).

P2: Different mechanisms at play during the regional and technological competition processes at emergence result on clusters with different structures.

If the success on the regional competition is based on a pure resource effect, the emergent structure will be characterized by a set of independent co-located actors. The variety on knowledge bases and competences will depend on the specificity of the resource launching the process. The size of agglomeration externalities will be limited due to the lack of interactions. Moreover, if the success on technological competition is based on the individual preferences and intrinsic performance of the technology, such a structure will be reinforced, because the demand side does not generate feedbacks pushing to re-organization of the supply side. However, if in the technological context network externalities are generated, actors are pushed to tie strategic interactions. The geographical length of these interactions will depend on the diversity and complementarity of regional knowledge bases.

If the regional success is based on mimesis, the local structure will be characterized by a set of independent co-located actors too. Although a collective identity may emerge, no relevant relations are generated. Moreover, mimesis only attracts actors with similar knowledge bases. The existence of regional diversity will depend on the previous industrial base in the region. This results in low agglomeration externalities and a lower capacity to defend the technology.

Finally, when the success of the regional competition is grounded on interactive motivation, two main structures may emerge. If the process is driven by a directed network effect the cluster will look like a hub-and-spoke (Markusen, 1996). Contrary, if the non-directed network effect predominates, a structure of marshallian type will result (Markusen, 1996). The existence of interactions grounds the generation of agglomeration externalities, and implies a minimal knowledge diversity that can be reinforced by the previous regional industrial base. From the technological point of view agglomerations driven by network effects enhance the construction of complementarity and compatibility, and so increase the possibilities to impose on the technological competition.

To sum up, the mechanisms at play along the phases of emergence are not structurally neutral. Resource effect and mimetic behaviors result on clusters with low interactions but based on the particular factor endowment or fashion. Contrary, network effects result on clusters anchored on the richness of local interactions, but their structure will depend on the nature of the technological field and the interactive motivations.

2.4. Regional and technological dynamics for viability

This section focuses on viability conditions of clusters. Firstly, we define what viability is. Secondly we analyze the interplay of different factors to reinforce or weaken the cluster's viability.

2.4.1. Viability conditions for the long-term dynamics of clusters

Clusters are complex structures composed of heterogeneous actors embedded in a larger landscape. So, the continuous transformations of the environment and changes on actors' behavior will influence the trajectory of the cluster by the generation of threats and opportunities of regional and technological nature. In the long-term a cluster can follow different trajectories. In a context without major exogenous shocks, and with endogenous processes reinforcing the current structure and positive lock-in, the cluster will keep on a stability path. A second possible trajectory is the decay and eventual disappearance of the cluster. On the one hand, this can be caused by an endogenous transformation of the positive lock-in into a negative one. This depends on processes such as the degradation of the regional conditions that had supported the emergence and lock-in (ubiquitation of resources or diseconomies of agglomeration), or organizational transformations in the technological domain when its cycle advances. On the other hand, the decline may be grounded on an exogenous transformation, such as the arrival of a new substitute technology or different events originated in political, social and economical spheres, to which the cluster does not manage to adapt. Finally, the cluster may follow a renewal trajectory that launches a new take off. This can be boosted either by layering, conversion and recombination endogenous processes (Martin, 2010), or by exogenous shocks to which the cluster adapts taking advantage of the opportunity.

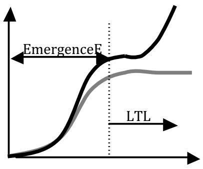
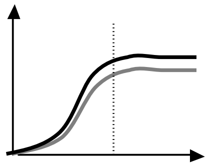
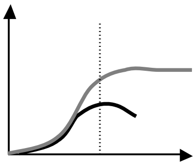
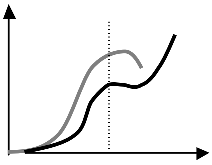
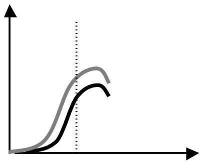
Consequently, face to a changing environment the long-term evolution of the cluster depends on its viability capacity (Suire and Vicente, 2009). Viability of clusters, as an aggregated capacity of the local system, has three dimensions. Firstly, the capacity to lock-in the technological and regional dimensions; a process is locked-in when any new adopter (entrant) prefers to choose the same technology (region) than the previous decision-makers, because the utility and profitability it obtains is bigger than with eventual alternatives. Secondly, the capacity to adapt to threats and opportunities of different origin: the capacity to move into a new technology and re-build regional conditions. Finally, the capacity to produce the change: it is not just being re-active but pro-active in producing potential renewal trajectories.

Viability of clusters depends on the strength of the regional and technological processes. Clusters, based on strong regional and technological processes, have the capacity to lock-in these dynamics and so reduce the risk of potential threats to arrive. Contrary, with weak processes the barriers for new technologies to diffuse and new regions to emerge are lower, capacities for long-term evolution are minored. Moreover, clusters based on strong processes have larger adaptive capacity than those based on weak ones. The strength of regional and technological processes is fundamental to nurture the generation of new paths for renewal. Consequently different combinations of strong and weak technological and regional processes result in clusters with divers viability conditions (Table 2.2[4]).

The upper-left case, represents long-viable adaptive structures. The cluster manages not only to lock-in the technological dynamics, but also its regional process is strong enough to generate and shift into new related and growing technological domains to avoid stagnation. Such is the case of Silicon Valley, also called Silicon Valley 5.0, due to

[4]Since the definition of regional and technological process depends on several features, these categories should not be interpreted as closed cases but as stylized representations in a continuum.

Table 2.2: Typology of viable clusters

		Regional Process		
		Strong		Weak
Technological Process	Strong			
	Weak		⟺	

X-axis : time ; Y-axis : cumulated employment in a technological field in the same region (black). Technological adoption (grey).

its capacity to create successive waves of development. Moving right on top of the table, the viability of the cluster is minored due to a weaker regional process. In the second case the cluster manages to lock-in the regional and technological processes, but it fails in dissociating its evolution from the technological one. The Jura cluster (Swiss) suffered this problem. Although the cluster was able to lock-in the watch industry into a mechanic technology paradigm during more than fifty years, when in the 70s electronic and digital watches developed the cluster, trapped by inertia, fails to quickly shit into the new paradigm and decline in parallel with mechanic watches (Glasmeier, 1991). In the upper-right case, the regional process is so fragile that, confronted to exogenous threats, even if the technological domain is solid, the cluster declines. This was the case of the Silicon Sentier when the Internet bubble crashes in the early 2000s. In spite of the continuous growth of the e-commerce a relocalization cascade produced the Sentier's decline (Vicente and Suire, 2007).

The lower-left case represents the paradoxical situation of a cluster with a strong regional process but with weaker technological dynamics. Even if the cluster does not manages to lock-in the technological process the regional process is strong enough to shift into a successful one. The NorCom cluster (Aalborg) manages to survive going through such a re-organization process. The de jure establishment of GSM as the new standard for mobile communications forced to NorCom firms to give up NMT systems in order to survive (Dahl et al., 2003). Finally the lower-right case represents a non-viable cluster, although it has emerged it has weak regional and technological process so weak capacity to lock-in or adapt.

2.4.2. Interplay of factors for viability

After defining viability and explaining that viable clusters require strong regional and technological processes, we focus on the identification of the main factors influencing the strength of these processes.

> P3: The strength of the technological process depends on the intrinsic performance of the technology, the size of switching costs and the size of network externalities. These factors are partially exogenously given and partially endogenously dependent on the strategies and actions of concerned actors.

Higher intrinsic performance over the existing technologies is a necessary but not a sufficient condition for a new substitute technology to emerge. Its relative advantage should be balanced by the size of switching costs: the smaller the performance gap between both alternatives and the higher the switching costs are, the stronger the lock-in. Network externalities reinforce the lock-in by increasing the performance of the existing technology and the size of switching costs. This explains QWERTY keyboard survival: the network externalities and the size of switching costs overcompensate the relative advantage of the more performing DSK keyboard and confirm QWERTY dominance (David, 1985).

The strength of the technological process is also affected by explicit actions of actors trying to defend their technology. Expectative management and pricing strategies will be used to strengthen the lock-in or incentive the shift depending on the position of concerned actors. Complementarity strengthens both dimensions of viability: lock-in and adaptability. It reinforces the lock-in by increasing the performance, network externalities and switching costs "by doing better" and "by doing more". Complementarity reinforces adaptability by linking independent industries through the solution of technical problems and the find of new uses. This regional branching process can potentially originate a new growing domain (Frenken and Boschma, 2007) and dissociate cluster and technological cycle. This strategy has been adopted by the Veneto Region to upgrade the competitive position of its mature industries. By combining sporting equipment, clothing and apparels, shoes and eyeglasses with new nanotechnologies and the creation and improvement of materials the cluster has entered a new growth cycle (Finotto, 2009). Similarly, compatibility strengthens the technological process. Horizontal compatibility reinforces the lock-in by avoiding alternative technologies to differentiate. Vertical compatibility positively affects the adaptive capacity by overcoming the advantages of new substitute technologies.

However, compatibility and complementarity are constrained by possible technical limitations and they depend on the will of concerned actors. Each firm decides to make compatible bridges depending on their initial conditions, their private incentives and the possibility to establish side payments (Katz and Shapiro, 1985). Finally, since they need the combination of different pieces of knowledge they depend on the existence, nature and structure of relations.

P4: The strength of the regional process depends on the degree of non-contestability of resources, the costs of re-location and the size of agglomeration externalities. These factors are partially exogenously given and partially endogenously dependent on the strategies and actions of concerned actors.

In the regional sphere, the more non-contestable the resource and the higher the re-location costs are, the stronger the regional lock-in is. In deterministic cases non-contestability is exogenous. However, with endogenously constructed resources, non-contestability only appears with collective processes of construction, because the replication of individual actions is easier than collective ones. Agglomeration economies reinforce the strength of the lock-in, because they increase the location costs savings and reinforce the non-contestability of the resources. In non-deterministic contexts, non-contestability and externalities depend on the existence of local relations and so on the strategic ability of actors to collaborate.

The strength of the regional process also depends on the ability to adapt to continuous changes in the external environment or the internal conditions. To anchor the firms to the region and avoid ubiquitation or the rise of agglomeration diseconomies, a strong regional process should be able to permanently re-build new non-contestable resources and regional specifications, and ensure the positive effects of agglomeration economies. This needs of creativity and attraction power. Although this can be done individually, collective answers are more effective.

The existence of social, industrial or knowledge networks and the participation in regional and technological spheres of many actors make them interdependent. In fact, achieving technological complementarity and compatibility require an actor's behavior that contributes to strengthen regional process in two ways. Firstly, it creates low contestable regional knowledge bases. Secondly, it increases the regional possibilities to launch a new growth wave through a branching process. Inversely, the necessary strategies to reinforce the regional process impact the technological one. The rise of agglomeration economies enhances the local circulation of knowledge and exchanges between actors in different stages of the value chain. This enhances the construction of complementarity and compatibility that requires the integration of different pieces of knowledge.

However, the strength of the processes behind viability is not only a matter of existence of relations but also of their several structural features. Firstly, the opposition between centrality vs. dispersion is relevant. While centralized networks in a single (few) actor(s) may be more coherent in their organization, they are more fragile and rigid because of its dependence on the central node evolution and decisions. A second structural feature is the balance between local and non-local ties, the buzz and the pipelines (Bathelt et al., 2004). The right balance enhances the local circulation of knowledge and reduces the risk of redundancy by incorporating new external pieces of knowledge. Too much internal or external focus is equally dangerous. Thirdly, strong processes in the regional and technological spheres need a balance of actors with different knowledge bases. This applies either for knowledge networks where actors in different knowledge phases interact (Vicente et al., 2011), or for industrial networks where actors in different stages of the value chain are in contact.

In summary, the long-term evolution depends on their capacity to avoid and adapt to the technological and regional threats and opportunities. This is defined by the strengths of the regional and technological processes whose strength depends on factors partially exogenous and partially endogenous. Since the effective endogenous creations require interaction, networks play an important role for viability. Since firms and institutions are heterogeneous the strength of the factors influencing viability conditions will also depend on the network structure.

2.5. Emergence and viability: two interdependent dynamics

In sections 2.3 and 2.4 we have shown that clusters are neither pre-established units nor never-ending stories. We argue here that emergence processes and viability conditions are not independent from each other. Given the fact that the cluster's development is done through time, inertia and path dependency are involved (Martin and Sunley, 2006). The structure emerged after a technological shift is the same facing threats and opportunities in the long-term. So emergence conditions influence the long-term dynamics of the cluster, because different emergence mechanisms create different structures. This does not mean that the cluster will not endogenously change, but the capacity to do that through layering, conversion and recombination mechanisms signaled by Martin (2010) will be conditioned to this emergence mechanisms.

Following proposition 4, the strength of the regional process for viability depends on exogenous factors and endogenous behavior of actors. With resource effect as mechanism of emergence, the cluster exists due to the availability of particular non-contestable resources. This implies a strong regional lock-in. As long as the underlying necessary resources continue to be non-contestable the regional dynamics will be locked-in. The region is the location norm of the industry because of the homogeneity of location preferences rather than by the generation of agglomeration economies, which may be weak due to the lack of interactions. However, their viability is minored due to their weak adaptive capacity. A transformation of the environment may reduce the non-contestability of the resource anchoring the firms to the region, without adaptive capacity the disappearance of the regional lock-in may cause the cluster decline. Furthermore, if no new alternative applications for the regional resources are found, the regional dynamics will fail to dissociate from the technological one. The decline of the later will lead to the decline of the cluster. Without interaction, the adaptive capacity to regional or technological transformations is defined by the sum of individual capacities with only weak synergies among them. No collective answer to adapt the region is developed.

A location norm emerged by mimesis is characterized by co-located similar firms without relations, they internally develop the required locational specifications. From the viability perspective, these agglomerations have weak lock-in capacities. If they are based on informational signals no factors to regionally anchor the cluster are developed. The locational specifications are internally developed, so they are reproducible and contestable. Moreover, without local interactions no major agglomeration externalities raise. Consequently, neither the existing resources, nor the increasing returns of co-location reinforce regional dynamics. Co-location only depends on the ephemeral strength of reputation and fashion. The adaptive capacity of these clusters is also weak. The adaptation to regional or technological changes is done individually rather than collectively. It depends on their individual creativity, absorptive capacity and flexibility. The Silicon Sentier, emerged by a location cascade, was just endowed with a collective image behind the Silicon label, but there were neither non-contestable resources nor a collective organizational structure. With the crash of the dotcom bubble in 2001 the value of the Silicon label was eroded and an inverse process of relocalization produced its decline (Pria, 2008).

Finally, when regional dynamics emerged by network effect, the resulting agglomeration is characterized by a set of co-located firms and institutions interacting among them in R&D collaborative projects and/or as a part of a production chain. A marshallian or a hub-and-spoke cluster appears depending on the relative importance of non-directed and directed network effects respectively. Both structures lead to a strong lock-in. Collectively constructed location specifications are less contestable. Moreover, the emergence and constitution of a network is a non-contestable resource in itself. Finally, with interactions, agglomeration economies can become important. Silicon Valley is the best-known example of these regional and technological lock-in capacities. The quantity, quality and variety of actors and relations in the region contribute to create a unique collective resource that homogenizes the heterogeneous location preferences of new actors. Either parent spin-offs located elsewhere, as Microsoft, or new start-ups continue to choose the Valley for their location (Suire and Vicente, 2011).

From the adaptability perspective, local networks with similar and dissimilar interactive actors increases the capacity to adapt to transformations, and even drive the change. Voluntary or involuntary collective action enhances the re-specification of locational conditions and the construction of related variety, complementarity and compatibility to overcome threats and find opportunities. However, viability depends on the network structure. Hub-and-spoke clusters are more rigid and fragile than marshallian clusters. On the one hand, the failure of Airbus, Thales Alenia Space or Astrium in Toulouse may imply the entire decline of the cluster due to their central role to articulate the whole cluster. On the other hand, face to a threat the adaptive capacity of the agglomeration is also strongly dependent on the individual adaptive capacities of the hub. Contrary, Silicon Valley evolution is not exposed to such central dependence, this endows it with a higher capacity to take advantage of opportunities.

Cluster's viability depends on the strength of the technological process too. However, as proposition 3 states this is partially dependent on the explicit strategies of firms and institutions involved on the technological field, because their actions contribute to improve the intrinsic performance, the size of switching costs and the size of network externalities. The nature of these strategies is linked to the regional dynamics and its mechanisms of emergence. A sustainable technological lock-in can be achieved without explicit strategies on the supply side. The adoption decisions made by users are enough to generate network externalities. Since the technological competition has a global dimension that exceeds the local context, even non-interactive emergence mechanisms may be supported by a long-term sustainable technological dynamics. However, location norms emerged by network effects may produce stronger technological dynamics. By enhancing cooperation between actors with dissimilar but complementary competences, complementarity and compatibility are more easily constructed. Consequently, they strengthen the technological lock-in, and enhance the adaptability to changes (or even trigger it). Contrary, mimesis or resource effect, getting together similar actors, reduces the possibilities to adapt and/or drive technological transformations by reducing the variety of resources blinding the opportunities to find new applications.

So, different mechanisms of emergence create different cluster structures with different viability conditions defined by the capacity to lock-in the process, as well as the adaptive and pro-active capacity to avoid and take advantage of regional and technological threats and opportunities. Although emergence mechanisms based on interaction have a priori better viability conditions, the existence of networks is neither necessary nor sufficient to explain viability, because it is also influenced by the resource contestability and the structural features of the network. So non-interactive mechanisms of emergence may result on viable clusters by the non-contestability of its factor endowment, and a cluster resulting from a network effect may show low viability because of the fragility of its structure.

2.6. Conclusion and discussion

This chapter has studied the lifecycle of technological clusters. We adopt a dynamic approach in order to avoid the traditional assumptions looking at them as isolated, pre-established and never-ending successful stories. While studies focusing on the emergence conditions to solve former limitations are the more and more common (Bresnahan et al., 2001; Brenner, 2004), the later questions, trying to study the life cycle of clusters and their long term implications, has attracted much less attention (Brenner and Gildner, 2006; Menzel and Fornahl, 2010; Suire and Vicente, 2011).

Clusters are defined over interdependent regional and technological dimensions, which are traversed by social, industrial and knowledge networks. The evolution of the cluster is guided by changes of these dimensions. Clusters emerge where the regional and technological dynamics succeed on the double competitive process created after a technological shift. Although a parallelism between the technological and cluster cycle can be drawn at the emergence stage, in the long-term this is not a symmetric process. The long-term survival of clusters depends on the dimensions of viability, which are defined with respect technological and regional dynamics. Different clusters' life cycles are explained by different capacities to lock-in, adapt and take advantage of landscape transformations.

We defend that dissimilar viability capacities of clusters depend on the nature of the emergence process. At emergence, the mechanisms explaining the success in the double competitive process produce different cluster structures. They will have different viability conditions and so produce cycles of different length. Non-interactive forms of emergence show low adaptive capacity only internally defined, but their lock-in capacities are dissimilar. While clusters emerged by mimesis are fragile, because they are grounded on reputation and informational signals that may blow up, those emerged on the base of a resource effect may keep in the lead as long as the resource remains non-contestable. Interactive forms of emergence show a priori stronger viability conditions. Locational specifications collectively constructed and the generation of agglomeration economies through interaction reinforces the lock-in. Moreover, interactions, subject to proper structural features, enhance adaptability by the development of related variety, complementarity, compatibility and the collective reconstruction of locational specifications. So clusters' birth and their different cycle-length depend on the strength of regional and technological synergies to face the multiple transformations suffered by its surrounding landscape.

Chapter 3

Lock-in or lock-out? How structural properties of knowledge networks affect regional resilience

This chapter is based on a paper co-authored with Raphaël Suire and Jérôme Vicente and published in Journal of Economic Geography[1]. This paper was written as a part of the work package 1 of the ANR-ORA T-Res project on regional resilience[2]. This paper combines the network approach of clusters presented on chapter 1 with the framework on cluster life cycles presented in chapter 2 to define two network properties that enhance both technological lock-in and regional lock-out. It also proposes two network statistics to measure them that we will use in chapter 4.

[1]Crespo, J., Suire, R., and Vicente, J., (2013). *Journal of Economic Geography*, forthcoming.

[2]In the T-Res project we collaborate with four more European teams: URU (Netherlands), RUFIS (Germany), GREThA (France) and CASS (United Kingdom).

3.1. Introduction

The literature largely acknowledges localized knowledge networks as a significant factor of regional performance in knowledge-based economies. In a context of complex knowledge and rapid change, research converges in signaling that regions' ability to host networks of complementary and interacting organizations is a key factor to explain regional performance differences (Owen-Smith and Powell, 2004; Rychen and Zimmermann, 2008). Largely evidenced, such a move toward(s) a relational approach to regional performance (Rychen and Zimmermann, 2008) has led, particularly in Europe, to a massive development of clusters policies based on incentives for collaboration and network development (Martin and Sunley, 2003).

Nevertheless, behind this large consensus, very little research has pursued the question of the long run evolution of regional innovative structures. Papers by Todtling and Trippl (2004), Hassink (2005), Suire and Vicente (2009), Simmie and Martin (2010), Menzel and Fornahl (2010), Crespo (2011), Boschma and Fornahl (2011), and Cooke (2011) constitute notable exceptions. They are the mark of a burgeoning and promising research field for understanding how some performing regions can decline at a given moment in time, while others are able to renew and sustain their growth in a disturbed economic environment. Mainly dedicated to innovative regions and technological clusters, this research is part of a more general wave of research on regional resilience. This wave is structured around formal communities of scholars (Swanstrom, 2008)[3] and seminal special issues (Christopherson et al., 2010), and concerns a wide range of challenges, such as the resilience of urban places (Wrigley and Dolega, 2011), the renewal of old industrial systems (Hassink, 2010), or the ecological transition of local innovation systems (Cooke, 2011). These researches are nowadays of a growing interest, as the macroeconomic context is characterized by chronic instability. Financial and economic crisis, but also rapid technological cycles, environmental considerations and new growing consumption paradigms challenge global but also regional policies.

Regional resilience and cluster life cycles are the key concepts that have recently emerged in the literature on regional development. These concepts reflect a common attempt: understanding the evolutionary process through which a regional ecosystem of organizations and institutions succeeds in maintaining its growth path by disconnecting its cycle from the cycle of technologies when these decline. Some regions have difficulties in coping with technological and market decline, even if they were performing during the maturity stage. Others reorganize resources and networks in order to enable them to enter into a new related stage. All this burgeoning research tries to go beyond a classical

[3]See also the publications of the Building Resilient Regions Institute: `http://brr.berkeley.edu/economic-resilience/`

view of resilience as a mechanical return to the equilibrium after exogenous and external shocks. It attempts to capture the endogenous mechanisms of adaptability, viewed as the ability of the actors and their social agency (Pike et al., 2010) to anticipate, evolve, and so adapt to disturbed and cyclic economic environments.

To deal with this question, we suggest combining a multidisciplinary theoretical analysis that discusses the critical factors of regional resilience, with an evolutionary economic geography framework (Boschma and Frenken, 2006; Martin and Sunley, 2007) that focuses on an out-of-equilibrium approach of regional science. Our contribution is centered on the study of the structural properties of networks that can help having a better understanding of the tensions and conflicts in adaptive systems between connectedness and increasing order on the one side, and the resilience properties on the other side. While the first ones typify the prominence and stabilization of a particular economic structure, the second ones require a high level of flexibility and restructuring capabilities (Pendall et al., 2010; Simmie and Martin, 2010; Cooke, 2011).

