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Abstract
The paper develops an evolutionary framework of regional resilience with a primary focus on the structural properties of local knowledge networks. After a presentation of the network-based rationales of growth and structuring of clusters, we analyze under which structural conditions a regional cluster can mix short run competitiveness without compromising long run resilience capabilities. We show that degree distribution (the level of hierarchy) and degree correlation (the level of structural homophily) of regional knowledge networks are suited properties for studying how clusters succeed in combining technological lock-in and regional lock-out. We propose a simple model of cluster structuring in order to highlight these properties, and discuss the results on a policy-oriented analysis. We conclude showing that policies for regional resilience fit better with ex ante regional 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.

Key-Words: Resilience, clusters, degree distribution, assortativity, regional policy

JEL classification: B52, D85, O33, R11, R12

1. Introduction

Literature largely acknowledges localized knowledge networks as a significant factor of regional performance in knowledge-based economies. Researches converge on the idea that some regions draw their performance better than others from their ability to home networks of complementary and interacting organizations (Lechner & Dowling, 2003; Owen-Smith & Powell, 2004; Graf, 2011). Largely evidenced, such a move toward a relational approach of regional performance (Boggs & Rantisi, 2003) has led, particularly in Europe, to a massive development of clusters policies based on incentives for collaboration and networks development (Martin & Sunley, 2003).

Nevertheless, behind this large consensus, few researches have pursued the questioning in direction to the long run evolution of regional innovative structures, except some very recent works. Papers of Suire & Vicente (2009), Simmie & Martin (2010), Menzel & Fornahl (2010), Crespo (2011), and Boschma & Fornahl (2012) constitute noticeable exceptions, as well as the mark of a burgeoning and promising research field for understanding how some performing regions can decline in a given moment of time while others are able to renew and sustain their growth in a disturbed economic environment. Such a questioning is nowadays of a growing interest as the macroeconomic context is featured 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 clusters life cycles are the key concepts that have recently invested this questioning. These concepts converge towards a common attempt: understanding the evolutionary process through which a regional ecosystem of organizations and institutions succeed in maintaining its growth path by disconnecting its cycle from the cycle of technologies when this later decline. Some regions can have difficulties to cope with technological and market decline, even if they were performing during the maturity stage, while some others reorganize resources and networks in order to leave a path for entering into a new related one. All these burgeoning researches try to go beyond a classical view of resilience as a mechanical return to the equilibrium after exogenous and external shocks. They attempst to capture the endogenous mechanisms of adaptability, viewed as the ability of the actors and their social agency (Pyke *et al*, 2010), to anticipate, evolve, and so adapt to disturbed and cyclic economic environments.

To deal with this questioning, we suggest to combine a multidisciplinary theoretical analysis that discusses the critical factors of network resilience, with an evolutionary economic geography framework (Boschma & Frenken, 2006; Martin & Sunley, 2007) that focuses on an out-of-equilibrium approach of regional science. Networks have been of a growing interest in social sciences since a couple of years (Borgatti & Halgin, 2011). They are at the heart of well-known theoretical researches in Sociology (Uzzi, 1997, Borgatti & Everett, 1999), Economics (Jackson & Wolinski, 1996), Geography (Glückler, 2007; Ter Wal & Boschma, 2009) and Management Sciences (Powell & Grodal, 2005), with a high level of absorption of results coming from physics and complex systems theories (Albert & Barabási, 2002; Newman, 2003). Considering that networks can be represented by a set of three basic primitives (the nodes, the ties that connect the nodes, and the resulting relational structure), networks theories give a simple but useful representation of social structures in a static sense, and are recently more 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. But on the other hand, networks have been central in many guidelines and white books for regional policies during the last years (OECD, 2007, 2009; European commission, 2008), and their weakness in certain regions has been interpreted by policy makers as the primary reason of their low performance. So although institutional, political, cultural as well as macroeconomic conditions matter for regional resilience, we focus on a better understanding of the network dynamics that have concentrated the attention of policy makers.

Our purpose is to draw simple but empirically testable signatures of local networks that give interesting properties for understanding the conditions of regional resilience. Section 2 discusses cluster's growth, structuring and properties, in the framework of the abounding literature on networks. Section 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 play simultaneously towards technological lock-in and regional lock-out. Section 4 proposes a simple and appreciative model of cluster structuring that highlights how these properties can play together. Finally, section 5 discusses the results and gives new insights for regional policies, confirming that network density is not the *panacea* of clusters policy