Networks have been of a growing interest in the social sciences for a couple of years (Borgatti and Halgin, 2011). They are at the heart of well-known theoretical research in Sociology (Uzzi, 1997; Borgatti and Everett, 1999), Economics (Jackson and Wolinsky, 1996), Geography (Glückler, 2007; ter Wal and Boschma, 2009) and Management Sciences (Powell and Gordal, 2005), with a high level of absorption of results coming from physics and complex systems theories (Albert and Barabási, 2002; Newman, 2003). Considering that networks can be represented by two basic primitives (the nodes, the ties that connect the nodes), network theories give a simple but useful representation of social structures in a static sense, and have more recently focused on a dynamic purpose (Ahuja et al., 2012). Obviously, on the one hand, theorizing regional resilience only through the dynamics of knowledge networks can be viewed as a partial and ceteris paribus approach, and in a sense it is, since other dimensions matter such as the cognitive, political and institutional ones, as perfectly identified in a seminal research of (Grabher, 1993). But on the other hand, scholars have also pointed out the key role of network dynamics on the renewal of clusters. For instance, in the early 1990s, Saxenian reminded that "*The resilience of the Silicon Valley (...) is the product of the region's dense networks of social, professional, and commercial relationships, not simply of unfettered markets or national policy*" (Saxenian, 1990, p.91). For Tödtling and Trippl, institutions and policies are not sufficient conditions for the renewal of clusters in mature regions and industries: "*Direct intervention and the provision of subsidies and infrastructure are generally not enough. (...) The renewal of clusters implies also a renewal of networks. This includes new links with knowledge suppliers as well as innovation networks among companies*" (Todtling and Trippl, 2004, p.1178). And more recently, Cho and Hassink (2009), in the line of Grabher (1993) showed that the difficulties of mature regions renewal could be found in political, cognitive and functional lock-ins, the latter being associated to networks: "*Their key feature concerns a particular constellation that negatively affects necessary economic renewal. Local networks of dominant industrial production become so narrowly focused on a particular type of retrogressive economic activities that is unable to shift into a new restructuring track. When being locked into rigid trajectories, the existing networks face increasing costs, due to reluctance and resistance, to replace old with new networks*" (Cho and Hassink, 2009, p. 1185).

Our purpose is to identify simple but empirically-testable signatures of structural properties of local knowledge networks that give interesting properties for understanding the conditions of regional resilience. Section 3.2 discusses cluster growth, structuring and properties, in the framework of the abounding literature on networks. Section 3.3 studies structural conditions for local knowledge networks to display performance and resilience properties. For that, we analyze how social agency and structural properties of clusters can simultaneously lead towards technological lock-in and regional lock-out. Section 3.4 proposes two statistical measures of cluster structuring that highlights how these properties can interact. Finally, section 3.5 discusses the results and gives new insights for regional policies, confirming that network density is not the panacea for cluster policy (Martin and Sunley, 2003), and showing that more targeted and surgical interventions are more effective at improving regional resilience.

3.2. Cluster and network theories

3.2.1. A (too) short history of cluster analysis

Clusters, simply defined at this stage as localized knowledge networks in technological and market domains, are nowadays viewed as a primary concept for regional competitiveness and growth policies. In Europe, since the Lisbon Agenda of 2000, cluster policies are one of the main tools for leading Europe towards "*the most competitive and dynamic knowledge-based economy in the world by 2010*"[4]. From guideline dissemination (European Commission, 2009) to the creation of a public-funded European Clusters Observatory (European Commission, 2009), the European Commission has convinced regional and national policy makers that competitiveness is highly correlated to the absorption of the "good practices" of cluster policies. Nevertheless, cluster success stories or declines are not the direct consequences of policy implementation, but the result of various historical trajectories. These trajectories mix public interventions but also different contingencies related to entrepreneurship, learning and self-organized

[4]Presidency conclusions of the Lisbon European Council, March 2000. See `http://www.europarl.europa.eu/summits/lis1_en.htm`

network formations (Saxenian, 1990; Feldman, 2001; Wolfe and Gertler, 2004). Apart from a few notable critical papers (Martin and Sunley, 2003), the academic literature has viewed clusters as a source of regional performance in modern economies. This is particularly true since the publication and wide diffusion of the empirical study of the Silicon Valley by Saxenian (1994), and the cluster theory developed by Porter (1998). Since then, geographers, economists, sociologists and also specialists of network analysis and management scientists have converged towards the idea that agglomeration economies arise not only from market forces nor from “cookie cutter” policy guidelines (Wolfe and Gertler, 2004), but also from non-market interactions and network formations that can give rise to an unpredictable local web of knowledge flows that improves or scleroses regional competitiveness. Clusters have increasingly been studied from a multidisciplinary angle. Economists have exchanged with geographers of innovation in order to understand how knowledge spillovers arise more from strategies of knowledge exchange than from “in the air” knowledge flows (Breschi and Lissoni, 2001). Economic geographers have exchanged with network sociologists by introducing social network analysis into regional systems of innovation (ter Wal and Boschma, 2009). And management scientists have done the same by analyzing local organizational networks as a source of structural embeddedness that favors the production and diffusion of knowledge (Owen-Smith and Powell, 2004).

3.2.2. Clusters as knowledge structures

A cluster can now be defined as a local relational structure that results from the identification of a set of nodes of various institutional forms (the organizational demography) and the ties between them (the relational structure). Inter-organizational ties in a cluster can be of different nature (productive, commercial, cognitive or social) and of different geographical length. Our discussion focuses on organizational relations locally constructed to exchange knowledge in high-tech technological domains. This relational structure can be represented in the form of a network, featured by structural properties that highlight the channels through which knowledge flows and the level organizations’ embeddedness[5].

[5]Cluster literature acknowledges that local interactions constitute only a part of the networks in which organizations are embedded. According to Bathelt et al. (2004), Wolfe and Gertler (2004), and Coe et al. (2008), successful clusters are those that succeed in building and mixing local and global channels to manage knowledge access at different geographical scales. In this vein, Owen-Smith and Powell (2004) introduce clusters as networks that are part of a nested system of networks mainly devoted to knowledge exploration, while global networks are more dedicated to relationships for technological integration and exploitation. And for Sturgeon (2003), Cowan et al. (2004), and Balland et al. (2013a), successful clusters are those that succeed, through their internal organization of knowledge flows, in turning new ideas into dominant design and technological standards, relying on strategic global partnerships for that purpose.

Considering the important role of this literature for cluster studies, our present purpose is limited to local networks and their structural properties. As a matter of fact, the following theoretical research

These structural properties can have a high degree of variability from one cluster to another. Clusters can have a very weak level of relational density if organizations value isolated strategies over knowledge partnerships, or if non-local partnerships are preferred over local ones. In that case, the clusters are no more than the simple result of a co-location process. On the contrary, clusters can display a high level of density when knowledge complementarities, trust and social proximity (Boschma, 2005) lead to high levels of local cohesiveness. Even with a fixed level of density, a strong variability of structural properties remains. The distribution of degree centrality can vary from flat to sloped. To put it differently, the shape of the degree distribution refers to the hierarchy of positions in the web of relations. Some organizations can have many relations due to a high relational capacity (Konig et al., 2010). This is generally linked to the size of the organizations, their absorptive capacities or the openness of their model of knowledge valuation[6]. On the contrary, some others remain poorly connected due to their newness, their small size or their closed model of knowledge valuation. Last but not least, beyond the level of cognitive homophily of the organizational demography, clusters can display various levels of structural homophily, which is generally captured by a network index of assortativity (Newman, 2003; Watts, 2004; Rivera et al., 2010). The structure of relations will be assortative when highly (poorly) connected nodes tend to be connected disproportionately to other high (weak) degree nodes, and disassortative when highly (poorly) connected nodes tend to be connected disproportionately to other weak (high) degree nodes. Therefore, the level of network assortativity gives a formal representation of the way knowledge flows between central and more peripheral nodes.

3.2.3. Cluster growth

Where do the nodes and the ties come from? Network theory is very useful for analyzing cluster properties. But the emergence of the aggregate properties commonly studied in physical systems has to be founded on micro-economic behaviors, including rationality, strategy and decision externalities, rather than on simple and myopic behaviors (Watts, 2007). In particular, these micro-foundations are necessary to understand how new entrants join a cluster, and (re)shape and/or reinforce its relational structure. Network theory has identified several drivers of network formation. Two of them are extreme and simple cases of node entry and tie formation.

stresses on the endogenous abilities of clusters to exhibit resilient properties. It means that the influence of the position of a particular cluster in the international and global hierarchy is considered as an exogenous parameter.

[6]The hierarchy of positions and degree centralities of organizations are only considered here at the level of local interactions. Following the previous note, this hierarchy can be stronger if we take into account global interactions and pipelines, for which big and hub companies are generally more concerned (Vicente et al., 2011).

Firstly, networks can evolve through the entry of new nodes that do not connect to any other node (isolates), or through the entry of new nodes that connect to others either by purely random attachment mechanism or by preferential attachment mechanism (Albert and Barabási, 2002). Random attachment means that entering nodes randomly connect to others with no particular preference for their position in the structure. Isolate entrants and random attachment mechanism will give rise to a rather flat hierarchy of node degrees (Erdös and Renyi, 1959). In terms of location decision externalities and individual strategies, both kinds of processes can be associated with a locational cascade (Suire and Vicente, 2009). In locational cascades, new entrants draw pay-offs from belonging to the structure as a whole, not from targeted connections to particular nodes in the structure. Locational cascades have been largely evidenced for clusters that attract new organizations because of an external audience and a geographical charisma (Romanelli and Khessina, 2005; Appold, 2005). Organizations converge to a "locational norm" since the charisma displayed by one place in terms of R&D productivity provides a signal of quality and a strong incentive for being located there, whatever the position in the relational structure.

Secondly, entries can occur through a process of preferential attachment. In this opposite case, nodes with many ties at a given moment of time have a higher probability to receive new ties from new entering nodes. The higher the degree of a node, the more the node is attractive for receiving new ties, so that the network grows through an increasing hierarchy (Albert and Barabási, 2002). This behavioral pattern of nodes can be associated to a network effect in location decision externalities. This means that the more new entrants are connected to highly connected nodes, the more their payoffs increase, due to the benefits of reciprocal knowledge accessibility and technological connections to an emerging and growing standard. This branching process is now linked to targeted connections in the structure rather than random ones, and is consistent with the relational constraints that typify the production and diffusion of technological standards in high-tech industries and markets (Farrell and Saloner, 1986; Arthur, 1989). It is also consistent with the relational behavior of spinoffs that tend to connect to their often highly connected parent's company (Klepper, 2010).

3.2.4. Cluster structuring

Beyond node entry, clusters structure themselves through the construction and dissolution of ties. The literature acknowledges two categories of individual incentives that shape social structures, and dissociate closure from bridging network strategies (Baum et al., 2012). Triadic closure implies that a node with links to two other nodes increases the probability for these two nodes to have a tie between them. Such an argument is grounded on the process of trust construction that grows between two related nodes, because it fosters cooperation and knowledge integration within groups of nodes. Closure in knowledge networks strengthens the mutual monitoring capability of organizations. Indeed, on one hand, it decreases the possibilities of opportunistic behaviors (Coleman, 1988). On the other hand, it increases the effects of conformity required by technological standardization processes: without such closure, organizations can be tempted to play the battle of standards and accept the risk of a payoff decrease. As this process develops, the clustering coefficient of the network increases, and triadic closure tends to shape a core-component in the network (Borgatti and Everett, 1999), in particular when closure prevails for highly connected nodes.

The second category of individual incentives relates to bridging strategies and introduces the idea of a more disruptive relational behavior. For a given network, bridging ties will be shaped when one node finds an opportunity to connect disconnected nodes or groups of nodes. Such an agency behavior (Burt, 2005) is more entrepreneurial than the former, since bridging provides access to new and non-redundant knowledge and new opportunities for improving innovation capabilities (Ahuja, 2000a; Ahuja et al., 2009). In the case of clusters, these bridging strategies have implications on the overall structure since they can enable better circulation of knowledge between the core and the periphery of a network (Cattani and Ferriani, 2008).

3.3. Are performing clusters also resilient?

The mechanisms of node entry and tie formation in clusters, as well as the resulting structural properties, are critical parameters in the economic analysis of the functioning and performance of clusters. But is performance incompatible with resilience, or are there particular structural properties that enable certain clusters to combine the two features? This question is crucial for the cluster research agenda, as well as for regional policies that face faster technological cycles and increasing turbulence in the economic environment.

3.3.1. Lock-in and lock-out in cluster growth trajectories

Regional resilience is considered here in an "out of equilibrium" approach (Simmie and Martin, 2010) that opens the debate on performance versus resilience of clusters. Such a debate requires an understanding of the complex dynamic process through which a system of local interactions succeeds in emerging as a competing and leading location in a particular technological domain, while maintaining the conditions of its renewal by adapting to patterns of technological life cycles, market dynamics and consumer's evolving paradigms. The direct transposition from physical network theory clearly shows that there is an opposition, or at least a trade-off, between efficiency and resilience (Brede and Vries, 2009). The more efficient the network is, minimizing ties and maximizing reachability, the more sensitive it is to external shocks and the more it exhibits fragility properties. Introducing strategic behavior, cognitive features and agency in network theory let us overcome the myopic behavior of nodes. The integration of the strategy in the relational behavior lets us challenge this trade-off. There is empirical evidence that some regional networks are able to re-direct their development paths through a complex overlapping process between a mature market domain and a new emerging related one, and so maintain their growth trajectories. Hassink (2007) for instance highlights the relational and institutional dynamics in West Münsterlad that explained the fruitful transition from the textile industry towards medical applications and devices. Such resilient processes are also observed by Cooke (2011) in the Silicon Valley, where the mature sector of semi-conductors that had led the Valley to be a successful place in the computer industry in the 90s has also been introduced and recombined with new applications in promising and efficient solar technologies.

The mechanisms through which these resilient processes occur have to be understood in terms of path dependency and adaptability (Pike et al., 2010; Simmie and Martin, 2010). Such an approach is better suited for understanding both the way in which a region draws its success from its ability to organize knowledge networks towards domination in a particular technological field (the performance property), and the ability of these networks to move from this field to another when the former declines (the resilience property). Do "winner takes all"-type clusters necessarily imply loser regions when market declines? To understand this causality, one has to distinguish the mechanisms that can lead simultaneously towards technological lock-in and regional lock-out, and then understand how the structural properties of knowledge networks contribute to both.

3.3.2. Regional resilience and the structural properties of knowledge networks

Successful clusters at a moment in time and in a particular technological field are the ones that have succeeded in going from the exploration of new ideas to the exploitation of a technological standard or dominant design on a mass market, with in between, a collective process of knowledge integration between complementary organizations along the knowledge value chain (Cooke, 2005). Beyond the traditional scheme of exploration/exploitation that typifies the innovation process of a single organization, the knowledge integration phase is at the heart of the cluster's purpose. Indeed, the success of many products results from their degree of compositeness, the variety of uses and applications supported by the products, scientific as well as symbolic knowledge, and the compatibility and easy interoperability between elements that are the rule of a dominant design diffusion. The chasm that sometimes prevents some products from reaching the mass market (Moore, 1991) is more often the consequence of a failed integration process, i.e a problem of industrial organization, rather than a problem of the product quality in itself[7]. Successful clusters are therefore the ones that achieve the imposition of well-integrated and performing complete technological systems on mass markets. As the literature shows (Klepper and Simons, 1997; Audretsch et al., 2008), these clusters evolve from an initial scattered structure of burgeoning organizations in the early market stages to a structure with a limited number of hub and oligopolistic organizations in mature markets. Along the life cycle of products, and especially composite ones, such a network dynamic produces path dependence and technological lock-in. The more the technologies generate increasing returns to adoption, the more markets for these technologies become locked-in and resist to other competing technologies (Arthur, 1989).

But are clusters producing these technologies necessarily locked-in too? The answer depends on the way in which their relational structure evolves along the life cycle of products. First, recall that networks can grow through preferential attachment. This means that the more nodes display a high degree, the more newcomers connect to these nodes, engendering a high level of hierarchy in the distribution of nodes. But secondly, recall that beyond network growth through node entry, networks can also evolve by the addition and rewiring of ties between existing nodes through closure or bridging (Baum et al., 2012). When closure prevails, the cluster evolves towards a high level of transitivity between nodes which is the mark of isomorphic and conformist relational behaviors. In that case, the structure of the cluster exhibits tight couplings into a core-component and a loosely connected periphery of nodes. The ossification of the cluster goes with the formation of an assortative network, in which highly connected nodes are tied predominantly with other highly connected nodes in the core, and peripheral nodes remains connected between themselves. On the contrary, a core/periphery structure with a disassortative web of knowledge relations can emerge as the entry of newcomers and rewiring process go. For that, the node bridging strategy has to prevail over the closure strategy. Consequently, highly connected nodes spend a share of their relational capacity on peripheral nodes, and the network as a whole displays more paths between the core and the periphery than for the assortative network.

The patterns governing the entries dynamics into networks and the structuring process that follows are at the heart of the lock-in/lock-out debate. Academics acknowledge that preferential attachment is a natural pattern of social and human networks that

[7]Organizations can have a voluntary strategy of niche products and thus a narrow market objective. This issue does not concern our aim, which is more focused on technological standards and mass-market products.

contributes to fostering the legitimacy of social norms and conformist effects in Sociology (Watts, 2004), or technological standards and dominant designs in Business Studies (Frenken, 2006). But the debate between closure and bridging is more controversial, and it is controversial for cluster studies too (Eisingerich et al., 2010). Indeed, closure favors technological lock-in and thus the ability of the relational structure to perform in markets. The tight coupling between high degree organizations favors conformism and trust in a stable and cohesive structure that prevents opportunism and promotes an efficient integration of knowledge in a context of weak environmental uncertainty. But closure favors network assortativity, and then prevents regional lock-out, since the low connectivity between the core nodes and the peripheral ones limits the re-organization of knowledge flows when uncertainty grows or when the market starts to decline. So when preferential attachment and closure interact, the ability of clusters to deal with a positive technological lock-in goes against their ability to produce the conditions for technological lock-out, and then resilience (Simmie and Martin, 2010). In order to foster adaptability and resilience, clusters also have to develop bridging strategies in order to open more disruptive relations between the core and the periphery of nodes, preserving minimal cohesiveness in the core, while multiplying the channels for potential or latent flows of fresh and new ideas coming from peripherals nodes (Grabher and Stark, 1997; Cattani and Ferriani, 2008). Such a mix of patterns does not undermine the hierarchy of degrees that emerges when the technology goes towards exploitation. But to be disassortative, the oligopoly structure of hub-organizations that appears as the technology reaches maturity has to maintain a not too low amount of entrepreneurial connections with the periphery, in order to overlap exploitation in a particular knowledge domain and exploration in another related one. Such a structural property of clusters is consistent with the behavior of firms according to their maturity and age. Indeed, Baum et al. (2012) develop evidence on the predisposition of organizations to deal with closure or bridging strategies according to their age. Supposing that the age of organizations is positively related to their hub position and high degree, then the resilience capabilities of local knowledge structures can be weakened by an insufficient level of connectivity with newcomers. If it is supposed that the capacity constraints in the amount of ties an organization can maintain is related to its size and age, as Konig et al. (2010) do, then the high capacities of hub and central organizations can be a strong source of resilience if they go against the natural tendency to reproduce existing and conformist ties. Ahuja et al. (2009) find empirical evidence on that by capturing the micro motives for more disassortative behaviors. They highlight a threshold and non-monotonic effect in the strategy of embeddedness and closure between central nodes. According to them, the growing benefits in terms of trust and knowledge acquisition can go with an increasing rigidity and conformity that produces disincentives for collaboration. Likewise, in spite of risks of knowledge hold-up and contract incompleteness, they find that peripheral organizations succeed in connecting to central nodes, through a “creeping” strategy facilitated by the ability of mature organizations to find sometimes new and disruptive opportunities to connect to peripheral newcomers.

3.4. Two simple statistical signatures of local network resilience

The level of hierarchy of node degree and the level of assortativity therefore appear as two simple statistical signatures of the ability of clusters to perform but also to avoid negative lock-in through their endogenous resilient capabilities. Other individual parameters matter, such as age or size, cognitive variety and the model of knowledge promotion and valuation of the organization. But each of them can be associated to the two former parameters since they influence the relational behavior of clustered organizations. Regional resilience studies should rely on the structural and topological properties of knowledge networks as key factors. The correlation between relational behavior and individual features has to be captured in parallel.

3.4.1. Degree distribution and degree correlation: statistical measures

Hierarchy and assortativity can be measured through two simple statistical signatures. The first corresponds to the degree distribution of the network. The more sloped the distribution is, the more the network displays hierarchy in the degree of nodes. From weakly connected nodes to highly connected nodes, the degree distribution exemplifies the level of heterogeneity in the network in terms of actual relational capacity. The second property corresponds to the degree correlation. Networks can be characterized as assortative or disassortative to the extent that they display a positive or negative degree correlation. A network is assortative when high degree nodes are connected to other high degree nodes, and low degree nodes are preferentially connected to low degree nodes, so that the degree correlation is positive. And a network is disassortative when high degree nodes tend to connect to low degree nodes, and vice versa, so that the degree correlation is negative. For a given amount of nodes and ties in a particular network, one can easily capture these two salient properties.

Consider a fixed number of nodes and ties in a network N[8]. If we note k the degree of a particular node h, we can then write two simple equations to characterize the

[8]Then we only focus on the structuring of the network. Entries are considered as exogenous, or occurring in previous periods. Such a supposition is consistent with the following policy focus, which only deals with the relevance of public funded incentives for collaboration in an existing structure.

network topology. By referring to a rank-size rule, we can classify node degrees from the largest to the smallest[9] and then draw the distribution on a log-log scale. Such that:

$$k_h = C(k_h^*)^a$$

with k_h^* being the rank of the node h in the degree distribution, C a constant and $a < 0$ the slope of the distribution or equivalently,

$$\log(k_h) = \log(C) + a \log(k_h^*)$$

Secondly, we can calculate for each node h, the mean degree of the relevant neighborhood (V_h), i.e,

$$\overline{k_h} = \frac{1}{k_h} \sum_{i \in V_h} k_i$$

where k_i is the degree of node i belonging to the interaction neighborhood of node h.

Then we estimate a linear relationship between $\overline{k_h}$ and k_h, such that

$$\overline{k_h} = D + bk_h$$

with D a constant and b a coefficient capturing the degree correlation.

If $b > 0$, the network N exhibits assortativity with a positive degree correlation, whereas if $b < 0$, the network N is disassortative with a negative degree correlation.

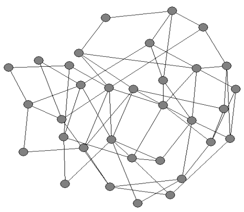
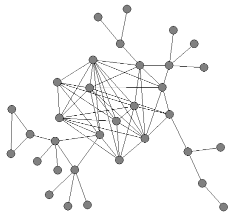
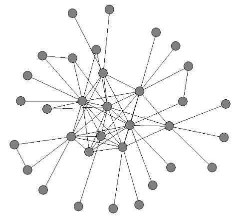
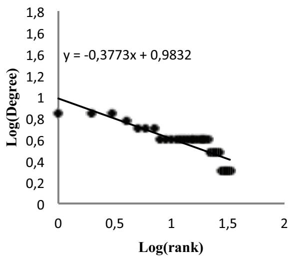
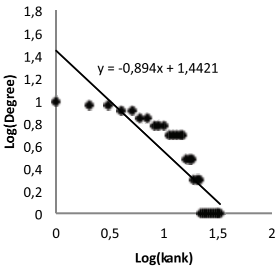
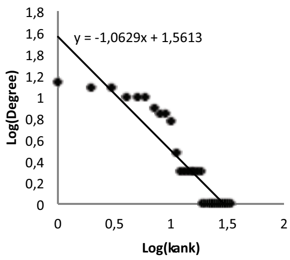
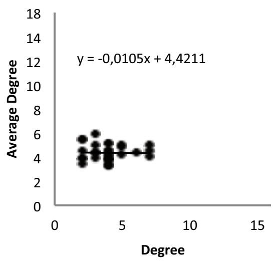
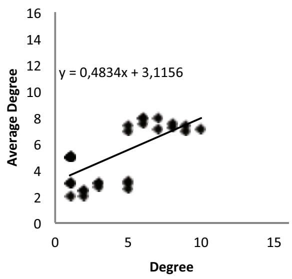
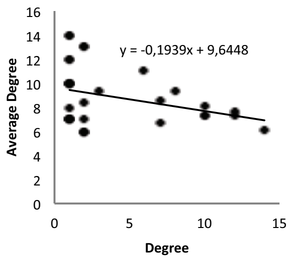
Finally, thanks to the ordinary least squares method, the joint estimation of parameters a and b enables us to characterize useful structural network properties.

$$\text{degree distribution: } \log(k_h) = \log(C) + a \log(k_h^*) \tag{3.1}$$

$$\text{degree correlation: } \overline{k_h} = D + bk_h \tag{3.2}$$

[9] If two nodes have the same degree, we arbitrarily rank them as long as it has no incidence on the slope on the power law.

Table 3.1: Network topology, degree distribution and degree correlation

	Random network	Assortative core/periphery network	Resilient network
Topology			
Degree distribution			
Degree correlation			

3.4.2. Discussion

Using equations 3.1 and 3.2, and considering a network N with a fixed number of nodes ($n = 33$) and ties ($t = 64$) , table 3.1 summarizes this proposition, giving more details on three typical topologies and their statistical signatures.

1. The so-called "random network" presents a relatively flat degree distribution |a|=0.37 with a degree correlation b∼0. From the point of view of a physical or engineering approach of networks, and whatever node is removed, such a network displays a high resistance to external shock. Due to a rather flat hierarchy within the whole network, regardless the node removed, the fluid will still find paths to irrigate the whole of the network. From the point of view of a more socio-economic oriented approach, such a network also displays a strong potential for knowledge flows re-organization and diffusion since the nodes are linked by many paths. But such a random network does not succeed in generating conformity effects and the emergence of technological standards. Indeed, the lack of cohesiveness and the

absence of a core group weaken the control of collective behaviors that would exploit products on the market by efficiently gathering pieces of knowledge.

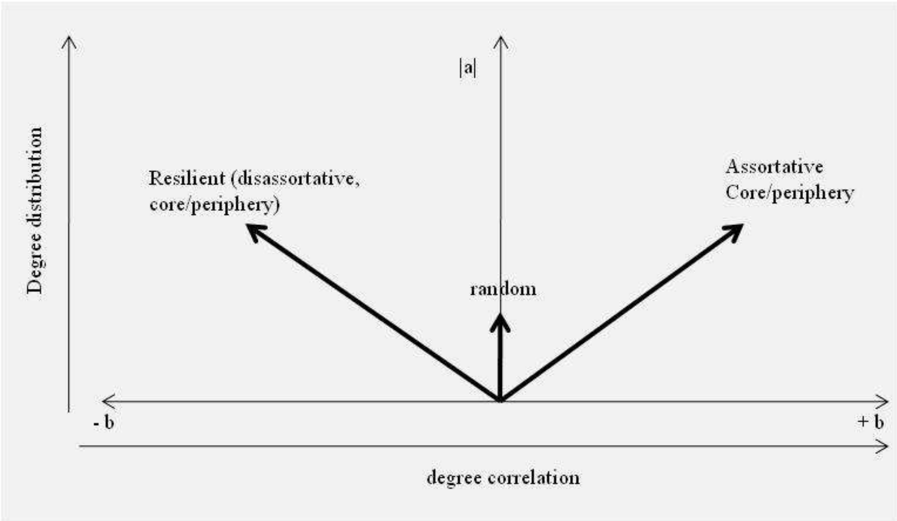
2. On the contrary, the "core/periphery and assortative network" presents a strong slope in the degree distribution $|a|=0.89$ so that the cohesiveness of the core promotes a conformity effect, and, from a technological perspective, a high probability of the emergence of a standard. Nevertheless, its strong assortative structure ($b>0$) weakens its resilience properties since the periphery is loosely connected to the core. From a physical or engineering approach of networks, an excess of cohesiveness and triadic closure into the core would engender a lack of modularity in the case of a targeted external shock. From a more socio-economic approach, this excess of assortativity will reduce the ability of the existing structure to activate new explorative ties when markets for the exploited technology decline, due to a weak level of bridging between the oligopoly structure and the peripheral ones. Therefore the assortative knowledge network favors technological lock-in without maintaining regional lock-out conditions because of its relative inability to overlap exploitation links on mature markets and explorative ones on emerging related ones.

3. Finally, the "core/periphery and resilient network" exhibits here again a high sloped degree distribution with $|a|=1.06$, but the degree correlation is now negative ($b<0$), so that the network presents a certain level of disassortativity. In other words, this negative correlation indicates a high level of connections between the core and the periphery, so that information and knowledge can circulate through many structural bridges between the core and the periphery. Thus targeted shocks on core members do not weaken the whole structure to the same extent as in the previous structure. Similarly, innovative or explorative behavior can diffuse more easily from periphery to core members, due to the ability of the oligopolistic organizations to combine closure and bridging ties in the overlapping explorative and exploitive phases in their relational patterns.

Figure 3.1 provides a more abstracted representation of these critical structural properties of local knowledge networks.

By representing degree distribution and degree correlation in the same layout, one can have a better understanding of how the structure and properties of local clusters can together improve aggregate performance and structural conditions for resilience. The further up in the layout a cluster is, the more its structural hierarchy enables it to impose standards and dominant designs on markets. And the further left in the layout it is, the more the disassortative patterns of relations increase regional resilience

Figure 3.1: Statistical signatures of cluster structural properties



capabilities. For physical networks, efficiency and resilience are incompatible (Brede and Vries, 2009). But for socio-economic networks, because of social agency and the ability of nodes to build and maintain ties for overlapping explorative and exploitative ties, performing networks are not necessarily incompatible with regional resilience. For the two to coexist, the emerging oligopolistic structure that arises when the technology reaches maturity has to remain sufficiently linked to fresh and new ideas coming from peripheral but promising nodes for future collaborations. On the other hand, when closure strategies in the mature oligopolistic structure exceed a certain threshold, then redundancy of knowledge flows and conformity effects prevail and the possibilities for regional resilience fall unavoidably.

3.4.3. Illustrations

Capturing the resilience of clusters through network distribution and correlation can find first evidences in the literature on case studies and fieldwork analysis, even if their theoretical backgrounds rely on more general considerations on clusters or different targeted conceptual entries.

For instance, Saxenian (1990) has led an empirical investigation on the resilience of the Silicon Valley during the 1980s, when the semiconductor industry had reached a high level of maturity and had started to decline in terms of high tech employment. She puts ahead the high level of disconnection between the mature core of established big companies and the burgeoning network of start-ups. While the core of big companies presented the characteristics of a closed oligopolistic structure during that period (mainly AMD, National Semiconductor, Intel), with a general purpose technology and mass production strategy, the network of start-ups was more focused on high performance and value-added components and presented on the contrary a highly- open structure of knowledge sharing, developed as "*a revolt against the established semiconductor firms*" (Saxenian, 1990, p.91). History repeats itself, since she quite rightly notes that "*Ironically, the region's established producers helped create this infrastructure during the 1950s and 1960s, but abandoned it in the 1970s as they shifted to high volume production. They came to view regional tradition of information sharing and networking as signs of immaturity rather than sources of dynamism, and they distanced themselves from customers and suppliers as they standardized products and processes*" (Saxenian, 1990, p. 95). Besides the well-known roles of serial entrepreneurship spirit and venture capital availability[10], Saxenian explains the resurgence and resilience of the Silicon Valley at the end of the 1980s by the building of new connections between the declining established core companies and these growing peripheral start-ups. "*While some like H-P and Apple began by pursuing the cost reductions and quality improvements of just-in-time production, they are now building long-term and trust-based relationships – particularly with suppliers of technically complex and fast-changing components*" (Saxenian, 1990, p. 103). Such a resilient process rests on two features of the cluster. On the one hand, the historical formation of a core of hub and highly-connected companies, which can be captured by a strong hierarchy of firm sizes and relational capabilities – and then a highly-sloped distribution of degrees – has led the Valley to become one of the leading places of technological integration and standards setting. But on the other hand, the connections of these core-companies to burgeoning and peripheral organizations – and then a more disassortative relational behavior – have led all the organizations to avoid conformist behaviors. As a matter of fact, as perfectly theoretically-developed in the above-mentioned research of Ahuja et al. (2009), established companies have found new sources of innovation and product differentiation in markets, while emerging companies have found growth perspectives through a better integration of their new products in well-diffused technological systems. Once again, Saxenian provides a good interpretation of such a network-based resilient process: "*Both customers and suppliers describe mutual commitments not to abandon each other during downturns or to exploit advantages during upturns*" (Saxenian, 1990, p. 103).

More recently, Cho and Hassink (2009), on the contrary, show that such a resilient process can fail in other contexts and technological domains. Following the theoretical framework of lock-in in regional development (Grabher, 1993), they study the renewal difficulties of the textile industry in Daegu (South Korea). Launched in the 1950s, this industry entered a strong crisis phase in the 1990s, and one of the local authorities' responses to that crisis was to develop and fund an ambitious project based on the

[10] See also on this point Kenney and von Burg (1999)

modernization of industry (The Milano Project). This project relied on public funds and incentives for the building of new networks based on a more research and design-oriented value chain. The purpose of such a project was to create the conditions of a lock-out and a renewal of an industry that had entered in a progressive phase of decline and lock-in. According to authors, the relative failure of this attempt of institution-driven resilient process relies on two main failures in the expected network evolution and adaptability. First of all, the traditional local network of producers is featured by a "*rigid or sticky structure (...) of horizontally interrelated producers around a handful of large supplier firms of 'raw fibers' and a number of large textile companies with markets outlets*" (Cho and Hassink, 2009, p.1193). Then, in spite of a hierarchy of positions and relational capabilities in the structure that helps the structure to exploit products on markets, they stress on the rigidity of the network and then the inability of its organization to open itself to new ideas or processes. This observation is reinforced by another one related to the strong weight of clientelism into the traditional network, "*that weakens local entrepreneurs' vitality and creativity for the endogenous restructuring of the textile industry*" (Cho and Hassink, 2009, p.1193). Such a clientelism is a mark of an excess of cohesiveness into the core of historical organizations, since it gives rise to an excess of conformity and passive behaviors, and a reluctance to new entries or more entrepreneurial connections, and then more disassortative behaviors. Secondly they point out an important reason for the failure of the renewal of the local textile industry: the Milano Project "*was headed by representatives of major research institutes*" (Cho and Hassink, 2009, p.1194). Thus, the major stakeholders of this "lock-out program" do not come from the traditional network, which naturally engenders conflicts and resistance to renewal for established organizations, and then dramatically reduces the emergence and development of more open relational behaviors from established companies towards newcomers. This kind of discontinuity in the whole of the network and the absence of bridging organizations that connect the established and the emerging networks weaken the resilience of the local industry, while such gatekeepers have been identified as the critical organizations of local industrial renewal in other empirical cases (Cattani and Ferriani, 2008; Lazzaretti et al., 2011).

3.5. Policy implications

Abstracting the analysis of regional resilience around only two statistical signatures of local knowledge networks could be seen at a first glance as a narrow entry for investigating such a complex process. Nevertheless, these signatures provide a large array of policy implications which go beyond, and should go beyond, policies based on network density and incentives for increasing collaborations. On the contrary, these statistical signatures of clusters allow us to avoid the strong tendency of "cookie cutter" clus-

Table 3.2: Policies supporting regional resilience

	$\Delta \mid a \mid = 0$ (1)	$\Delta \mid a \mid > 0$ (2)	$\Delta \mid a \mid < 0$ (3)
$\Delta b = 0$ (A)	Laissez faire	Reinforce the upper part of the hierarchy of knowledge networks	Reinforce the lower part of the hierarchy of knowledge networks
$\Delta b < 0$ (B)	Promote structural heterophily and disassortativity	Reinforce the upper part of the hierarchy of knowledge networks. Promote structural heterophily and disassortativity.	Reinforce the lower part of the hierarchy of knowledge networks. Promote structural heterophily and disassortativity.
$\Delta b > 0$ (C)	Reinforce the structural homophily and assortativity.	Reinforce the upper part of the hierarchy of knowledge networks. Reinforce the structural homophily and assortativity.	Reinforce the lower part of the hierarchy of knowledge networks. Reinforce the structural homophily and assortativity.

ters policy guidelines (Wolfe and Gertler, 2004), by defining various and more surgical interventions. If knowledge collaborations and networks matter, regional policies can be under-productive if an unconditional index of network density is defined as a goal for supporting clusters. Between laissez-faire and a standard and costly increase of relational density, our statistical signatures provide stylized nine categories of targeted policies[11]. Basically, policy makers can concentrate their attention on only one instrument, the other one remaining fixed ($\Delta \mid a \mid \neq 0, \Delta \mid b \mid = 0$ or $\Delta \mid b \mid \neq 0, \Delta \mid a \mid = 0$), or can play a mixed strategy with both variables at the same time ($\Delta \mid a \mid \neq 0, \Delta \mid b \mid \neq 0$). Table 3.2 gives an overview of the policies.

Considering cases when one of the two critical parameters is fixed, meaning that policy makers have to target their incentives on one of the two network properties to

[11] We should take them as stylized categories because they are based in our abstract discussion that has not specified cognitive features of nodes and the nature of cognitive ties.

enhance performance and resilience properties, two categories of "surgical" policies can be implemented.

- Firstly, for clusters that host highly connected companies and that can be considered by policy makers as having reached a mature oligopolistic structure, cluster diagnostics should lead policy makers to act on the assortativity dimension of knowledge networks. In this case, $\Delta \mid a \mid = 0$, and policies are type-1 and ties-oriented. Besides a laissez-faire policy (1.A-policy), two instruments are available for policy makers. On the one hand, they can interpose to resolve the insufficient level of connectivity between recent newcomers or burgeoning SMEs and the core of mature organizations. In this case, a re-allocation of public funded ties from an excessive cohesiveness of the core to a better connection between the core and the periphery (1.B policy) increases the long-run dynamics of clusters and the capacity of the overall structure to overlap mature technologies and emerging ones, without compromising the oligopolistic core-structure. Thus this 1.B-policy fits with clusters that displayed an excess of assortativity between core members and between peripheral members, so that fresh and new ideas produced in the periphery have difficulties irrigating the core-component of the cluster. On the other hand, even if some organizations are high degree ones, the knowledge network can exhibit an insufficient level of cohesiveness into the core. In that case, leading organizations do not succeed in maintaining a high level of knowledge integration. Such a 1.C-policy focuses on few but important missing links to improve the closure of high degree organizations, a necessary condition for clusters to impose technological standards on mass-markets.

- Secondly, cluster policies can focus only on the organizations' degree. In this case, policies are actor-oriented and target their action on the hierarchy of the network structure. Besides laissez-faire, clusters which face problems for reaching maturity in mass-markets should benefit from an A.2-policy. It concerns clusters that do not succeed in building an oligopolistic structure of organizations and display in their overall structure a lack of relational capacity of organizations. But these policies are inappropriate for clusters that have reached a leading place in the field. In this case, windfall payoffs for central organizations will decrease the policy efficiency. On the contrary, cluster diagnosis can highlight an excess of isolation of organizations and therefore policies aim to reinforce the lower part of the degree distribution. Decreasing the slope of the degree distribution does not mean reducing the degree of leading organizations of clusters, but on the contrary, increasing the degree of newcomers or isolated organizations. Such an A.3-policy, which should consider specific programs for a better integration of

SMEs and start-ups in local knowledge networks, is particularly suited to enhance the regional lock-out capacities of clusters.

Furthermore, combining ties and actor-oriented policies, mixed strategies for policy makers appear as more efficient for regional performance and resilience than an unconditional and costly watering for collaboration. Ex ante diagnosis should help policy makers to orient public funds towards increasing the capacity of clusters to overlap mature and emerging knowledge domains, and thus develop more open structures of knowledge interaction (all type-B policies). On the contrary, when a lack of cohesiveness weakens the knowledge integration process, all type-C policies are suited and prevail on the others. Likewise, all type-2 policies are suited to reinforce leading companies to compete in mass markets, while type-3 ones are dedicated to an increasing capacity of SMEs and burgeoning companies to connect to more central organizations in order to provide fresh and new ideas.

Degree distribution and degree correlation appear as interesting catalysts for policies towards regional resilience. They provide simple but targeted tools for applying distinctive surgical policies. Policies for regional resilience have to be replaced and contextualized (Bristow, 2010). Indeed, according to the particular situation of the cluster in terms of structural properties and market position, the simple increase in relational density can lead to unproductive outcomes and reduction of resilience capabilities. These two structural properties do not challenge cluster policies as a whole nor conclude on the relevance of laissez-faire (Martin et al., 2011). On the contrary, they invite us to consider particular targeted incentives for bridging potential missing links in cluster long run dynamics.

3.6. Conclusion

In spite of its high level of abstraction and complexity, the science of networks applied to regional science provides promising perspectives for static as well as dynamic analysis of clusters. Here we have tried to show that it was possible to reduce this complexity to two simple statistical signatures of knowledge networks. Degree distribution and degree correlation highlight the critical structural properties that increase the performance of clusters in a particular technological field, without decreasing their resilient properties. If the hierarchy of degrees is a more or less common pattern of social and organizational networks, disassortativity is less manifest. Indeed, human and social behaviors are generally characterized by structural homophily, so that the more an agent increases its relational capacity, the larger is his tendency to interact with other highly connected agents. However, this property of assortativity of local knowledge networks weakens the ability of clusters to combine market exploitation and absorption of fresh and new ideas, and then, can be a source of negative regional lock-ins.

The combined measures of degree distribution and degree correlation confirm that a window of parameters exists, for which clusters can display performance in the short run, and resilience in the long run. Capturing this window more precisely requires an additional effort of modeling. Moreover, as we have pointed out earlier, clusters are relational structures that are more or less embedded in larger networks of global relationships. The form and the degree of this embeddedness can also play a role on the local properties of resilience, in particular through the study of how big companies connect themselves to transnational networks[12]. Combining local and global interactions in a search for more complex statistical signatures could be a promising challenge in the future. But at this stage, such a framework furnishes new perspectives to highlight empirical evidence on the ability of regional systems of innovation to resist and adapt to turbulent macroeconomic environments, new growing consumer paradigms and the shortening of market cycles. It also constitutes a first step for a policy platform for resilient regions. In particular, policies based on the support of disassortative links will help clusters to overlap technological domains and then follow a stable rather than a declining growth trend.

[12]Introducing global relationships as an endogenous parameter of cluster resilience could be an additional and relevant step for further researches. At this stage, the structural properties of local knowledge networks give interesting first results on the ability or not of clusters to reach maturity and performance in a particular knowledge domain, while maintaining renewal abilities towards a related new one. Obviously, in a more extended approach, these results will be conditional to the level of structural embeddedness of the cluster in global innovation networks (Sturgeon, 2003), since technological exploitation on global markets still remains important once the resilient process is engaged.

Chapter 4

Network structural properties for cluster long run dynamics. Evidence from collaborative R&D networks in the European mobile phone industry

This chapter is based on a paper co-authored with Raphaël Suire and Jérôme Vicente. It aims to test the theoretical propositions done in Crespo et al. (2013) and explained in chapter 3. This paper was written as a part of the work package 2 of the ANR-ORA T-Res project on regional resilience[1]. We keep using the network approach of clusters developed in chapter 1, and we use the degree distribution and degree correlation measures proposed in chapter 3 to test the effect of hierarchy and structural homophily on innovative capacity in mobile phone sector in Europe[2].

[1]In the T-Res project we collaborate with four more European teams: URU (Netherlands), RUFIS (Germany), GREThA (France) and CASS (United Kingdom).

[2]We thank Thomas Scherngell from Austrian Institute of Technology (Austria) and Mathieu Becue from GREThA (France) for giving us access to syres EUPRO and PATSTAT databases respectively.

4.1. Introduction

The literature has underlined the importance of networks for cluster performance, either to boost innovative capacities of clustered firms or to enhance firms formation and growth (Jaffe et al., 1993; Audretsch and Feldman, 1996b; Pouder and John, 1996; Buenstorf and Klepper, 2009). Porter (1998) already pointed to interaction and networks as one of the basic components of clusters, together with the co-location and the industrial dimensions. The current context featured by complex knowledge and rapid change has exacerbated the importance of networks. Innovation and knowledge creation are interactive processes (Nooteboom, 2000; Antonelli, 2005; Sorenson et al., 2006). Consequently, cluster innovative performance is strongly dependent on the capacity to host interactive organizations possessing and combining different and complementary competences and pieces of knowledge. In the policy sphere, these ideas have sustained the popularity of cluster policies to boost collaboration (Martin and Sunley, 2003). In the academia sphere, they have been strengthen by the current "relational turn" in economic geography (Bathelt and Glücker, 2003; Boggs and Rantisi, 2003), as well as the increasing availability of relational data and powerful analytic tools.

The convergence of these trends has produced an important bulk of studies trying to go beyond the treatment of networks as a metaphor. Researches form economy, sociology, management science and geography have tried to open the black box of networks by studying their formation, properties and evolution. This wave has structured around two interdependent questions. On the one hand, the decision of tie formation/disruption and the parameters behind partners selection (Jackson and Wolinsky, 1996; Ahuja, 2000b; Rivera et al., 2010; Balland, 2012). On the other hand, the features of the relational structure emerging from the aggregation of individual relational decisions (Borgatti and Everett, 1999; Uzzi and Spiro, 2005; Vicente et al., 2011).

Network functioning is heterogeneous across/along industries and space. Literature on technological systems has shown that network tie formation and network structuring may differ across technologies or industries (Broekel and Graf, 2012), as well as along the technological or industrial cycle (Balland et al., 2013b; ter Wal and Boschma, 2011). Similarly, network functioning may be not independent of the geographical context. In that sense several papers have tried to identify both structural properties of networks in cities, clusters and regions favoring or hampering their innovative performance (Fleming et al., 2007; Breschi and Lenzi, 2012), and the features and behavior of actors in key positions in the structure (Giuliani and Bell, 2005; Morrison, 2008). The recent literature on cluster life cycles and regional resilience try to ally both of them to study how dissimilar network structures in particular locations perform differently by their capacity to associate or dissociate in the right moment of the technology life cycle (Crespo et al., 2013).

The present chapter joins this literature. Our aim is to test the influence of two new structural properties of networks in cluster innovative performance: network hierarchy and network assortativity (Crespo et al., 2013) They complete small world and core/periphery structural measures at two levels. On the one hand, hierarchy introduces a structural measure of the existence (or not) of leading organizations able to coordinate systemic processes of innovation. On the other hand, assortativity introduces a measure of the structural openness, i.e. the connectivity between the core and the periphery that enhances the circulation of knowledge between both, favoring the arrival of new ideas. We test the influence of these two properties on the European mobile phone sector, which is characterized by standardization, modularity and rapidly shrinking product life cycles. Our results show that cluster innovative performance need hierarchical and disassortative networks. This seems particularly important for industries where standardization processes and aggregation of complementary services are important, as it is the case in the mobile phone sector. Moreover, the important shock suffered by mobile phone sector in 2000 lets show that the influence of hierarchy and assortativity varies between growth and maturity industrial stages.

In the remainder of the chapter we proceed as follow: Section 4.2 develops the theoretical concepts we aim to test. It examines hierarchy and assortativity arguing why they matter for cluster innovative performance and elaborates the corresponding hypothesis. We discuss them with particular insights on the mobile phone sector in Europe. Section 4.3 presents the context of the analysis, the data collection process, the variables construction with particular detail on the two measures proposed for hierarchy and assortativity, and the estimated method used. In Section 4.4 we present the main results of the estimated models. Section 4.5 discusses the results on the context European mobile phone technological domain. Finally, Section 4.6 concludes.

4.2. Network properties for cluster performance

4.2.1. Networks and clusters

Taking a network perspective to approach cluster, we can define them as a set of local nodes (organizations) in a particular field, and the ties defined on them. Organization in clusters have heterogeneous institutional forms, relational capacities and cognitive bases. They may construct relations of different nature (productive, commercial, cognitive or social) that work, primarily or subsidiary, as channels for voluntary or involuntary knowledge flows. The union of organizational and relational sets results in a network through which knowledge and information circulate more or less efficiently depending on its structural features.

The current context is featured by increased competition based on differentiation and rapid change. The continuous development of new products with an increasing number of complementary services and utilities drive the competition for the market (Moore, 1991). Organizations need to collaborate with others in order to get complementary pieces of knowledge and create differentiated products fast enough to be competitive. Consequently, the knowledge creation process becomes complex and composite (Nooteboom, 2000; Antonelli, 2005).

Atmoshere (Marshall, 1890), *noise* (Grabher, 2002) or *buzz* (Storper and Venables, 2004) are some of the concepts developed to underline the importance of co-location to gain access to valuable information and knowledge, voluntary or involuntary circulating locally. Thick local relational sets become the scaffolding for fast diffusion of knowledge that boost innovative performance of clusters. Local organizations may also build up relations with organizations located elsewhere. Such distant relations, or pipelines, fill two functions. On the one hand, they give access to no-redundant ideas circulating elsewhere, and so as source of novelty, they may increase the innovative performance of the cluster (Uzzi, 1997). On the other hand, they are fundamental to embed the local cluster in a larger network that configures the global technological domain (Owen-Smith and Powell, 2004). The performance of the local environment and the global technological domain are mutually reinforcing (Bathelt et al., 2004).

However, networks are in permanent change. The process of network configuration is done by a successive and cumulative decisional process. Organizations chose their location (entry/exit decision). These are strategic decisions taken at a moment of time with a vocation to last give rise to the local set of nodes. Moreover, organizations chose their partners. Partnership construction is also strategic but much more fluid. So, organizations are continuously creating, maintaining or disrupting relations of different nature with other organizations. This self-organized process of organizations entry/exit and of relations formation/disruption produces a large diversity of structures not neutral for cluster innovative performance (Markusen, 1996; Cattani and Ferriani, 2008).

The link between innovation performance and the heterogeneity of network structures has produced several attempts to identify which network structural properties favor or hamper regional innovation performance. The most popular efforts concern small world networks (Kogut and Walker, 2001; Uzzi and Spiro, 2005; Fleming et al., 2007; Schilling and Phelps, 2007). They simultaneously exhibit high clustering and low average path length (Watts and Strogatz, 1998). The combination of these two properties is said to boost innovation. Clustering influences innovation because closure of networks generates trust (Granovetter, 1985; Coleman, 1988), and trust promotes collaboration and facilitates risk sharing, resource pooling and information diffusion. Low path length boost innovation because it increases network connectivity, and so it makes easier knowledge circulation and transmission. Core/Periphery networks have also received important attention. They exhibit a group of organizations densely connected: the core; and a set of organizations loosely connected to it: the periphery (Borgatti and Everett, 1999). In this case, most of the studies have focused on differential performance between core and peripheral organizations, rather than in the influence of core/periphery structures in aggregate performance (regional or cluster). They argue that organizations in the core (or in intermediary positions) have a better access to knowledge flows (Giuliani and Bell, 2005), higher survival rates (Mitchell and Singh, 1996) and higher creative performance (Cattani and Ferriani, 2008). Such structures tend to be stable on time (Orsenigo et al., 1998) due to preferential attachment mechanisms (Barabási and Albert, 1999), and the influence of prior network structure in new ties formation (Gulati and Gargiulo, 1999). Thirdly, some authors have introduced the geographical dimension more explicitly to study the influence of network openness on performance, i.e. how the local structure of relations is embedded in a global context. They conclude that distant relations have a positive influence in regional innovative performance, because they breath new ideas into the region to avoid redundancy and lock-in (Bathelt et al., 2004; Breschi and Lenzi, 2012). In these structures the local organizations building distant relations, knowledge gatekeepers, have a prominent role for both cluster performance and vulnerability (Morrison, 2008; Hervás-Oliver and Albors, 2012). Recently, Crespo et al. (2013) have argued that hierarchy and assortativity of local networks matter for cluster performance. These structural properties account for the existence of a core/periphery structure, and for the features of the connexions between both. We develop both of them in the following sections.

4.2.2. Hierarchy

Organizations in clusters are heterogeneous at several levels. From a relational perspective there are three features of the organization that influence his engagement in a collaboration. Firstly, organizations have different absorptive capacity. The higher the capacity of an organization to identify, assimilate and exploit new external knowledge (Cohen and Levinthal, 1990), the higher his incentives to collaborate. Secondly organizations may have different models of knowledge valuation or management (Dasgupta and David, 1994; Owen-Smith and Powell, 2004). The more an organization prioritizes accessibility over appropriation, the more open to collaboration it will be. This choice depends on the institutional nature and the strategic positioning of the organization. Finally, organizations differ on their size. Since relations construction and maintenance is expensive in time and resources, we can expect that larger organizations, with more resources, will be more active in collaboration than small ones.

Network hierarchy refers to the heterogeneous relational capabilities of organizations in the cluster, reflecting an unequal distribution of power in the cluster. Organizations with many relations, the core, may co-exist with others loosely connected, the periphery. The first, on the top of the hierarchy, have a prominent position to lead the systemic technological process. The second, in the lower levels of the hierarchy, bring the different complementary modules to integrate.

We can consider clusters as successful when they manage to impose standards or dominant designs in a given moment of time. Consequently, when products are complex, the need to construct linking mechanisms among the different components increases (Tushman and Murmann, 1997). Hierarchical networks become efficient structures to set up compatibility and interoperability among the different components in order to reduce system dysfunctions and enhance diffusion. So, clusters are the locus for imposing integrated technological systems, and hierarchical structures a necessary condition.

H1: Network hierarchy displays a positive effect on cluster innovative performance

4.2.3. Assortativity

Innovation is the result of a re-combination process, where blocks of existing knowledge are melded for new knowledge creation. So, although hierarchy matters to organize the collective process, innovative performance will also depend on the structural degree of openness. It is not only a matter of having some leading core firms or institutions to organize the process, but also about how these different hierarchical levels are interconnected. We refer to it as the assortativity property of networks. It reflects the tendency of nodes in a network to connect with other nodes that have similar or dissimilar degree. A network is assortative when highly connected nodes tend to interact with highly connected nodes, and poorly connected nodes with poorly connected nodes. At the opposite, a network is disassortative when highly connected nodes tend to interact with poorly connected nodes, and conversely.

Network structural properties emerge with the network evolution manifested by nodes entry (or exit) and by their decisions in the formation or disruption of relations. Partners selection decision considers, among other factors, the existing network structure as well as the particular structural position of certain nodes that make them more or less attractive (Ahuja et al., 2009; Baum et al., 2012)[3]. When closure behavior dominates bridging behavior in partners selection, assortative networks emerge. Organizations create new relations with organizations already collaborating with their own partners. Their motivations for such behaviors are enhanced trust, lower monitoring costs, and lower risk of opportunistic behaviors. Contrary, when bridging behavior dominates closure behavior disassortative networks emerge. Organizations adopt a disruptive relational strategy and build up new partnerships with isolated organizations or disconnected groups of organizations. In doing so they look for new and no redundant knowledge that enhances higher innovative potential.

Assortative networks are closed. There are groups of organizations that collaborate, but these groups are not properly connected. Consequently, there is a redundancy of knowledge flows within the network that may produce negative lock-in and reduce the cluster innovative performance. Due to an excess of conformism in the relational pattern, the new explorative ideas that are often produced in the periphery by new SMEs do not reach the exploitation phase in the core of the cluster. The core and the periphery of the network are not sufficiently connected, i.e. there are important missing links between the leading organizations in the core and the burgeoning periphery. Contrary, with disassortative networks, the organizations in the top of the hierarchy multiply their relations with the periphery. Leading organizations have access to many more sources of new knowledge. Consequently, innovation and the exploitation of this innovation are enhanced. With disassortative networks, the lock-in in a technological trajectory does not imply a cluster lock-in.

H2: Network assortativity has a negative impact on cluster innovative performance.

4.2.4. Hierarchy and assortativity along industrial cycles

Industries suffer deep transformations as time goes by. Along the industry life cycle demographic and innovation patterns, as well as market competition regime change (Anderson and Tushman, 1990; Utterback and Suárez, 1993; Klepper, 1997). In early stages, industrial output and new firms entries grow at high rates. At the same time, the number of exits is low, so the number of firms in the industry grows. From the technology perspective, the industry is still in the ferment era, a dominant design or standard has not emerged yet. Therefore, firms offer many different versions of the

[3]In the establishment of new relations and the selection of partners individual and dyadic features also matter. The firsts, explained above, refers mostly to size, absorptive capacities and knowledge management strategy. The second refers to the similarities or differences between both potential partners. The proximity approach gives a powerful framework to integrate five different dimensions (Boschma, 2005).

product and the competition regime is driven by innovation. There is a competition "for the market" and not a competition "in the market". With time, although market keeps growing entry of new firms slows down and existing firms start to exit. Consequently, the industrial organization changes. It ossifies around a reduced number of firms, and the emergence of a dominant design or standard. The nature of competition shifts towards price considerations and the aggregation of complementary services and utilities. As a result, process innovations efforts to cut costs gain importance to the detriment of product innovations.

To the extent that industrial organization and the competitive regime change along the industrial life cycle, we can expect a modification of the influence of hierarchy and assortativity on cluster performance across industrial stages. ter Wal and Boschma (2011) discuss the relation between network configurations evolution and the industry life cycle. They argue that, at the emergence stage, networks are quite unstable and not hierarchical given the sharp uncertainty about technological developments. In the growth stage, the network evolves toward a stable core-periphery structure due to the prominence of preferential attachment mechanism (Orsenigo et al., 1998), a hierarchical structure emerges. When the industry reaches maturity networks in the industry get locked-in due to the fixed patterns of interaction and the higher probability of peripheral nodes to exit. This trajectory may have two possible issues. On the one hand, the introduction of a new radical technology may start a new industrial and network cycle. The new cycle can be structure-reinforcing or structure-loosening depending on the fact that the organization introducing the breakthrough was in the core or in the periphery (Madhavan et al., 1998). On the other hand, if no radical new technologies are introduced, the industry decline, firms exit continues and the network disappears. The evolution towards one or the other trajectory depends on the assortative or disassortative nature of the network.

H3: Hierarchy and assortativity have different influence of cluster innovative performance when the industry is in a growing stage or in a maturity stage.

4.3. Data and methods

4.3.1. Research setting

We situate our study in the context of European mobile phone technological domain. During the last 30 years mobile phones have completely changed from pure voice-communication devices to multi-functional handsets. Nowadays, smartphones integrate voice-communication with digital camera, music player, payment systems, GPS, gaming or numerous Internet services. This process, based on technological convergence and modularity, has transformed mobile phone into a transversal technology with very flexible frontiers in continuous expansion, i.e. mobile phones are complex systems materializing the new mobility paradigm.

A succession of mobile phone generations has accompanied such product transformation. From the 1G to the current 3G, or incipient 4G, mobile phone communications have increased their capacity, both in higher transmission speed and in richer content of the message. Each generation is based on a different communication standard. The analogue 1G was superseded by the digital 2G. The GSM standard, impulsed by the European Commission, overcame the limits of the analogue systems in terms of efficiency in the radio-spectrum allocation and in terms of interoperability. GSM was a success. From the mid-90s mobile phone markets experienced tremendous growth, and they achieved penetration rates around 100% in most European countries in early-2000s. At this stage competitive pressure increases and traditional strategies of product customization and cost reduction become important. They go with new product developments consisting in the aggregation of functionalities and services, i.e. new product innovations. This growth and the proliferation of new services encouraged the development of a new standard, the 3G (UMTS). However, several factors hampered the transition from 2G to 3G giving rise to two different strategies: migration by big leap forward, or migration by small steps though EDGE or GPRS standards, also called 2.5G.

Nowadays, the main players of the mobile phone technological domain continue to be network operators and manufacturers or Original Equipment M anufacturers (OEMs). The core business of network operators is to attract paying consumers to the use of services on their telecom networks that convey voice and data (e.g. Vodafone, Telefónica, T-Mobile). OEMs refer to organizations that manufacture and brand handsets (e.g. Nokia, Eriksson). However, the competitive pressure, the integration of new functions and the rapid product change has pushed the OEMs to interact and outsource to third parties certain number of activities: suppliers of components, assemblers of electronic components, prototype developers, universities... This has contributed to open the mobile phone sphere to actors originally from different domains, either as providers of new piece of knowledge to integrate in the system (e.g. Microsoft) or to become an OEM (e.g. Apple, Google).

The mobile phone technological domain in Europe is an interesting context for the study of the influence of network hierarchy and network assortativity for two main reasons. Firstly, it is a sector characterized by the integration of complementary modules constituting complex system, rapidly shrinking product life cycles, and strong standardization processes. So, organizations are pushed to interact with others in order to get new knowledge and competences in sufficiently short time to remain competitive, i.e. knowledge networks are central for the technological domain evolution, and clusters are well know locus to enhance such knowledge flows. Secondly, European organizations and public authorities have been key for the mobile phone development. On the one hand, they established the GSM standard that enhances the diffusion of mobile phones. On the other hand, four out of five players that dominated the GSM market were European (Nokia, Ericsson, Siemens and Alcatel). This indicates the importance of European regions in this technological domain. Thus, we can expect to find several regions with a relatively important concentration of interactive organizations on mobile phone related activities.

4.3.2. Data

Data sources and extraction To test our hypotheses we exploit data of different nature from two different sources. Data on organizational networks are constructed through R&D project collaborations based on European public funded projects by Framework Programs (FP1-FP7) from the Syres EUPRO database. FP are created by the European Union (EU) to support and encourage research. Although the strategic objectives and thematic priorities may vary between funding periods, they follow a simple schema in which potential participants meet other organizations (firms or institutions) to elaborate and submit a proposal to the Commission. Funded projects may be quite heterogeneous in their field, duration and number of partners, but to the extent they try to foster trans-national cooperation they always involve organizations from several EU countries.

Syres EUPRO contains information on all projects funded on FP1-FP7 as well as the organizations involved on them from 1984 to 2010. Syres EUPRO is based on raw CORDIS data, but it has been improved at several points: *i)* identification of unique organization name, *ii)* identification of unique organization type *iii)* creation of economic meaningful sub-entities *iv)* identification of genealogy of participants, and *v)* regionalization (NUTS1 and NUTS2 level) (Barber et al., 2008). For each project, it lists the title and a brief description, start and end dates, broad subject categories and the organizations involved. For each organization participating in a project, it lists the name of the organization with unique identifier at sub-entity level, organizational type, non standardized address and standardized location at NUTS1 and NUTS2 level.

As for previous contributions (Autant-Bernard et al., 2007; Scherngell and Barber, 2011; Balland et al., 2013c), several reasons legitimize the choice of public funded R&D collaborations. Firstly, steps towards standards construction with greater signal capacity and security, and the integration of new services result of collective projects. Secondly, based on strategic consideration European governments tried to boost the mobile phone industry from the very beginning, with particular concerns in intra-European compatibility and roaming. EU funds to finance these projects were fundamental. The consequence was the development of the GSM common standards, and the early growth of the European mobile phone sector. Finally, many governments have had a prominent role in the sector through the actions of the monopolistic position of former national operators and the national regulatory agencies.

To measure cluster innovative performance, we use patent applications counts to the European Patent Office (EPO) regionalized by the inventors address. Although patents are just a partial measure of the innovative performance of regions, they have been largely used to this end (Fleming et al., 2007; Lobo and Strumsky, 2008; Breschi and Lenzi, 2012), because they contain abundant information, they are of relative easy access, and they are quite homogeneous across regions. We select patents related to the mobile phone technological domain using PATSTAT database elaborated by the EPO. We regionalize these patents by inventors address using REGPAT database elaborated by the OECD and based on PATSTAT database[4].

Mobile phone has become a transversal technology. To include the different mobile phone dimensions we have used a keywords approach. We select mobile phone projects and patents from syres EUPRO and PATSTAT databases by looking for certain keywords in their abstracts. We define "mobile", "phone" and "telecommunication" as basic recursive keywords, and we use boolean operators to combine them with specific words associated to four layers that define the mobile phone industry: *i)* infrastructure layer, *ii)* security layer, *iii)* service/software layer, *iv)* terminal layer. The selection of these keywords is based on expert advise.

Our final data on projects and patents span from 1988 to 2008. The keyword methodology produced a sample of 978 projects and 4124 participants from the collaborative R&D base. Projects are assigned to a year on the base of their starting date. For the patents database we get a sample of 8692 patent applications[5].

Network definition We construct networks for each year of the period 1988-2008. Collaborative R&D networks are build from affiliation matrix based on projects. Affiliation matrix contains organization-by-project information: a_{ij}=1 if the ith organization is involved in the jth project and 0 otherwise. From the affiliation matrix we get an organization-by-organization unimodal matrix: if $b_{ij} \geq 1$ ith and jth organizations have at least one project in common, if b_{ij}=0 they do not collaborate

Projects are annually assigned by their starting date. Since the average duration of projects is 30.6 months, we used 3-years moving windows to construct collaborative

[4] April 2012 version
[5] Patents applications are selected considering docdb patent families to avoid double counts.

R&D networks. Due to the objectives of European cooperation FP projects are conditioned to the involvement of partners from different countries. We deal with this bias by assuming that when two organizations of the same region are in a common project they know each other, and so they have an effective collaboration. Contrary, for organizations of two different regions we assume that a collaboration exists only when they are in at least two common projects in the same year-window, otherwise there is only a policy bias and the effective collaboration does not exist (Autant-Bernard et al., 2007). Consequently, two organizations in the same region have a relation at year t, if they collaborate in at least one project in year t, $t-1$ or $t-2$. Two organizations in different regions have a relation at year t, if they collaborate in at least two projects in year t, $t-1$ or $t-2$

Geographical scale The geographical boundaries of clusters are very elastic, and systematic data at cluster level are rare. So, although we acknowledge that clusters geographical borders usually do not match with administrative divisions, we are constrained by data availability. Then, organizational networks and patent counts are regionalized at NUTS2 level, this is the smallest aggregation level to locate organizations in Syres EUPRO database.

The calculation of network properties requires networks with a minimum size. Networks with too small number of nodes do not have a minimal critical mass to properly calculate structural properties. To avoid this problem we decide to work only with the 19 NUTS2 regions that have more than 50 participations along the whole period (1988-2008). So, we obtain a panel with 19 regions and 21 years

4.3.3. Dependent variable

We measure regional innovative performance of clusters by the number of regional patent applications per year. Patent applications are annually assigned based on their "priority date", which is considered as the closest date to the invention act. Regional assignation is done by inventors address. In case of patents applications with several inventors in different locations a complete assignment is done, i.e. patent application X is assigned to region r when an inventor of the patent X is located in region r. As a result we have a discrete variable taking 0 and positive integer values.

4.3.4. Independent variables

Measuring network hierarchy. Crespo et al. (2013) measure the level of network hierarchization as the slope of the degree distribution, i.e. the relation between nodes degree and their rank position . We sort nodes by degrees from the largest to the smallest, and transform them in log-log scale[6].

$$k_h = C(k_h^*)^a$$
$$\log(k_h) = \log(C) + a\log(k_h^*)$$

Where k_h denotes the degree k of node h, k_h^* denotes the rank of node h in the distribution, C is a constant and a is the slope of relation. By construction a will take 0 or negative values. In order to simplify interpretation, we transform it in absolute terms. If a has a high value, in absolute terms, the network will display a high level of hierarchy. There will be some nodes with many relations in a prominent network position and others with few relations. Contrary, low a values, in absolute terms, correspond to a network structure with flat hierarchy. Consequently, all nodes have more or less the same number of relations, relational capabilities are quite homogeneous and there is no leading organization.

In hypothesis 1, we argue that hierarchy has a positive impact on cluster innovative performance. However, this effect might reach a threshold beyond which higher hierarchy damages innovative performance. To test for non linear effects we introduce the squared term of the network hierarchy measure.

Measuring network assortativity. To measure the level of assortativity or disassortativity of networks we use degree correlation as defined by Crespo et al. (2013): it is the slope of the relation between nodes' degree and the mean degree of their local neighborhood. For each node h we calculate the mean degree of his neighborhood V_h. A node i is in the neighborhood of node h when both of them are in the same region, and they have, at least, one collaborative project together, i.e. they have a relation. If k_i is the degree of node k the mean degree of node h can be calculated as follows:

$$\overline{k_h} = \frac{1}{k_h}\sum_{i \in V_h} k_i$$

Then we estimate the relationship between nodes' degree and the mean degree of their neighborhood:

$$\overline{k_h} = D + bk_h$$

[6] To avoid non existing logs for isolate actors we consider that all actors have at least one relation with themselves

Where D is a constant and b is the degree correlation. By construction b is enclosed between one and minus one. If b is positive and get closer to one, then the network is highly assortative, meaning that highly connected nodes tend to interact with highly connected nodes, and poorly connected nodes with poorly connected nodes. At the opposite, if b is negative and get closer to minus one, the network is disassortative, meaning that highly connected nodes tend to interact with poorly connected nodes, and conversely.

Interactive variables. We check for interplay between assortativity and hierarchy with interactive variables. To do so, we create dummy variables to split observations in two categories: *i)* observations with high hierarchy, in this case the variable takes the value 1 if degree distribution is above the median, 0 otherwise; and *ii)* observations with low hierarchy, in this case the variable takes the value 1 if hierarchy is below the median, 0 otherwise. We create interactive variable by multiplying these two dummies with degree correlation. With this method we test if degree correlation has a different impact when associated to networks with high or low hierarchy levels. To test hypothesis 3 we use interactive variables too. We create two dummy variables to split observations in two sub-periods, prior and after 2000[7]. We multiply them by degree correlation and degree distribution to identify differential effects of hierarchy and assortativity in the first and second period, i.e. prior and after the bubble crash.

4.3.5. Controls

To rule out potential bias and possible competing hypothesis we introduce control variables at network and regional level. Small world networks may enhance regional innovation by their combination of local dense interaction and short average path length. While the first enables trust formation and collaboration, the second favors connectivity and the arrival of new knowledge. We introduce *clustering coefficient* (CC) computed as "*the average fraction of paris of neighbors of a node which are also neighbors of each other*" (Newman, 2000) to control for the local cliquishness effect.

To control for the short path length and the existence of non redundant relations, we elaborate two measures based on their different geographical scope. *Internal reach* (IR) focuses on within-region relations. It is calculated as the average of the weighted distances of each local node j with all other local nodes k. It takes the value 0 if all local nodes are isolates, and it takes the value 1 when every local node is connected with a path of distance one to all other local nodes (Breschi and Lenzi, 2012): $IR_{NUTS2_r} = \frac{\sum_{j=1}^{n_r}\sum_{i=1}^{n_r}\frac{1}{d_{ij}}}{n_r}$, where n_r denotes the number of inventors located in region r, and d_{jk}

[7]The dummy for the first period takes the value 1 for years 1988-2000, and 0 otherwise. The variable for the second period takes the value 1 for year 2001-2008, and 0 otherwise

the geodesic distance between organizations j and i, belonging to the local network of region r. Contrary, *external reach* (ER) focuses on between-region relations, i.e. the relational distance between local nodes and non local nodes: the pipelines. We compute it as the average of the weighted distance of each local node j with all other non local nodes h. Similarly, it takes the value 0 if non local actor has an external tie, i.e. a relation with an actor in another region. It takes the value of 1 if all actors in a region are connected by a path of length one to all actors in all other regions (Breschi and Lenzi, 2012): $ER_{NUTS2_r} = \frac{\sum_{j=1}^{n_r}\sum_{h=1}^{n_h}\frac{1}{d_{jh}}}{n_r n_h} * 100$, where n_r denotes the number of inventors located in region r, and n_h the number of inventors located in all other regions. Similarly, d_{jh} denotes the distance between inventors j and h.

We include two more controls about the cohesion of the local inter-organization network. Network size and network density account for the number of nodes and the number of ties. Network size is simply the number of organizations in the region (*Ln number of org*[8]). *Network density* is calculated as the actual over the potential number of ties among local organizations. It takes the value 0 when all local nodes are isolates, and it takes the value 1 when all local nodes form a clique.

In addition to network features we control also for regional features that may influence their patenting capacity. We include variables for the regional availability of resources and size. Firstly, R&D expenditures are a fundamental indicator for the regional resources mobilized for innovative activities. However, systematic data at NUTS2 level were not available for the period of analysis. However, given the fact that location patterns of R&D collaborations tend to be stable over time (Acs et al., 2002), the use of fixed effects models should account for much of the variation (Fleming et al., 2007; Lobo and Strumsky, 2008). We support it with three key variables added to our model. Firstly, we use the number of inventors in region i at year t (*Ln inventors*). It accounts for the number of people actively engaged in inventive activities. Furthermore, we use regional population in thousand of inhabitants at year t to control for regional size (*Ln population*). Finally, to control for urbanization economies, we use population density calculated as population over regional land extension in square kilometers (*Ln population density*).

Our model considers regional knowledge bases too, a fundamental regional feature that may affect patenting activity of regions in the mobile phone sector. To this end, we compute controls for knowledge diversity and for knowledge specialization. Firstly, we computed Herfindahl-Hirschman Index using the shares on technological domains in each region (*HHI technology*). The EPO examiners assign patents to technological fields following the International Patents Classification (IPC).We use patent classes

[8] All independent count variables are introduced in logarithmic terms

from patents assigned to region i at year t to calculate *HHI technology* variable. It varies between 0 and 1, and measures the extent to which a region is specialized in a narrow set of technologies (high HHI technology), or it has a diversified knowledge bases (low HHI technology). Secondly, we computed a mobile phone *specialization index* based on the number of inventors. For each region i at year t we calculate the number of regional inventors in the mobile phone sector over the total number of inventors in the region. We compare it with the same ratio aggregated for all regions. If the resulting index is superior (inferior) to 1 the region is (not) specialized in mobile phone technological domain. While HHI technology variable may indicate diversification or specialization in any technological field, specialization index variable focus only on mobile phone sector.

4.3.6. Estimation framework

To measure the innovative capacity of regions we construct the variable regional patent applications on mobile phone technological domain annualized by priority date. We model it for a period of 21 years going from 1988 to 2008, and for 19 NUTS2 European regions. Regional patent applications can only take integer non-negative values. Consequently, the appropriate estimation methods are count models based on Poisson distribution:

$$Pr(Y = y) = \frac{e^{-\mu}\mu^{y}}{y!}$$

Where μ is the rate parameter. In the Poisson distribution the mean and the variance are equal (equidispersion). To obtain the Poisson regression model we specify μ_i with the independent variables X_i under the standard assumption of exponential mean parametrization: $\mu_i = e^{x_i'\beta}$, $i = 1, ..., N$. However, the Poisson regression rarely fits in practice because, as in our data, the variance is greater than the mean: data are overdispersed. Under overdispersion the Poisson estimates are consistent but inefficient, and underestimate standard errors leading to spuriously highly z-values. Negative binomial models let solve this accounting by unobserved cross-sectional heterogeneity with a mixture of Poisson and Gamma distribution:

$$Pr(Y_i = y_i) = \frac{\Gamma(\alpha^{-1} + y_i)}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})} r_i^{y_i} (1 - r_i)^{\alpha^{-1}}, \text{where } r_i = \frac{\mu_i}{\mu_i + \alpha^{-1}}$$

Negative binomial model is preferred because our data exhibit overdispersion, we reject Poisson model at $p < 0.000$.

Given the panel structure of our data we modeled regional mobile phone patens with conditional fixed-effects specification to control for unobserved heterogeneity across regions[9], i.e. it considers within-region variation only. Generational effects are directly estimated by including dummy variables for each generation existing in the mobile phone history. Consequently, the basic negative binomial model we estimate has the following form:

$$\ln(y_{it}) = \sum_{j=1}^{J} \beta_j X_{itj} + \sum_{h=1}^{H} \gamma_h Z_{ith} + \alpha_i + \phi_g + \varepsilon_{it}$$

Where the dependent variable is the number of patent applications on the mobile phone sector of region i at year t. The independent variables X is a vector with the network structure variables that test our hypothesis (degree distribution and degree correlation), Z is a vector with the network and regional controls we use, α is the regional fixed effect, ϕ refers to the mobile phone generation fixed effect and ε is the idiosyncratic error term[10].

Table 4.1: Descriptive statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Patent applications	8.76	15.94	0	112	399
External reach	3.48	3.66	0	25.17	399
Internal reach	0.98	1.31	0	9.08	399
Clustering coef.	0.41	0.39	0	1	399
Density	0.13	0.18	0	1	399
Ln number of org.	2.32	1.33	-4.61	4.72	399
Ln inventors	6.46	1.2	2.2	8.84	399
Ln population	15.09	0.57	13.77	16.27	399
Ln population density	6.24	1.42	4	9.13	399
HHI technology	0.01	0.01	0	0.12	399
Specialization Index	1.84	3.46	0	38.5	399
Degree distribution (abs)	0.5	0.27	0	1.05	399
Degree distribution^2	0.07	0.08	0	0.37	399
Degree Correlation	0.72	0.27	-0.59	1	399

[9] Either fixed-effects or random-effects provide consistent results, but the Haussman test supports the use of fixed effects

[10] We run all the analysis with STATA 11.

Table 4.2: Variables correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Patent app.	1.00												
(2) External reach	0.06	1.00											
(3) Internal reach	0.32	0.37	1.00										
(4) Clustering coef.	0.07	0.10	0.27	1.00									
(5) Density	-0.07	0.47	0.02	0.03	1.00								
(6) Ln number of org.	0.24	0.13	0.47	0.38	-0.22	1.00							
(7) Ln inventors	0.51	0.10	0.22	0.01	-0.12	0.23	1.00						
(8) Ln population	0.14	0.16	0.40	0.03	-0.10	0.31	0.46	1.00					
(9) Ln pop. density	-0.15	-0.14	-0.02	-0.01	-0.13	0.01	-0.20	-0.33	1.00				
(10) HHI technology	-0.22	0.02	0.05	0.05	-0.02	-0.01	-0.74	-0.18	0.17	1.00			
(11) Specialization I.	0.33	0.14	0.04	0.07	0.16	0.01	0.03	-0.17	-0.10	-0.05	1.00		
(12) Deg. distribution	0.23	0.31	0.59	0.59	-0.13	0.65	0.18	0.24	-0.09	0.04	0.04	1.00	
(13) Deg. distribution^2	0.10	0.14	0.35	-0.08	0.05	-0.20	0.04	0.08	-0.06	0.07	-0.02	-0.06	1.00
(14) Deg. correlation	-0.20	-0.64	-0.54	-0.09	-0.21	-0.30	-0.12	-0.21	0.13	-0.04	-0.04	-0.58	-0.06

4.4. Results

Tables 4.1 and 4.2 present the descriptive statistics and the correlation values for all variables. The correlation values are relatively low for most of the variables. Higher values concern variables catching network structural properties. This is often the case given the influence of network size over all network measures. However, we compute the variance inflation factors and we find that multicollinearity is not a problem.

Table 4.3 present the modeling results to test our hypothesis. Model 1 is the baseline model with all controls. Model 2 includes the explanatory variables for hierarchy and assortativity, and model 3 examines their interaction. Finally, model 4 checks for differential impact of the explanatory variables in the emergence and maturity stages of the mobile phone sector. Model 4 has the best fitting.

In model 1 the coefficient estimate of *Ln inventors* is positive and significant since it captures the resources potentially available on the region for innovative activity. The unexpected negative and significant sign of *Ln population* probably indicates an overlapping effect with the Ln inventors variable. The variables *Ln population density* is positive and significant. Thus, it shows that positive urbanization externalities dominate congestion effects for mobile phone patents production. The positive and significant effect of *specialization index* as opposed to the non significant effect of *HHI tecnlogly* underline the role of specialization economies over the Jacobian externalities for the regional production of mobile phone patents. For network controls, we have that *external reach* has an unexpected negative and significant effect. It may indicate the risk of too much outward-looking relations (Bathelt et al., 2004), in particular with small networks. This "excess" of external relations is linked to the nature of the data, since FP-projects are conditioned to non local cooperations. *Internal reach* and clustering coefficient are both negative and non significant reflecting the ambiguous results of the empirical small world literature. While Breschi and Lenzi (2012) find support for the small world model, results of Fleming et al. (2007) are much less concluding due to insignificancy of variables, particularly for clustering. Finally, *density* is positive and significant, and *network size* is positive and non significant.

Our first hypothesis finds support in model 2. Once accounting for regional characteristics and basic network connectivity, the linear and non linear effects of degree distribution are both positive, although only the non linear is significant. So, strong hierarchy in local networks of organizations in a given technological domain favors patenting activity. The marginal effect shows that an increase of 0.1 in degree distribution implies an increase of 0.97% in regional mobile phone patent applications[11]. Model 2 also supports our second hypothesis about the effects of assortative networks on in-

[11] Marginal effect computed at the mean value of all variables in the model

novative performance. We find that the degree correlation coefficient is consistently negative and significant for regional patenting activity: an increase of degree correlation 0.1 units produces a reduction of 0.076% in the regional patent counts on the mobile phone technological domain, i.e. more assortative networks are less performing.

Model 3 studies potential interaction between both properties. We construct two interactive variables that split degree correlation in two groups: degree correlation associated with high degree distribution, and degree correlation associated with low degree distribution[12]. In model 3 the conclusions for hierarchy hold. Similarly, the coefficients of both degree correlation variables are still negative and significant. So, assortative networks have a negative impact on regional patents production either when the network has a strong or a weak hierarchy. However, a Wald test indicates that both coefficients are significantly different, assortativity has a bigger negative effect on innovative performance when the network has low hierarchy[13].

In model 4 we test our hypothesis 3 on the differential effect of hierarchy and assortativity along the technological domain cycle. We extend model 2 to test if degree distribution and degree correlation change their influence on innovative performance prior and after 2000. We test this hypothesis with interactive variables obtained as a product of our explanatory variables (degree distribution and degree correlation) and two temporal dummies, one for the pre-crash period (1988-2000) and other for the post-crash period (2001-2008). We find partial support for hypothesis 3. For degree distribution, the linear effect is significant in both periods, but it has a negative impact on the patenting performance of regions in the first period, and a positive effect in the second. The Wald test confirms that both coefficients are significantly different. Concerning degree correlation, the estimated coefficients are negative and significant for both periods, i.e. assortativity damages innovative performance of regions in mobile phone technological domain prior and after the telecom crash. Thus, model 4 validates hypothesis 3 for hierarchy, but not for assortativity.

To sum up, these results support the first two hypothesis on hierarchy and assortativity: (1) strong hierarchy and (2) disassortativity increase patenting activity of region in the mobile phone technological domain. However, the hypothesis 3 on the shifting role of these properties along the technological cycle finds weak empirical support, it holds for hierarchy but not for assortativity.

[12]A network is qualified as highly (lowly) hierarchical when its degree distribution is over (below) the median.

[13]We have also checked as percentile 66 as cut point for high/low hierarchy. Both degree correlation variables have a negative effect on regional production of patents, but it is only significant when associated with low hierarchy suggesting a compensation effect between both, i.e. networks with strong hierarchy cancels the negative effect of assortativity.

Table 4.3: Conditional fixes effects negative binomial of patent applications (1988-2008)

	Model 1		Model 2		Model 3		Model 4	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Intercept	14.81***	(5.742)	14.46**	(5.697)	17.26***	(6.097)	53.45***	(9.900)
External reach	-0.0483***	(0.0162)	-0.0947***	(0.0193)	-0.0947***	(0.0190)	-0.0864***	(0.0164)
Internal reach	-0.00950	(0.0341)	-0.0716*	(0.0385)	-0.0467	(0.0385)	-0.121***	(0.0345)
Clustering coef.	-0.109	(0.110)	-0.115	(0.127)	-0.112	(0.126)	-0.0819	(0.112)
Density	0.770**	(0.344)	0.815**	(0.351)	0.901***	(0.339)	0.784**	(0.320)
Ln number of org.	0.0506	(0.0551)	0.0594	(0.0619)	0.0629	(0.0606)	0.0736	(0.0570)
Ln inventors	2.101***	(0.190)	1.966***	(0.171)	2.026***	(0.168)	2.287***	(0.143)
Ln population	-2.119***	(0.422)	-2.036***	(0.417)	-2.249***	(0.450)	-5.325***	(0.790)
Ln population density	0.365***	(0.139)	0.426***	(0.154)	0.439***	(0.164)	2.286***	(0.421)
HHI technology	-2.655	(10.25)	-8.976	(10.24)	-7.940	(9.996)	-25.05***	(8.854)
Specialization index	0.121***	(0.00789)	0.130***	(0.00783)	0.131***	(0.00755)	0.142***	(0.00694)
Degree distribution			0.0672	(0.271)	-0.234	(0.278)		
Degree distribution^2			1.127***	(0.428)	1.338***	(0.428)		
Degree correlation			-0.763***	(0.253)				
D. cor. × High D. dist.					-0.488*	(0.255)		
D. cor. × Low D. dist.					-1.283***	(0.306)		
Degree distribution p1							-0.784**	(0.333)
Degree distribution^2 p1							0.188	(0.550)
Degree correlation p1							-1.312***	(0.289)
Degree distribution p2							1.063***	(0.291)
Degree distribution^2 p2							0.385	(0.513)
Degree correlation p2							-0.414*	(0.245)
N	399		399		399		399	
AIC	1578.7		1561.3		1556.0		1536.8	
BIC	1634.6		1629.1		1627.8		1616.6	
Log likelihood	-775.4		-763.7		-760.0		-748.4	

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

All models include generation indicator with 1G omitted.

We tested the robustness of the results to alternative model specifications. We have assumed that innovative performance of regions is continuous. We have also done the analysis by considering the annual relative performance of regions as dependent variable. We sort the regions by their number of patents in year t, and we construct a categorical ranking variable by assigning 2 for the top 3 regions, 1 for regions in positions 4 to 6 and 0 otherwise. Since the order of categories was meaningful we estimated an ordered probit model. The results of the analysis were consistent with those presented in table 4.3 and discussed above.

From 1988 to 2008 there are several regions that do not get any mobile phone patent in certain years. So, to deal with an eventual "excessive" number of regions with 0 counts, we estimated zero-inflated negative binomial models (ZINB)[14]. ZINB models rely on the assumption that zero-counts and positive-counts comes from different data generating processes. Thus, ZINB are two-parts models, consisting of both binary and count model section. In the binary section we estimated a probit model with variables referring to the regional features. In the count section we include regional variables and network variables. The results concerning degree distribution and degree correlation are consistent with the regressions presented in table 4.3 too. In particular the inclusion of degree distribution and degree correlation variables improved significantly the overall fit of the model as compared with the baseline model[15].

4.5. Discussion

These findings provide interesting evidence for a better understanding of the critical role of network properties for clusters performance, and then, complement a growing literature on that purpose (Owen-Smith and Powell, 2004; Boschma and ter Wal, 2007; Broekel and Graf, 2012; Balland et al., 2013c). Moreover, these findings corroborate evidence on particular industrial dynamics in which knowledge variety and complementarities, technological integration and standardization influence the structural organization of clusters, their long run dynamics in a context of competing regions, as well as their endogenous capabilities of resilience.

First of all, model 2 supports the hypothesis according to which, along the whole period of time, stronger network hierarchy favors innovative performance of clusters, while stronger network assortativity damages it. On a one hand, European clusters that have better performed are the ones which contributed to bringing out few but dominant and leading companies, able to coordinate a wide range of other organizations holding separated but complementary pieces of knowledge, and able to integrate them in a systemic and complex technology. On the other hand, beside the critical role of

[14]36% of our observations have 0 counts.
[15]The estimation of a Hurdle model reached the same conclusions.

hierarchy, the less clusters are assortative, the more their output in terms of patents increases, meaning that competing clusters are the ones that display a wider range of pathways between core-organizations and loosely-connected ones, such as new entrants or spin-offs. To put it differently, the innovative capabilities of clusters do not solely depend on the co-existence of leading organizations with a high relational capacity and other peripheral and loosely-connected ones. The hierarchical structure of clusters had to be coupled with a particular structure of knowledge flows in which new explorative, or even disruptive, ideas find channels to join the experienced and well-established core of leading organizations enabling to turn these ideas into new tradable products for exploitation.

These findings tend to confirm a large part of the literature on the complex industrial organization of the mobile phone industry. Concerning the positive role of hierarchy, Funk (2009) and Funk (2011) show that the success of mobile phone OEMs (Original Equipment Manufacturers) in the definition of a dominant design depends on their ability to coordinate a critical mass of complementary products in order to diffuse the final product as widely as possible. At the opposite, one can expect that flat hierarchy in clusters implies a lack of global vision of the complex device, and then some risks of non-compatibilities or dysfunctions that weaken the ability of the clustered organizations to set up a dominant design. Concerning the negative influence of assortativity, literature has shown that the vertical integration between related and even unrelated features have turned the industry into the production of multi-functional devices (Giachetti and Marchi, 2010). In this context, Koski and Kretchmer (2009, 2010) have found that innovations in terms of openness towards previously unrelated technologies have played a stronger role for the performance of OEMs than the traditional network and epidemic effects at play on the consumer side. Therefore, one might expect that clusters in which leading organizations devote their relational capabilities to connect themselves favor technological standardization. However, it can prevent the entry of potential providers of unrelated assets, redundant knowledge flows and then generate a high risk of conformism.

More outstanding are the findings on network hierarchy and assortativity when we refine the analysis by splitting the period into two sub-periods (Model 4). Indeed, following previous theoretical and empirical attempts (Menzel and Fornahl, 2010; Balland et al., 2013a; Crespo et al., 2013), our period is rather long to be able to capture differentiated effects of these properties on the aggregate performance of clusters along the particular life cycle of the mobile phone industry. In particular, the Internet bubble crash which concerned the whole industry of information technologies constitutes a significant event for the organization of the industry and an important step between its development and its maturity. If the negative role of assortativity remains unchanged when the two periods are taken into consideration, at the opposite, we can see a changing role of hierarchy along the industry life cycle. Here again, our findings corroborate a large part of the literature on industrial dynamics. Indeed, during the first period, the more clusters display a high level of hierarchy, the less they perform in their patenting activities. On the one side, one could interpret that clusters hosting big companies such as national incumbents (traditional network operators) performed less in terms of innovation during the initial stages of development, since their main concern was more to re-orient their customer bases towards the first generation of mobile handsets than to participate to the wave of burgeoning innovations in the mobile phone industry. On the other side, as early demonstrated in the industry life cycle approach of Klepper (1996, 1997), small companies and recent entrants are responsible for a large part of product innovations, in an entrepreneurial technological regime which is favorable to innovative entries and unfavorable to well-established big companies. Moreover, the logic of knowledge accessibility in which these burgeoning companies are involved to combine complementary pieces of knowledge is typical of the early phase of cluster formation (Audretsch and Feldman, 1996a), with flat hierarchy, and far from the process of ossification around a couple of leading companies that typifies more mature clusters. The long run analysis of the mobile phone industry by Giachetti and Marchi (2010) confirms our findings. According to them, a large part of innovations during the early and growth phases in the 1980s and 1990s arises more from a structured process of collaboration between OEMs, components suppliers, original design manufacturers and public research organizations, than from the control of the integration process by the oligopolistic networks operators.

At the opposite, during the second period, strong hierarchy favors cluster performance in patenting activities, together with low assortativity. To explain such a change, the arguments of Klepper (1996, 1997) and Audretsch and Feldman (1996a) on the life cycle of the industry and the geographical counterpart still apply, at least partially. As a matter of fact, as in many other industries, and after a growth stage with intensive entries, a shakeout occurs and clusters achieve more or less their final form with a more oligopolistic structure, and the continuation of the spin-off process, that allow clusters to insure their sustainability, rather than to decline (Menzel and Fornahl, 2010; Crespo, 2011). Therefore, the return of the positive effects of hierarchy could be explained by this prototypical trend of industry, where performing clusters are now the ones in which some leading organizations have crossed the chasm between the early and the mass market and are able to coordinate actions and knowledge of other co-located organizations to maintain their position. This explanation might be relevant, but only partially, since Klepper's view of the life cycle of industries, reinforced by the observed patterns of innovation of Abernathy and Utterback (1978), links the ossification of the industrial structure along the cycle of the industry to the changing nature of innovation, which goes from product innovation to process innovation. However, these patterns do not match with the particular long run dynamics of the mobile phone industry. Many authors (Funk, 2009, 2011; Koski and Kretchmer, 2009, 2010; Giachetti and Marchi, 2010) underline the acceleration of the rhythm of product innovations by the well-established companies during the period of shakeout and maturity. These product innovations were driven by the impact of technological convergence between the mobile phone, Internet, computer and media industries, as well as the introduction of other advanced technologies that make handsets "smarter". In this context, competing clusters in the shakeout and maturity phases of the mobile phone industry were the ones which succeeded in mixing the ossified structure with an open network structure that favors connections and knowledge channels between the core-organizations of the industry and new and fresh unrelated ideas that allow OEMs to increase their portfolio of new applications and uses. Such a pattern shows that the prototypical process of ossification along the cycle of the industry does not go against the persistence of product innovations if network structures exhibit a sufficient level of disassortative relational behavior. In that sense, model 4 clearly shows that the resilience capabilities of clusters after the telecom bubble crash is linked to the ability of the whole structure of networks to deal with hierarchy and disassortativity (Crespo et al., 2013), in order to avoid the "trap of rigid specialization" (Grabher, 1993) that generally pushes clusters towards decline.

4.6. Concluding remarks

In this essay, we have tried to contribute to the growing literature on clusters dynamics that puts the structural properties of knowledge networks at the center of the analysis. Our main contribution to this literature shows that for clusters involved in the production of complex and systemic technologies, the properties of hierarchy and assortativity bring new ways to capture the reasons why some clusters perform better than others, and through what kind of structural mechanisms they resist to economic shocks and perform all along the cycle of markets. Previous literature has clearly showed that small-world properties matter for that purpose. Since these properties perfectly capture the trade-off between closure and bridging, or between cohesiveness and openness of networks, they give an interesting view of the mechanisms at play in the structural organization of clusters. Here, we show that considering hierarchy together with assortativity allows going further. They represent properties that put together some traditional basics of industrial organization, such as the process of oligopolization along the cycle of the industry, with the geographical but also relational dimensions of these industrial structures. In particular, our analysis shows that the increasing hierarchy that allows industry to reach maturity does not necessarily lead to lock-in situations for clusters that host part of this industry. If the relational structures typifying some of these clusters display a sufficient level of disassortativity to prevent rigidities and preserve openness towards new and fresh knowledge, thus they will maintain opportunities for product innovation in the long run. Other studies, including other industries and other methodologies, will be necessary in the future to confirm these preliminary but promising results.

Chapter 5

Why can collective action fail in local agri-food systems? A social network analysis of cheese producers in Aculco, Mexico

This chapter is based on a paper co-authored with Denis Requier-Desjardins and Jérôme Vicente, and currently revised and re-submitted to Food Policy. This paper was written within the context of a ECOS-Nord Project (Number M09A03) between the LEREPS and the ICAR (Mexico)[1]. The project aimed to introduce social network analysis in the evaluation of collective action in Local Agri-food Systems (LAS). Although this is a radically different context concerning a low-tech sector, the adoption of a network perspective gives also interesting insights to understand the coordination process between actors with convergent and divergent interests. We collected primary data to show how different levels of connectivity in multiplex networks may reveal clannish behaviors to explain the failure of a collective action. Such results converge with the theoretical propositions of chapter 2, where we explained that cluster development and viability in the long term is contingent on the strength of the regional process.

[1]Action title: Processus d'activation des ressources locales dans le développement territorial des zones rurales au Mexique : une approche par les systèmes agroalimentaires localisés et les réseaux sociaux.

5.1. Introduction

During the last decade, Local Agri-food Systems (LAS) have been the subject of a growing attention from scholars as well as local and global policy makers in developing countries. Local Agri-food Systems can be defined as specific concentrations of small farmers specialized in a particular food-processing industry (Requier-Desjardins et al., 2003; Thompson and Scoones, 2009). The emergence and the structuring of these systems appear as catalysts for rural development, agriculture modernization and a better market reachability for farmers (Markelova et al., 2009). Literature on development highlights the necessity of local collective action as a condition to support such a challenge. It requires the building of a common vision, shared interest, reciprocity and cooperation between members belonging to a clearly-defined perimeter of relations (Ostrom, 1990; Meinzen-Dick et al., 2004). One of the relevant "spaces" of coordination identified by scholars in developing countries corresponds to culturally-inherited districts or clusters, featured by a long tradition of specialization and social capital (Rabelloti, 1995; Nadvi and Barrientos, 2004; Morales and Giuliani, 2012)

This is precisely the ambivalent effects of social capital on the development of collective actions in LAS we want to capture in this research. From the highly-diffused benefits of social capital (Dasgupta and Serageldin, 2000) to the issue of elite capture highlighted by Platteau (2004), disentangling this ambivalence requires entering the black box of social capital. Literature has identified several important dimensions, such as trust and reciprocity, shared norms, connectedness and networks, all of them being crucial for the development and success of collective actions. Here, following some emergent researches (Giuliani and Pietrobelli, 2011; Spielman et al., 2011), we isolate connectedness and networks, and propose an original way to analyze the success or failure of collective action according to the structural properties of local and social networks. However, even if we only consider this dimension to the detriment of others, we stress on the plurality and the multiplexity of these networks, considering that the qualitative and quantitative valuation of social capital on the adherence to a particular collective action requires investigating and comparing several types and contents of relations, and then several "matrixes" of relations, such as family, friendship and cooperation in production. The basic idea is that social networks are not self-sufficient to provoke the entire adherence to collective actions. The probability of actors to stay in, stay out, or exit a collective action will depend on how these multiplex networks articulate themselves, and how their respective structural properties provide good or wrong incentives to collectively act toward a common goal.

Our theoretical predictions are tested in the case of the cheese producers community in Aculco, Mexico. In 2004, the federal government identified the rural region of Aculco as a LAS of cheese production, and the Unión de Productores Lácteos de Aculco (UPLA) was created. Since then, it has received funds from the government to improve the production process (with the project of a pasteurization plant) and the commercialization (with the project of a collective trademark). A long immersion and in-depth analysis have allowed gathering primary data, in order to have a complete view of the degree of adherence to collective action, the individual characteristics and attributes of cheese producers and the structural dimensions of the different networks in which they are embedded.

A first glance at the data report clearly displays a failure of the UPLA project since only 25% of the cheese producers joined it and were involved in the producers association in 2010, compared to 71% in 2004, when the program was launched. This decreasing rate of adherence clearly expresses a failure of the program since it is felt as such by the remaining farmers adhering to UPLA during our immersion in Aculco. They have expressed an increasing reluctance to pursue the investment in public goods (the pasteurization plant and the collective trademark) as far as other farmers exited UPLA. They feared their collective investments might turn under-efficient and dreaded to see the image of their products spoiled by other farmers using outdated production methods outside of any common rules. More than an attrition of the collective action, which could naturally arise if the main objectives of the program had been reached, this case study clearly appears as a failure since the necessary threshold of adherence has never really been attained[2]. But this decreasing degree of adherence to the formal collective action does not necessarily and directly implies a lack of structuring of producers. The explanations require investigating how the actors' embeddedness in different kinds of interpersonal networks and the structural properties of these networks affect the ability of cheese producers to cooperate inside or besides the UPLA frame.

After summarizing in section 5.2 the main contributions on the role of social capital on the force of collective actions, section 5.3 develops a framework relying on the ambivalent effects of the structural properties of interpersonal networks on the success and failure of collective actions. We argue that the strength of social relations is not a guarantee of trust and cooperation, in particular when an excess of bonding and closure in interpersonal networks creates asymmetries in power and influence, and then entry barriers or disincentives to join a formal collective action. Section 5.4 presents the context and data of the empirical study. It details the different kinds of social networks in which Aculco cheese producers are involved. Section 5.5 proposes a social network analysis in order to map and discuss the structural properties of the different

[2] This feeling of failure clearly appeared during the interviews, a large majority of farmers expressing their disappointment: *"I do not like it because it goes too slowly, I regret my involvement. People leave it because they do not see any progress"; "We were in UPLA but we quit because we do not see any future for small producers", or "That business is not going to work, the foundation is not good".*

identified networks. It highlights the multiplex structure of social relations in Aculco and the position of UPLA members compared to non-UPLA ones. Section 5.6 goes further by studying the critical role of these structural properties on the incentives to stay in, stay out or exit UPLA. Section 5.7 discusses the results on the ambivalent role of social networks in the adherence of collective actions in rural areas of developing countries.

5.2. Theoretical backgrounds

5.2.1. Collective action in local agri-food systems (LAS)

Altenburg and Meyer-Stamer (1999) and Nadvi and Barrientos (2004) have emphasized the key-challenge for poor regions to promote through formal collective actions the survival and development of small-scale enterprise clusters producing low-tech and traditional products. Relying on the experiences of clusters and districts in developed countries (Morales and Giuliani, 2012), for which business and social networks have been evidenced as significant supports for local development, these researches have focused on the conditional transferability of these experiences in poor regions (Rabelloti, 1995). The purpose was to identify the conditions under which particular communities could collectively improve the quality of products and reach a better market accessibility (Hellin et al., 2009; Barham and Chitemi, 2009).

This is typically one of the main challenges for Local Agri-food Systems in developing areas. The survival of LAS generally relies on traditional Marshallian externalities, meaning that specialization and cooperation generate increasing returns on a local scale. But from survival to development, collective actions are required, in particular when the conditions of survival are affected by trade liberalization, globalization, competition and market openness. Many programs have been designed to support collective actions in rural areas. Among others, the PRODAR (Programa de Desarollo de Agroindustria Rural), promoted by the IICA (Inter-American Institute for Co-operation in Agriculture), aimed at supporting rural agro-industry in Latin America, in order to boost small farmers participation in markets and improve conditions in rural areas (Boucher et al., 2000). The basic idea is that the simple co-location of farmers is not a sufficient condition to foster LAS in developing countries, in particular, as noticed by Requier-Desjardins et al. (2003), Henson and Reardon (2005) and Tregear et al. (2007), when quality and safety standards, product qualification, and food traceability along the commodity chain are required to improve market access. The image of the product, which relies on a region and tradition, depends on the collective willingness of all community members to maintain a high level of quality (Dentonin et al., 2012). The degradation of the quality by a small part of the community, and the existence of isolated and cheating strategies, could generate negative consequences on the reputation and the gains of the community as a whole. The simple identification of a production cluster and a bounded community of people involved in a same activity and facing the same external constraints such as market conditions do not necessarily lead a collective action to success. Although trust is important, one should also study whether the different forms of social structures in which community members are embedded produce incentives or disincentives to collectively act towards a common goal.

5.2.2. Social capital as a support of collective action: a brief overview

Collective action generally refers to the voluntary and intended action of a group trying to benefit from its shared interest to achieve a common goal (Ostrom, 1990). As a result, collective actions are strongly related to the incentives to cooperate within a bounded community of people facing a common challenge. In order to reach this goal, they create a common system of rules and sanctions. Community bounds definitions are important since they correspond to a space of interdependencies in the valuation of a public good such as local and natural resources, but also safety and quality standard for an agri-food product (Requier-Desjardins et al., 2003; Markelova et al., 2009; Barham and Chitemi, 2009). Cheating and free-ride behaviors from a minority inside a community can engender negative externalities for the rest of the community, so that the degree of adherence to collective action and the means to increase this degree are crucial for maintaining the valuation of the public good in the long run.

Literature largely acknowledges that the expected outcomes of a particular collective action depend on the existence and strength of social capital in the concerned community. The essential meaning of social capital is related to the patterns of interactions, which refer to the importance of inherited or constructed social structures in which individuals are embedded. Pretty and Ward (2001) give a clear overview of the key attributes of social capital in developing countries. *i)* Trust is one of them. Social relations in communities favor trust due to the convergence of expectations that arises more easily when people know each other. Such a convergence is crucial to stabilize long term obligations in communities and consequently reduce monitoring costs and cheating behaviors. *ii)* Reciprocity and exchange are a direct consequence of trust. The existence of social bonds, such as family or friendship ones, appears as a fundamental lubricant of cooperative and reciprocal ties in production or resources management. *iii)* The benefits of common norms and sanctions also arise from the existence of social structures. The degree of structural embeddedness of individuals leads them to weigh their own interests and gain opportunities against the collective responsibilities of the group. *iv)* Finally, connectedness and networks are a key-principle for the appraisal of social capital. The observation of a geographically-bounded community cannot directly lead to the existence of social capital. The latter is shaped by a set of direct and indirect social interactions, and then by network structures. The strength of social capital depends on the plurality of these networks, their degree of overlapping, and to what extent their structural properties favor or not the convergence of expectations within the community.

5.3. Propositions: Social capital, variety of ties and structural properties of networks

Social structures are shaped by different and various types of relations and social ties. According to sociologists, one can talk about multiplex structures (Lazega and Pattison, 1999; Skvoretz and Agneessens, 2007). Moreover, for each type of ties, the social structure resulting from the aggregation of these ties can exhibit different structural properties, and then different patterns of interactions from one community to another (White et al., 1976). These complex structures of social networks can be summarized around three main testable propositions.

5.3.1. Multiplexity

Bounded communities can be characterized by different forms of social relations. Gathering these relations into one general form of social capital can be misleading, since it prevents from studying complementarity, substitutability, convergence or conflicts between them. The natures of social ties can be numerous, from family or friendship ties to labor or production ties, or to ethnic or religious ties. The multiplex dimension of social networks and their eventual overlapping and dissociation have important implications for entering the black box of social capital due to the similar or dissimilar patterns of distribution they can have within the community. Some individuals can have a high level of relational capital in one particular social structure and remain isolated in the others. Some papers have investigated this plurality of social relations in developing contexts. For instance, in an empirical study of small textile producers in Bolivia, Annen (2001) distinguishes the family network from the network of other "trusted persons" (friends, partners), and shows that depending on the relationships activated by producers, they will have a differentiated evolution of their sales. In this particular case, the more producers benefit from their non-family network, the more their sales increase, the main reason being the constraints imposed by the family context on the development of new opportunities. In the same lines, van Staveren and Knorringa (2007) compare small and medium footwear enterprises in Ethiopia and Vietnam, using the traditional distinction between bonding and bridging social capital for characterizing the multiplex structure of relationships. They show that family relationships reinforce trust and cooperation in production activities, but prevent producers from going beyond the domestic market. The level of adherence and the resulting success or failure of a particular collective action would probably find better explanations in the distinction and the overlapping between different forms of inherited and constructed social structures. Therefore, networks multiplexity influences the degree of adherence of community members to a collective action.

5.3.2. Connectedness, closure and bridging

Structural properties of networks are nowadays key-fundamentals for understanding group performances in organizational and business studies (Ahuja et al., 2012), or the connectedness dimension of social capital in development studies (Pretty and Ward, 2001). The debate between closure and bridging (Coleman, 1988; Burt, 1995; Lin, 2001) is important for that purpose. On the one hand, if collective actions require a high level of trust and cooperation, then closure and cohesion are important features of social networks working in favor of a fruitful collective action. Following Coleman's view on social capital (Coleman, 1988), closure in social networks, i.e. the degree to which everyone knows and interacts with everyone else in a network, is a marker of group solidarity, and a condition for enhancing trust. In particular, triadic closure[3] increases expectations convergence and group cohesion. It also limits the risks of opportunistic behaviors due to the control a third individual can have on a bilateral relationship between two other connected ones. But on the other side, if convergent expectations arise when information perfectly flows within the community, some missing links inside the network can generate "unconnectedness" and thus isolated individuals or groups of individuals. Such a structure can prevent the community from adhering as a whole to collective action, due to a lack of communication, trust and habits of cooperative practices. Following Burt (1995), fully-connected networks in which particular brokers connect unconnected people or groups of people constitute an important resource for collective action and innovation (Klerkx and Leeuwis, 2009). For instance, communities in which some individuals connect unconnected cliques of producers, unconnected groups of friends or unconnected families have higher chances to reach a wider adherence to a collective action than communities in which the social structure exhibits separated cohesive groups of individuals. Accordingly, a community can display different relational patterns and thus different forms of social capital. If closure matters for trust and cooperation, it goes against connectedness in a network as a whole. There-

[3]Triadic closure is the property among three nodes A, B, and C, such that if a tie exists between A-B and A-C, there is a tie between B-C

fore, this trade-off appears as a crucial parameter for assessing the role of social capital in the degree of adherence to a collective action.

5.3.3. Centrality, power and influence

Beside closure and connectedness, individual and group centralities are also important for the structuring of collective actions. Relationships matter for collective actions, but matter differently and sometimes negatively according to these centralities. By centrality, we mean the relational influence of particular individuals or groups within a community, which can be assessed by different measures reflecting the hierarchy of positions. Degree centrality, that is the number of direct connections of a certain nature an individual has, is a key-parameter in network theories (Borgatti, 2005). The flat or sloped distribution of degrees in a network gives an idea of the distribution of power and influence in this network. As for closure and connectedness, the distribution of degrees has an ambivalent effect on the ability of a community to reach the goals of a collective action. On the one hand, the more a community displays a highly-sloped distribution, the more some individuals are able to connect to others and the more the communication structure can lead to a high level of convergence in the expectations of the community members. Due to their high relational capabilities, some individuals can act as reassembling agents or mediators between non-interacting or disagreeing persons, in particular when their high degree of centrality goes with a high level of betweenness centrality, i.e. their propensity to connect unconnected community members. Consequently, the hierarchical structure of social capital does not go against collective action since the presence of leading community members can be helpful for the diffusion of cooperative behaviors. But on the other hand, the hierarchy in degree distribution can be a marker of persistent and self-reinforcing power asymmetries that can be a source of collective action failures, when these asymmetries generate entry barriers and exclusion. The high influence some people or groups of people have can be oriented towards non-economic purposes and discrimination, and can therefore prevent the public or quasi-public good from being produced or managed by the community as a whole. As pointed by van Staveren and Knorringa (2007) in several empirical studies, family and kinship relationships, as well as ethnicity or religion, appear on the one side as a relational cement and loyalty facilitator for cooperation. But on the other side, they can also be the main source of entry barriers, when this loyalty is bounded to a leading subgroup and engenders exclusiveness and clannish behaviors. Moreover, as noticed by Platteau (2004) and Classen et al. (2008), the high influence some leading actors exhibit in a community can be a strong source of “elite capture” that prevents collective action from succeeding. Therefore, if centrality and power of actors or groups of actors facilitate the diffusion of cooperative behaviors, it can also give rise to entry barriers and clannish behaviors for potential newcomers in the collective action.

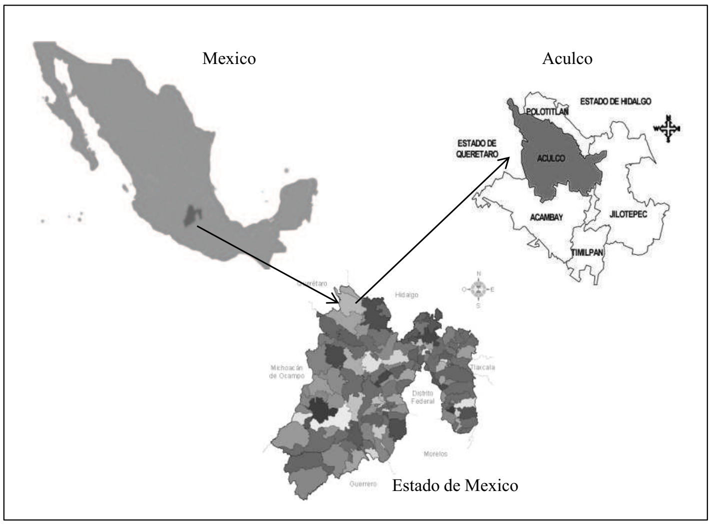
Network multiplexity and structural properties that typify communities are key-fundamentals of social capital. Investigating them can lead to capture the critical parameters that allow having a better understanding of why some collective actions succeed while some others fail. The following sections propose to test these theoretical propositions providing evidence on a particular case of collective action in a specific agri-food cluster in Latin America. The context and the collection of data including basic descriptive statistics are presented in section 5.4. Beside an in-depth analysis of the concrete forms of social relations shaping the community, such an investigation requires identifying and mapping the nature and structure of social networks in order to typify the complex and multiplex structure of social capital (section 5.5). Finally, combining individual characteristics of community members with the properties of the social structures in which they are embedded, section 5.6 proposes an econometric test providing a better understanding of the reasons why actors decide to stay-in, exit or stay out of the framework of the collective action under study.

5.4. Context and data

5.4.1. The context: Aculco region and the LAS of cheese production

Aculco is a district located in the northwest of the Mexico State, in the middle of the triangle formed by Mexico DF, Toluca and Queretaro (Figure 5.1). The roads network gives a very good access to some of the most important consumption centers in the country. Aculco has traditionally been a milk production area. In the 1960s, the government investments in infrastructures such as irrigation channels, dams, roads and other agricultural infrastructures boosted the milk production activity. At the same time the cheese production activity started to grow. However, only in the 1980s did the cheese production activity take off. Indeed, as milk producers faced problems in selling their milk, they turned to cheese production. Therefore, this first wave of growth was the consequence of a forward vertical integration process by which milk producers started to produce cheese by transforming their own milk. The second wave of growth, in the late 1990s and 2000s, was mostly driven by a spin-off process. Workers who used to be employed by a relative or a friend started their own activity attracted by the higher profits and the low level of initial investment. In Marshallian terms, and following Pietrobelli and Stevenson (2011), Aculco clearly presents the characteristics of a cluster, due to the high level of specialization and the density of interactions between

Figure 5.1: The Aculco District - Mexico



co-located cheese producers, mixing competition in regional or national markets with cooperation along the production process.

Aculco queserías are small family businesses. They produce four types of cheese (Oaxaca, manchego, molido and panela) and some milk derivatives. The specificities of Aculco cheese come from the milk properties resulting from the climatic conditions, the altitude of the area (more than 2,000 m) and the quality of local forage crop for cattle. Queserías get the milk required for their production through three different ways: some cheese producers are also milk producers and use their own milk for their cheese production. Secondly, cheese producers buy milk directly from milk producers. Since milk production units are quite small, each quesería has several exclusive milk providers. Finally, there are also milk collectors. They go around several milk producers to collect milk and sell it to cheese producers. All these backward linkages are local and sustained by informal agreements.

Queserías produce their cheese on their own. No shared production infrastructures exist. However, punctual interaction may occur when a cheese producer has a milk shortage at a given moment of time. Cheese producers sell their own production through different channels. Firstly, most of them have their own store to directly sell their products in Aculco. Secondly, cheese producers establish trading relationships with wholesalers and retailers to sell their cheese. The market for Aculco cheese works on a regional scale. The customers are located 100km around Aculco, basically from Querétaro to Toluca and Valle del Bravo, few of them going to México DF. It is the cheese producer himself who makes the distribution. Cheese producers are very reluctant to share commercial information because no formal agreement is established between them and their customers. Moreover, competition is purely based on price strategy, so no customer loyalty exists and cheese producers use secrecy to avoid the risk of other producers stealing their customers.

In 2004, the Unión de Productores Lácteos de Aculco (UPLA) was founded as an attempt of collective action. The financing of the UPLA project could be achieved thanks to the associates' periodical contributions and the important investment received from different public institutions at the state and federal levels (Espinosa-Ayala et al., 2010). It represents the unique initiative bringing several cheese producers of Aculco together in a common project. The motivations for such a project were to improve the input quality, i.e. the milk, and the constitution of a common project for commercialization. As regards input quality improvement, two lines of actions were planned: the shared acquisition of milk, and the construction of a plant to control and pasteurize milk for the associate members in order to produce their cheese in better sanitary conditions. As regards commercialization collaboration, the objective was the creation of a UPLA trademark. Pushed by institutions to foster collective action, this program was initially well-received by the community of cheese producers, from the bigger and long-established producers, who saw the opportunity to better market their products, to the small and young farmers, who saw in UPLA a way to access external resources for the development of their activities.

Table 5.1: UPLA demography of cheese producers

	2004	2010		2004-2010
UPLA members	32	17	UPLA exit	17
Non UPLA members	13	49	UPLA entry	2
Total	45	66		

In its early stages UPLA gathered 32 Aculco cheese producers. However, the association has ever since experienced some few entries and an important number of exits (Table 5.1). Currently, UPLA is composed of 17 cheese producers and a quite large number of associates that are not dedicated to cheese production. Seven years after its foundation, the plant for pasteurization was still not working, no structure to share milk acquisition was settled and today, they still distribute their cheese without any reference to UPLA or Aculco origin.

5.4.2. Data collection

The empirical analysis about Aculco cheese producers is based on primary data collection. Our dataset was constructed through a set of interviews of cheese producers from Aculco, and some additional key local actors during the autumn 2010. This work was constrained by the lack of a reliable and updated census of the local cheese producers. The several attempts to estimate the number of producers have given quite heterogeneous results (ranging from 40 to 150) due to the non-officially registered, sporadic and intermittent nature of their activity. Facing this, we constructed our database in the following way: in a first step we interviewed the thirty-five prominent cheese producers identified by Martinez et al. (2009). Through several name generator questions, the respondents had to name other cheese producers they knew. In a second step, the new producers were incorporated into the database and thus interviewed in subsequent stages. Consequently, we constructed a snowball process (Scott, 2000) that ended with 66 respondents and 12 non-participants. We checked it with a local expert who confirmed that all the prominent producers were present in the database. We systematically interviewed the manager of the quesería. Given the small size of most of the exploitations, the manager is also directly involved in the cheese production process and its commercialization. The structured questionnaires were designed to obtain information on three main subjects: *i)* demographic information on individual features of each cheese producer, *ii)* their involvement with other cheese producers in a collective organization such as UPLA, and *iii)* the set of relations of different natures that cheese producers have with each other.

The relations existing between two cheese producers in Aculco can be of very different nature. In order to capture the strength of social capital, we focus on three main types of relations: production, family and friendship. A production relation between two cheese producers exists when they have shared some equipment or input for cheese production and distribution in the last two years. In this sense, long term agreements do not exist in Aculco. Production relations are only transactions that cover daily production adjustments. A family relation between two producers exists when they belong to the same family. Two actors belong to the same family if they are close relatives, i.e. first and second order relatives. Finally, two cheese producers have a friendship relation when they declare to be friends. We consider them as friends if they spend part of their spare time together. In all three cases we consider links as non-directed. A relation between cheese producers j and i exists when at least j or i has declared its existence.

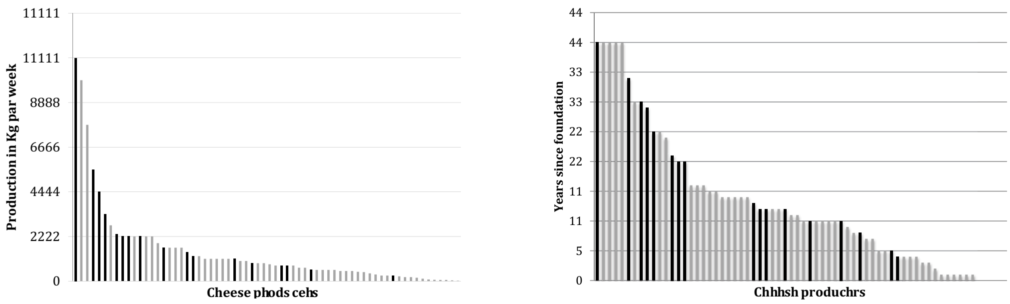
Additionally, to get an institutional view of the context and local project of development, we run three semi-structured in-depth interviews with key local institutional actors directly involved in the cheese production sector: *i)* the president of UPLA, who is also a cheese producer, *ii)* an expert from the agency for rural development of Mexico State, Sedagro, and *iii)* a member of the local government.

Table 5.2: Mean of production and age of Aculco cheese producers

	Av. size	Av. age
UPLA cheese producers	2233 kg/week	17.9 years
Non-UPLA cheese producers	1120 kg/week	11.2 years

Figure 5.2: Characteristics distribution of Aculco cheese producers

(a) Size (b) Age



5.5. A social network analysis of cheese producers in Aculco

5.5.1. Basics on network methods

Social networks theory is largely used in sociology and organization science for theorizing striking patterns of individual behaviors and social structures (Ahuja et al., 2012), and enhancing the empirical methods for capturing such patterns. According to Gorgoni and Pietrobelli (2010), Giuliani and Pietrobelli (2011), and Spielman et al. (2011), social networks analysis becomes nowadays a powerful methodology to evaluate the degree of the collective efficiency of clusters in developing countries. Following this argument, our purpose is to show that this methodology gives interesting insights in order to value the strength and extent of collective action, in particular for whoever wants to assess more formally the role of social capital and social embeddedness in the collective activation of local resources.

5.5.2. Descriptive statistics on the Aculco cheese producers networks

Table 5.2 and figure 5.2 summarize the mean and distribution of the individual characteristics of Aculco cheese producers in terms of size and age. Figure 5.3, representing the family, friends and production networks, gives a first appraisal of the social structures of Aculco cheese producers. The existence of multiplex relations has been theoretically identified as a critical parameter of social capital because it allows us to understand how different kinds of relations overlap or dissociate.

Firstly, the family network is composed by a central and dense core of producers belonging to the same family, while isolated farmers and a small share of dyadic and triadic family relations gravitate at the periphery. Moreover, UPLA members belong for a large part to the central family core.

Secondly, the friendship network has quite a different structuring. Even though many cheese producers remain isolated in the friendship network, it shows a higher level of connectedness compared to the family network. Consequently, information can be disseminated more widely than in the family network where closure is predominant. Compared to the family network, UPLA members display a weaker degree centrality. Nevertheless, it is surprising to observe the weak level of triadic closure inside the friendship network. Closure is a regular pattern of friendship networks in sociology (Coleman, 1988), since trust and commitment are more likely with mutual friends, as noticed by Granovetter (1992), for whom "*My mortification at cheating a friend may be substantial even when undiscovered. It may increase when a friend becomes aware of it. But it may become even more unbearable when our mutual friends uncover the deceit and tell one another*" (Granovetter, 1992, p.44).

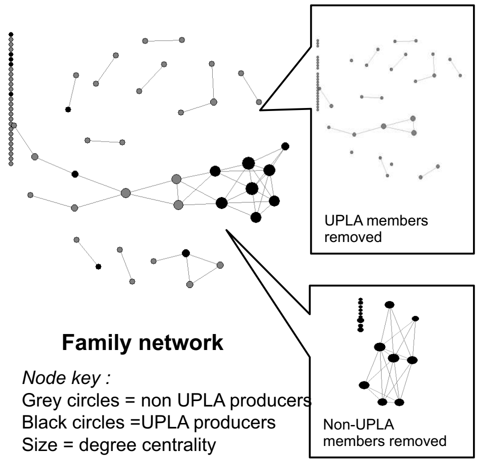
Thirdly, the production network is featured by a higher level of connectedness because it has few isolated cheese producers and a continuous reachability among the others. Most UPLA members occupy a central position in the production network. Although UPLA members are less numerous in proportion to the overall demography, they play a key-role in the structuring and "continuity" of cooperative behaviors in the production network.

More precise observations can be carried out using simple and key network descriptive statistics that highlight the main structural properties of social networks in the community (table 5.3). Firstly, UPLA members represented 25.75% of the Aculco cheese producers community in 2010, recalling that this share has decreased since the creation of the collective action framework in 2004. Density is a basic measure of the relational thickness of networks[4]. Here the production network displays a weak number of isolates and a higher density (3.45%) than the family and friendship networks taken separately, which display close levels of density (around 2.1%). But the remarkable observation relies on the fact that UPLA members concentrate 43.48% of the family relationships. One did not expect such a high figure considering the number of UPLA members. Besides, they represent only 15.56% of the friendship relationships.

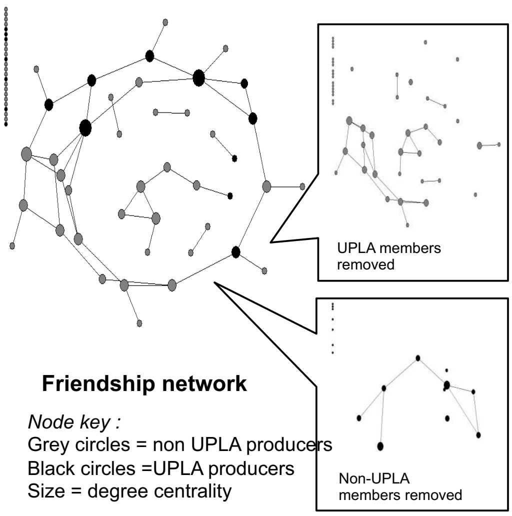
[4]Considering L the number of links and N the number of nodes, network density is defined by $D = L/(N(N-1)/2)$

Figure 5.3: Family, friendship and production networks visualization

(a) Family network



(b) Friendship network



(c) Production network

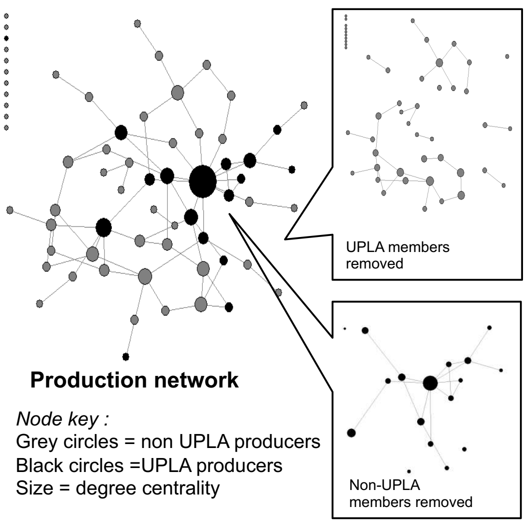


Table 5.3: Networks statistics and structural properties

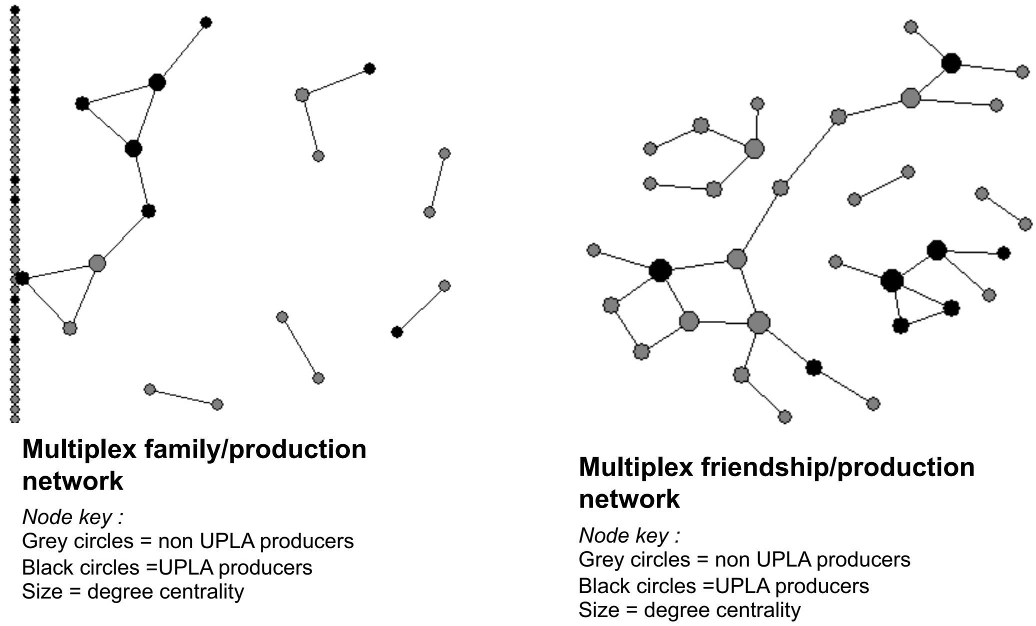
	Family network	Friendship networks	Production network
Number of nodes	66	66	66
-UPLA members (%)	17 (25.75%)	17 (25.75%)	17 (25.75%)
Number of links	46	45	74
-Between UPLA members (%)	20 (43.47%)	7 (15.56%)	18 (24.32%)
Density	0.0214	0.0210	0.0345
Isolated nodes	27	24	9
-UPLA members (%)	(5)	(7)	(1)
Giant component (% of nodes)	16 (24.24%)	27 (40.91%)	52 (78.79%)
-UPLA members (%)	9 (56.25%)	8 (25.63%)	14 (26.92%)
Clustering coefficient	0.504	0.124	0.086
-of UPLA network	(0.838)	(0.467)	(0.331)
Share of transitive triples	0.5909	0.0769	0.0714
-in UPLA network	(0.7416)	(0.3333)	(0.2308)
Mean degree	1.394	1.364	2.242
-in UPLA network	2.353	0.824	2.118
Minimum degree	0	0	0
Maximum degree	7	5	12
Average in betweenness score	-	14.126	57.805
-for UPLA members	-	24.472	129.679

Secondly, the above observed network connectedness and "continuity" of social relations find here a more quantitative appraisal through the weight of the giant component of each network. The giant component is defined by the group of nodes which are linked to each other by at least one path of intermediaries (Moody and White, 2003). The size of the giant component decreases from the production network to the family network, meaning that connectedness is higher in the production network than in the family and friendship ones, so that neither strict relations nor causality can be done at this stage between social structures and cooperation in production activities.

Thirdly, clustering coefficients and shares of transitive triples provide information on the degree of closure within the cheese producers' community of Aculco. Given that social networks have a strong tendency to shape more clustered groups (see proposition 5.3.2), the clustering coefficient measures the degree to which actors in a network tend to group together (Watts and Strogatz, 1998). The share of transitive triples is a measure of triadic closure. A triple exists when a tie between i and j, and a tie between j and k, imply a tie between i and k. Both measures show a decrease of closure from family network to production network, friendship network being in an intermediary situation. The closure scores among UPLA members are systematically higher. The high score for the family network is a regular pattern for this peculiar kind

Figure 5.4: Multiplex networks visualization

(a) Family-Production networks (b) Friendship-Production networks



of social structure. But for the friendship network, the weak score is surprising, even if it grows when only UPLA members are considered. Theoretical arguments suggest that a weak closure finds explanations in a lack of trust within the community, which can account for the weak degree of cohesiveness in the friendship network.

Finally, descriptive statistics provide information on the distribution of influence and power in the social structure of the Aculco community (see proposition 5.3.3). The mean degree of UPLA members of the family network is strongly higher than the mean degree of the family network in the community as a whole. The opposite may be observed for the friendship network. These two opposite patterns imply a more balanced situation in the production network since the influence of UPLA members, measured by their mean degree centrality, is close to the mean degree in the whole of the community. Nevertheless, UPLA members have a stronger power of in-betweenness centrality in the production network, meaning that they display a stronger ability to connect together un-connected producers than non-UPLA members (more than in the friendship network)[5]. The average in-betweenness score underlines the high level of disconnection of the production network when UPLA members are removed, as shown in figure 5.3.

[5]For a particular node k in a network, the in-betweenness centrality of k is measured by $g(k) = \sum_{i \neg j \neq k} \frac{\sigma_{ij}(k)}{\sigma_{ij}}$, where σ_{ij} is the number of shortest paths between i and j and $\sigma_{ij}(k)$ the number of these paths passing through k

Table 5.4: Multiplex networks statistics

	Production network		Production network		Production network	
	Links	Share	Links	Share	Links	Share
Production	-	-	15	32.61%	33	73.33%
Family	15	20.27%	-	-	0	0%
Friendship	33	44.59%	0	0%	-	-
Pure	27	36.39%	30	65.22%	12	26.67%
Total	74	100 %	46	100 %	45	100%

If we now focus on the interplay between these networks (see proposition 5.3.1), we can study the degree of overlapping between family and production networks on the one side, and friendship and production networks on the other side. As a matter of fact, the UPLA framework of collective action relies on the cooperation between producers towards the improvement of cheese quality. So it becomes important to detect if upstream the collective action, the well-connected network of production matches better with one network than with the other.

The results are displayed in figure 5.4 and table 5.4. Unexpectedly, the degree of overlapping strongly differs from one another, with a higher degree between production and friendship networks. 44.59% of the relations in the production network rely on friendship relations, meaning that 73.33% of friendship ties are also production ties. These scores dramatically decrease for the family network, giving ambivalent explanations on the role of the family embeddedness on the collective action. The adherence to UPLA is strongly linked to the core component of the family network, but without highly visible counterpart in terms of cooperative relations in the production activities. And as expected, due to a higher density of the production network, more than one third of cooperative relations in production (36.38%) are not coupled with any other social relations, meaning that a significant part of productive relations are unrelated to social relations.

These simple descriptive statistics highlight the social structures of the community and open the black box of social capital. They allow us to identify interaction patterns between these different types of networks, as well as the particular positions of UPLA members in the overall structure of relationships. On the one hand, a strong share of UPLA members belongs to the core component of the cohesive family network. And at the same time, UPLA members have a strong power of structuring within the production network, since they participate to its high connectedness. On the other hand, this strong family embeddedness goes with an opposite pattern in the friendship network (the quasi absence of clustering and triadic closure in the friendship network), whose ties are mainly among non-UPLA members. Therefore, even though it is impossible to infer causal relations between adherence to the collective action and social capital at this stage, the multiplexity of networks and the study of their structural properties provide crucial information on the connectedness dimension of social capital and the complex patterns of interaction that typify it.

5.6. An empirical test on the critical factors of collective action adherence

Network analysis provides interesting tools and methodologies for a thorough observation of complex and multiplex dimensions of the social structures that shape a community. The above analysis has allowed going further the "rhetoric" of social capital by an in-depth analysis of the concrete forms of social relations that shape the community. But to have a better understanding of the reasons why cheese producers decide to stay-in, stay-out or exit the framework of UPLA, one has to disentangle the explanatory variables through an econometric test. Therefore, the following test will try to capture the structural determinants at play in the adherence to a particular collective action, also introducing individual control variables, as it is required in network-based econometric tests (Ahuja et al., 2012). The multinomial regressions presented below show that the decisions of cheese producers to stay-in, stay-out or exit UPLA are not just a matter of "being connected", the nature of connections being also important.

5.6.1. Variables

Dependent variable. Section 5.2 discussed that the existing definitions of collective action tend to underline several common elements: *i)* it needs the involvement of a group of people, *ii)* with a shared interest, and *iii)* a common action towards that interest (Meinzen-Dick et al., 2004). In that sense, UPLA is the only existing initiative to institutionalize a collective action among the cheese producers in Aculco. UPLA gathers together several cheese producers with the common interest of improving the quality of their cheese, and working together for the construction of several common infrastructures to reach this quality improvement.

The issue of collective action success measurement is a complex one. In that respect, we adopt a minima criterion based on the number of concerned actors, i.e. cheese producers, who have joined the UPLA initiative. The data analysis shows that from the 32 members who initially joined UPLA in 2004 only 15 remain, and from the 21 cheese producers who started their activity after 2004, only 2 joined UPLA (table 5.1). In order to analyze the factors at play in the stay-in, stay-out or exit decision, we collected data on the UPLA status of each cheese producer in 2010. For each producer we coded a discrete variable, *UPLA_status*, with three categories. On the one hand, some cheese producers have not ever been UPLA members (coded with 0). On the other hand, some cheese producers are used to be members and decided to leave UPLA (coded with 1). Finally, some cheese producers are UPLA members (coded with 2, reference category).

Independent variables. Following our theoretical arguments, we use simple network measures derived from the production network, family network and friendship network. They are used as independent variables to explain the commitment of cheese producers in the UPLA collective action. The first variable, *Production Centrality*, measures the number of production relationships each cheese producer has, i.e. the cheese producer degree centrality in the production network. This variable enables us to take into account the position of each actor in the self-organized system of production in Aculco. The second variable, *Family Rel in UPLA*, measures the number of family links that an actor (being or not in UPLA) has with UPLA members. Similarly, the third variable, *Friend Rel in UPLA*, counts the number of friendship relationships that an actor (being or not in UPLA) has with other cheese producers adhering to UPLA.

Controls. We include several control variables at the individual level, i.e. variables referring to the own features of the cheese producers. According to table 5.2, we control cheese producers' prominence by their size or their historical relevance. Consequently, we include the size of the quesería measured by the log of kilos of cheese produced per week. Additionally, we add age (*Age*) and quadratic age (Age^2) of their foundation. Finally, we control the individual effort done by a cheese producer to improve the quality of his production or to create a new product: cheese variety or milk derivative. The dummy variable *Experimentation* takes the value 1 if the cheese producer has done any effort in that sense in the last two years, and 0 otherwise.

5.6.2. Model specification

To explore the reasons why UPLA fails as an organized collective action, we model the status of Aculco cheese producers according to their UPLA membership in the year 2010, i.e. seven years after its foundation time. We use a multinomial logit specification. The latter is suitable since our dependent variable is a discrete one with more than two categories. The Hausman-McFadden test shows that our data verify the independence of irrelevant alternative assumption ($p>0.5$ for each of the three alternatives). We run all analysis in R.

5.6.3. Results

Table 5.5 presents the descriptive statistics and correlation for each variable. Their values are relatively low. The exceptions are the intermediate correlation between production centrality and family relationships in UPLA, as well as friendship relationships in UPLA. We computed the variance inflation factors (VIFs) to check if multicollinearity was present, but we found that it is not a problem for our regressions. To compare the models we use the log-likelihood and the McFadden R2.

Table 5.6 presents the results using category 2 (UPLA member) as reference category. Model 1, the baseline model, includes the control variables about the individual features of cheese producers. Model 2 and model 3 include the structural position of each actor. Finally, model 4 represents the full model. As we go from model 1 to model 4, the model quality of adjustment improves.

Table 5.5: Descriptive statistics and table of correlations

		Mean	Std. Dev	Max	Min	1	2	3	4	5	6
1	logSize	1332.833	1867.589	10000	15						
2	Age	12.955	11.236	40	0	0.3273					
3	Age^2	293.439	447.534	1600	0	0.2658	0.9495				
4	Experimentation	0.576	0.495	1	0	0.1036	0.2454	0.2462			
5	Production Centrality	2.242	1.896	12	0	0.3740	-0.0038	-0.0233	-0.0233		
6	Family Relations in UPLA	0.773	1.717 7	0	0.2476	0.1179	0.1080	0.1080	0.4052		
7	Friends Relations in UPLA	0.439	0.763	3	0	0.2158	0.1189	0.1189	0.4311	-0.0745	

Table 5.6: Multinomial logit models of UPLA status

	Model 1		Model 2		Model 3		Model 4	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
0:(intercept)	11.0112***	(3.4310)	16.7920***	(5.1204)	22.5554***	(7.2167)	26.8306***	(8.5932)
0:logSize	-1.1383***	(0.4387)	-0.9138	(0.5809)	-1.1781*	(0.6926)	-0.8476	(0.7520)
0:Age	-0.4419***	(0.1516)	-0.7917***	(0.2523)	-1.3623***	(0.4705)	-1.6961***	(0.5726)
0:Age^2	0.0087**	(0.0034)	0.0143***	(0.0051)	0.0276***	(0.0099)	0.0328***	(0.0118)
0:Experimentation	1.0471	(0.8582)	1.1283	(1.0813)	1.4613	(1.3650)	1.9908	(1.5675)
0:Prod. Centrality			-1.7923***	(0.5397)			-1.6373**	(0.6898)
0:Family Rel in UPLA					-3.3528**	(1.6647)	-3.0057*	(1.6956)
0:Friends Rel in UPLA					-2.9773***	(1.0991)	-2.7927**	(1.2276)
1:(intercept)	3.8884	(3.1264)	6.2806	(4.0489)	13.8229**	(6.4568)	15.5210**	(7.4371)
1:logSize	-0.7408*	(0.4071)	-0.6351	(0.5068)	-0.8887	(0.5604)	-0.6757	(0.6132)
1:Age	0.0716	(0.1604)	-0.1009	(0.2092)	-0.6703	(0.4162)	-0.8679*	(0.5036)
1:Age^2	-0.0015	(0.0035)	0.0015	(0.0043)	0.0143	(0.0089)	0.0176*	(0.0106)
1:Experimentation	1.1323	(0.7827)	1.3478	(0.8597)	1.4429	(1.1816)	1.9329	(1.3052)
1:Prod. Centrality			-0.5519	(0.3445)			-0.5412	(0.4240)
1:Family Rel in UPLA					-1.6264**	(0.6800)	-1.6262**	(0.7080)
1:Friends Rel in UPLA					-1.7893**	(0.8197)	-1.6670*	(0.8712)
N	66		66		66		66	
Log-Likelihood	-47.799		-37.926		-31.841		-27.93	
McFadden R^2	0.3101		0.4526		0.5404		0.5969	

Robust standard errors in parentheses. * $p < 0.10$. ** $p < 0.05$. *** $p < 0.01$

Model 1 shows that *age* and *size* are significant variables to explain why a cheese producer has never joinned UPLA. Being a big producer reduces the probability of being excluded from UPLA. Similarly, young queserías have a higher probability of being excluded from UPLA. However, in this case the effect is not linear. Young queserías founded after the creation of UPLA have a higher probability of being excluded, but the negative effect of age over UPLA adherence is decreasing. The effect slows down, in particular when the creation of the quesería is prior to the foundation of UPLA. Model 1 also shows that in the case of farmers who decided leave UPLA, *age* is not significantly different. Although *size* is significant, its coefficient is much less important. Having a higher production per week reduces the probability to exit UPLA by comparison with the reference category.

In order to test our propositions, model 2 adds the variable relying on the cheese producer embeddedness in the network of production exchanges. The introduction of *Production Centrality* does not change the conclusions as regards *age* and *experimentation*, but now the *size* variable becomes insignificant for both members who have never been in UPLA, and for members who have left it. However, the influence of *Production Centrality* in 0 and 1 categories is not the same. *Production Centrality* is strongly significant for cheese producers that have never been in UPLA. On the contrary, *Production Centrality* does not produce any significant difference between former UPLA members and current UPLA members. The above results show that the cheese production units that have never joined UPLA are recent, small and peripheral in the structure of productive relationships. However, since size, age and production centrality for category 1 are not significant, we can conclude that the stay-in/exit pattern of cheese producers is not based on their individual features and their embeddedness in the production network.

Model 3 adds the multiplex considerations of our propositions and considers friendship and family relationships instead of production relationships to explain the UPLA status of cheese producers. The conclusions as regards the individual features of cheese producers (*size, age* and experimentation) do not change, but from the relational perspectives, results are quite different. Either friendship or family relationships with UPLA members significantly influence the probability of being a UPLA member. In particular, having an additional friendship or family relationship with a UPLA member strongly diminishes the probability of being excluded from UPLA. In the same sense, model 3 shows that an additional friendship or family relationship with a UPLA member strongly reduces the probability of exiting UPLA.

From these results, we infer that although all prominent cheese producers in Aculco were initially invited to take part in the UPLA initiative, finally only did the ones linked with strong social relations such as family and friendship remain. The personal logic has dominated the production logic. The full model 4, with the best adjustment indicators, confirms these results. In comparison with UPLA members, the reason why some producers never joined UPLA lies in the fact that their prominence in the production network and their embeddedness in the family and friendship networks were too weak. On the contrary, the exclusion of cheese producers that were once in UPLA and decided to exit is based on their under-embeddedness in the key family and friendship networks, but not in the production network. In other words, incentives to remain in UPLA are more influenced by personal pressures, such as clannish behaviors, than the actual participation in the production network.

5.7. Discussion

In 2011, at the end of the study, the pasteurization plant was not built and after all the meetings between the remaining UPLA members, the collective trademark was far from being elaborated. The mixing of network analysis and econometric test provides interesting findings for a discussion on the reasons why the UPLA initiative has not reached the expected objectives. The most striking finding relies on the critical factors able to explain the weak and decreasing degree of adherence to the collective action. As a matter of fact, the study of the production network has shown that the community displayed a high degree of connectedness in production relationships, with a weak amount of isolated cheese producers and a continuity of cooperative behaviors in the community, measured by the size of the so-called giant component of the network. One might have expected such network properties to be an incentive to join the collective action. That is not directly what the empirical test confirms. On the one hand, models 2 and 4 show that increasing the probability of being central decreases the probability of never joining the collective action. But on the other hand, there is no significant effect for members who have left UPLA compared to remaining UPLA members, meaning that the decision to “play alone after playing together” is not negatively influenced by the position in the production network. Then centrality and power in the production network remain more important than the simple connectedness only for farmers who have not yet joined the collective action. As theoretically suggested, when some actors exhibit a high level of centrality, coordination works better between connected actors, but with a high risk of entry barriers for potential newcomers.

Moreover, the multiplex dimension of networks brings additional explanations on the probability to stay-in, stay-out or exit UPLA, confirming our theoretical proposition on the significance of multiplex social structures for a successful collective action. One should bear in mind that descriptive statistics on the multiplex family/production network displayed a weak degree of overlapping between family relationships and production ones, while the family network is typified by a highly cohesive structure of members that had joined UPLA. This observation invites us to consider the interaction between the incentives to join or exit the collective action as regards the actual involvement in the network of cooperation in production activities and the degree of family embeddedness. Models 3 and 4 display interesting results for that purpose, since it clearly appears that as regards the likelihood to stay in UPLA, decreasing the number of family relationships with UPLA members dramatically increases the probability to stay out UPLA. More outstanding, the causality remains true for the probability to exit UPLA. These findings confirm our theoretical predictions on the ambivalent role of closure and bonding social capital. The structural properties of cohesiveness and closure of social networks such as family ones are on the one side a source of loyalty, trust and collective commitment; but on the other side, when these structures display discontinuities and dominant cohesive groups, it can also be a cause of discrimination and clannish behaviors. In this respect, our findings converge with the qualitative evaluation of the Aculco cluster by Espinosa-Ayala et al. (2010), and more generally, with the findings of Boucher (2004) and Correa et al. (2006) in other agri-food clusters in Latin America.

Finally, one might have expected the friendship network to be a counterweight to the disincentives produced by the exclusiveness power of the family network. Nevertheless, the results remain unchanged when friendship is taken into consideration (Models 3 and 4). For outsiders and exiting members compared with those remaining insiders, the probability to join or re-join UPLA increases with the number of UPLA friends. But as confirmed by the very peculiar structural properties of the friendship network, this result is not so noteworthy. On the one hand, we have stressed the surprising form of this network with regards to the regular patterns of friendship structures. As a matter of fact, the friendship network being typified by a very weak level of closure, it is likely that the resulting weak level of trust and cohesiveness reduces incentives for cheese producers to join (or re-join) the collective action. On the other hand, the closure of friendship increases when only UPLA members are considered, so that a small window of clannish behaviors remains within the group of people that have already joined UPLA.

These findings corroborate the initial feeling perceived along the interviews, during which some positive comments but also recurrent defiant words on cooperation and UPLA benefits appeared. According to a farmer who has left UPLA, "*there were good intentions in UPLA but a few have tried to use it to their own advantage*". Another confirms: "*I was member but I decided to quit because family people that had nothing to do with production began to enter*". Rather than an exception, this example of "elite capture" is common across clusters in the developing world[6]. The leading producers in Aculco, closely related in a family clique, come together to access support and investment from institutions. Other members of the production network do not perceive any benefits from UPLA membership due to the exclusionary nature of the family ties. The problem of elite capture is clearly perceived by some farmers according to whom "*It is a scam! The owner is going to take everything. I do not want problems*", and "*They made an association but it is for personal profit*". These family pressures are also reinforced and thus not counter-balanced by the very weak level of trust and closure in the friendship network: "*Trust is missing. We do not say the truth even among us*"; or "*Everybody knows each other and they cheat on prices and efficiency. Nobody tells the truth*". Moreover, some farmers that had never joined UPLA or exited the association mention the high entry fees: "*Although I was invited I have never gone to a meeting. After that I could not enter anymore because they charge 30000 pesos and I do not have that money*"; or "*I was in UPLA but I quit because they charge too much money. In each meeting they ask for more. It was the reason why many people quit*". If this entry fee might appear as an excessive transaction cost for the success of the collective action[7], the reasons why some of the farmers did not want to pay for UPLA are more due to a shady management of the money than to the amount of money in itself, as confirmed by some of the farmers: "*The accountancy is not clear because there is a bad administration*", or "*They made an association but it is for personal profit*", or "*The administration of UPLA is bad. It is the shady company of X*[8]". Even though transaction costs for UPLA do matter, they matter less than the opaque behavior of the cohesive family structure that engenders mistrust and a strong disincentive to join UPLA.

5.8. Conclusion and policy perspectives

Since our study concerns a single case of collective action in a particular place of Latin America, it would be too ambitious to draw some general principles for rural development areas and policy implications on Local Agri-food Systems in developing countries. Nevertheless, our findings suggest taking into caution the "celebratory tone" (Portes, 1998) of the positive role of social capital on collective actions, as it also suggests that social capital is a fuzzy concept that requires investigating more deeply the complex and multiplex dimensions of social networks. Firstly, considering that connectedness is

[6]We thank one of the referees for suggesting associating our findings about clannish behaviors to the typical phenomenon of elite capture observed in the literature.

[7]We thank one of the referees for suggesting linking transaction costs with social structures for a better understanding of the entry barriers.

[8]"X" is the first name of the most central cheese producer, who is also the executive of the association.

a key-dimension of the strength of social capital, we have highlighted the main structural features and overlaps of the different social networks in which Aculco farmers are involved. This leads us to discuss the level of continuity in cooperative behaviors and exchanges among the cheese producers given the existing structure of power and influence. Secondly, we have introduced this multiplex dimension of social structures in a quantitative empirical test in order to find more accurate explanations on the role these social structures play on the incentives (or disincentives) to adhere (or not) to the collective action. As a result, our analysis clearly suggests that if social networks can foster collective actions, the reverse can also be true, under certain conditions of structural properties.

For this case study, local policy makers might have interest in trying to disseminate within the community the benefits of collective action by relying on the professional network – here the production network – and by avoiding the excessive pressure of the small family clique, which turns the benefits of the collective action towards its own interest. This case study also recalls the difficulty to find the proper cursor between strict frameworks of collective action and more loosely-monitored ones. As a matter of fact, the current failure of UPLA, after a promising start, is not the consequence of unrealizable objectives for cheese producers. It even remains crucial for them to reach the quality standards and product qualification required by the evolving market conditions in developing countries. To that end, one has to go beyond the idea that social networks are self-sufficient, by setting more formal institutional devices that control the risks of power asymmetries and entry barriers and make up for the lack of incentives. The development of “innovation brokers” (Klerkx and Gildemacher, 2012) perfectly fits with this strategy[9]. The regeneration of UPLA in the future should be based on the entry of such brokers in the program, who would act as systemic intermediaries in order to reduce conflicts, restore trust and monitor the development of the project with a higher level of transparency. Beside both technical and strategic know-hows, this or these brokers need to be legitimated in the eyes of the Aculco farmers by a clear third-party and independent position, free of any pressures some of the farmers could be able to exert.

This study might be developed to follow the evolution of this community in a longitudinal analysis, and the methodology might be extended to other communities and other forms of collective action. But at this stage, network structural properties and multiplexity would offer promising perspectives for whoever wants to enrich the empirical analysis of clusters in developing areas.

[9]We thank one of the referees for suggesting this crucial policy implication.

Conclusion

The main objective of this thesis was the identification of network structural properties for dynamic performance of clusters. This is, the features of network structure enhancing the capacity of clusters to extend their life cycle by establishing technological lock-in and constructing new paths for regional lock-out. Thus, this dissertation has adopted a network approach of clusters. We have focused on the relations between actors in the cluster to identify structures of interaction whose diverse forms affect cluster long term dynamics.

We have combined network theories and evolutionary economic geography insights to study the interplay between the regional and the technological/industrial dynamics behind cluster evolution. We have applied our theoretical reflexions to two different contexts. On the one hand, the mobile phone technological domain in Europe, i.e. a high-tech sector in developed countries. On the other hand, the production of cheese in Aculco (Mexico), i.e. a low-tech sector in a developing country. The main result of the work presented here is that the particular structure of knowledge, production and social networks affects the cluster long term dynamics.

Main results and implications

This thesis contributes to develop a framework that integrates relational approaches and network theory with cluster life cycle analysis. In fact, this thesis extends the literature on cluster life cycles by introducing the network structure dimension. Firstly, the literature on cluster life cycles has analyzed factors such as *i)* entry/exit dynamics (Klepper, 1996), *ii)* the evolution of agglomeration economies particularly referring to knowledge flows (Audretsch and Feldman, 1996a; Neffke et al., 2011b), *iii)* the balance between homogeneity and heterogeneity of actors cognitive bases and their relatedness (Menzel and Fornahl, 2010; Neffke et al., 2011a), and *iv)* the shifts on competition and innovation (Abernathy and Utterback, 1978; Utterback and Suárez, 1993; Audretsch and Feldman, 1996a), while the consideration of network structures along the cycle has remained relatively unexplored, with the notable exception of ter Wal and Boschma (2011). Secondly, the literature on networks and clusters has focused on structures favoring competitiveness and innovation (Owen-Smith and Powell, 2004; Fleming et al., 2007). Our contribution bring closer both streams of the literature. On the one hand, we add network structure as an additional factor to understand cluster life cycles. On the other hand, we extend the literature on networks and clusters by studying structural properties for dynamic performance of clusters, i.e. we go beyond the static competitiveness view.

Thus, we stress the importance of relations as unit of analysis to understand economic geography phenomenons (Bathelt and Glücker, 2003; Boggs and Rantisi, 2003; Sunley, 2008; Boschma and Frenken, 2010). It let us extend the analysis beyond the individual attributes considerations to integrate the relational behavior of actors. In this dissertation we go one step further, we study the structure emerging from the aggregation of individual relations. We defend the idea that networks with the same organizations but with different relational mechanisms may exhibit different structural properties, and this influences performance in the short and long term. Thus, the micro-macro transition is not only an additive property, i.e. networks resulting of organizational interaction exhibit properties that are different from the sum of the parts.

The second contribution of this thesis goes in this direction. We identify two network properties that favor the cluster long term viability: hierarchy and disassortativity. The combination of both conducts to a cluster life cycle extension, because they contribute to associate and dissociate industrial and cluster cycles at the right moment by establishing and maintaining technological lock-in while enabling regional lock-out. On the one hand, hierarchy favors the coordination in complex systemic processes of innovation. On the other hand, disassortativity or structural heterophily multiplies the connexions between the core and the periphery to bring novelty. The understanding of these properties let us extend the debates of the popular small world networks (Watts and Strogatz, 1998; Uzzi and Spiro, 2005; Fleming et al., 2007). Networks simultaneously exhibiting hierarchy and disassortativity may also have small world properties. However, the explicit consideration of hierarchy and disassortativity let us better integrate industrial organization issues and their change (Abernathy and Utterback, 1978; Utterback and Suárez, 1993; Klepper, 1996, 2002). Moreover, network hierarchy and structural homophily/heterophily may bring light on the understanding of industrial relatedness and its construction (Boschma and Frenken, 2009; Neffke et al., 2011a), one of the basic concepts to explain change in economic geography.

This effort to introduce social network analysis in clusters has also produced an original contribution on the collective action literature in localized agri-food systems. We contend that the study of actors adhesion (or not) to collective projects should not only consider individual cost-benefit calculations, it is also contingent on the adhering behavior of other actors with whom he interacts at different levels. Social network analysis let us show how certain groups of actors, based on certain type of relations (family or friends), may construct exclusion mechanisms of actors not belonging to this group. Even if their embeddedness in other types of relations legitimizes, *a priori*, their adhesion. The use of multiplexity analysis may shed additional light on the ambivalent effects of social capital and performance.

Finally, our study of clusters from social network perspective has been source of several contributions of methodological nature concerning measures, methods and data treatment. The first and most important one concerns the development of two measures for hierarchy and structural homophily. On the one hand, we propose to use degree distribution to measure the level of hierarchization of the network. It is calculated as the slope of the degree-rank relation, where higher slope (in absolute terms) implies more hierarchical networks. On the other hand, we propose to use degree correlation as a measure of structural homophily. It is calculated as the slope of the relation between nodes degree and the average degree of the actors in his neighborhood. Positive slope (getting closer to one) means that the network is assortative. Negative slope (getting closer to minus one) means that the network is disassortative. A second methodological contribution concerns the use of multiplexity relations. Actors in clusters may construct linkages of different nature. So, among the same set of actors different network structures may emerge depending on the type of relations we focus on. This thesis has originally proposed to look at the interplay and overlapping between these different networks to understand success and failure of collective action processes. Thirdly, this dissertation proposes an alternative way to define transversal technological domains. The growing number of uses associated to mobile phone handsets makes it difficult to assign it to a limited number of standard industrial classes. Therefore, we use an alternative strategy for patents and projects selection based on key words associated to the mobile phone technological domain. To do so, we use boolean operators to combine some generic key recursive words, with other specific ones associated to particular mobile phone layers. Finally, this dissertation proposes a way to deal with cluster identification issues that constraint systematic cluster studies. From the global network of the technological domain we identify clusters by their increased relational density. Thus, clusters are not supposed but revealed.

Policy implications

Clusters have been seen as a source of growth and regional development. Consequently, regional, national and international governments and institutions have been quite productive in the elaboration of programs and guidelines to support clusters development (OECD, 2007a,b; European Commission, 2008, 2009). This thesis does not have policy issues as a primary concern, but the outcome of our reflexions may have interesting policy implications, although further development is needed. Based on the well established principle that innovation is an interactive process, policy makers have usually focused on univocal actions to increase density. However, this thesis has argued that performance it is not just a matter of density. The particular emerging structure is equally relevant, and we have shown that structures with different properties will show different performance. Consequently, we contend that policy efficiency gains can be obtained with more accurate or surgical interventions. On the one hand, performance of structures is sometimes hampered by some few but persistently missing links. On the other hand, policies boosting creation of relations in an undifferentiated way may result in the reinforcement of the existing non-performing structures. In both cases the consequence is an inefficient and costly allocation of resources. In this sense, this dissertation suggests the need of much more accurate interventions based on previous diagnostic of the cluster structural organization. From the network perspective there is no a single intervention mechanism to unconditionally increase relational density, but a diversity of tools that may be applied depending on the particular situation. The development of a framework for policy analysis of the network structure and the development of the appropriate tools in each case are interesting issues for our future research agenda.

Limits and further research

This thesis presents the firsts steps towards the understanding of the structural properties of networks for cluster long term viability. This work has obtained promising results, but it has also encountered several limits of different nature. Overcoming them opens new exiting research paths for the future, either in economic geography or in organizational science.

We have identified hierarchy (degree distribution) and assortativity/disassortativity (degree correlation) as important parameters to explain cluster dynamic performance, and our study on the European mobile phone sector confirms it. However, theoretical and empirical limitations push us to go further. From the theoretical perspective two drawbacks remain. On the one hand, we have studied both properties as independent from each other. On the other hand, although we have associated these properties to particular mechanisms of network growth and change, several network mechanisms co-exist. Consequently, emergent structures will never be in the pure extreme cases but in hybrid situations. Then, the development of formalized analytical models seems interesting for two reasons. Firstly, they may help to identify ranges of critical values for each of the two properties, as well as their interplay, for dynamic performance. Secondly, they may ground the development of simulation models to better grasp the link between relational mechanisms and network structures, i.e. the interplay between the dyadic level and the whole network level that let us go from network theory to a theory of network origin, and back. Simulation models may also be helpful to study the link between hierarchy, assortativity/disassortativity and dynamic performance by the progressive entry and exit of nodes.

From the empirical perspective, our results are constrained by data availability. We constructed networks from R&D public funded project co-participation. These data are useful because actors are organizations, because span a relatively long period, and because they represent an homogeneous definition of relation across several clusters. However, they also have some limits that call for further research to confirm our promising results. On the one hand, they represent only a short part of the whole number of relations in a cluster. On the other hand, they may be obviously biased by policy objectives. Finally, once we apply spatial and temporal division we get cluster network structures rather small, consequently the panel dimension is reduced, and this limits dynamic analysis. Thus, further empirical researches will increase our knowledge in this issue. These empirical works should diversify towards different industries, use data of different nature such as strategic alliances, and use different methodologies such as the above mentioned simulation models, or historical case studies.

This dissertation has emphasized the importance of network structures for cluster dynamics performance, and in particular, the role of two structural properties. However, by doing so, we have left aside organizational attributes. We have worked on several assumptions based on the literature to argue that peripheral organizations bring novelty and core ones benefit of market success and reputation. However, a more decided integration of organizational attributes (cognitive bases, organizational nature...) and strategic behaviors in the consideration of structural properties for dynamic performance of clusters seems necessary. Such an effort could be interesting to bring closer two dimensions of the cluster life cycle literature: network properties on the one hand, and the construction of relatedness through branching process on the other hand.

Finally, the discussion of this thesis around network structural properties has exclusively concerned local networks. We have acknowledged that local actors are embedded in a larger network that defines the global technological/industrial domain. However, we have not integrated these non-local relations as part of the discussion on structural properties. The study of this non-local dimension, by integrating multinationals and geographical gatekeepers, and how they may modify the structural properties of local networks is an additional extension to our results.

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Dynamique des clusters et économie géographique évolutionniste : essais sur la structure des réseaux et le cycle de vie des clusters.

L'objectif principal de cette thèse est d'étudier l'évolution des clusters. La littérature concernant les clusters s'est longuement intéressée aux raisons de leur existence ainsi qu'à la manière dont ils favorisent l'innovation, la productivité et la croissance. Nous étudions comment ces effets durent dans le temps, poursuivant l'objectif d'identifier les déterminants de la performance dynamique des clusters. Il s'agit, ainsi, d'expliquer pourquoi certains clusters déclinent tandis que d'autres continuent à fonctionner grâce à un renouveau constant. Cette thèse adopte une approche des clusters par les réseaux. Nous défendons l'idée que les structures de réseau hétérogènes des clusters démontrent des capacités différentes à s'associer ou à se dissocier des cycles industriels/technologiques au bon moment. Ainsi, nous identifions les propriétés de structure du réseau qui favorisent la performance dynamique des clusters ou la résilience des clusters. Nous appuyons nos développements théoriques sur des regards empiriques dans deux contextes bien différents. D'une part, nous étudions les structures des clusters de l'industrie de la téléphonie mobile en Europe. D'autre part, nous analysons la structure des relations entre les producteurs de fromage d'Aculco (Mexique). Le résultat principal de ce travail montre que la hiérarchie et la disassortativité des réseaux, ainsi que les interactions entre des réseaux de natures différentes (multiplexité), influencent la capacité des clusters à éviter les lock-in négatifs, conduisant à leur déclin, et favorisent le lock-out pour la survie du cluster, c'est-à-dire la prolongation de leur vie.

Mots clés: Structure de réseau, cycle de vie des clusters, résilience, action collective, économie géographique, téléphonie mobile.

Understanding clusters dynamics in evolutionary economic geography: essays on the structure of networks and clusters life cycle

The main objective of this thesis is to study clusters' evolution. The literature on clusters has widely studied why clusters exist and how they favor innovation, productivity and growth. Our concern is to study how these effects hold over time. Therefore, we aim at identifying the determinants of dynamic performance of clusters to explain why some clusters decline while others keep working by continuous renewal. To do so, this thesis approaches clusters from a network perspective. We contend that clusters with heterogeneous network structures exhibit different capacities to associate and dissociate cluster's evolution and industrial/technological cycle at the right moment. Thus, we identify the properties of network structures that favor dynamic performance of clusters or cluster resilience. We support our theoretical developments with empirical insights in two different contexts. On the one hand, we study the structure of clusters in the European mobile phone industry. On the other hand, we analyze the structure of relations between cheese producers in Aculco (Mexico). The main result of this work is that network hierarchy, network disassortativity and the interplay between different networks (multiplexity) influence the capacity of clusters to avoid negative lock-in leading to cluster failure, and favor lock-out to enhance cluster continuation, i.e. extending the life of the cluster.

Key words: network structure, cluster life cycle, resilience, collective action, economic geography, mobile phone industry.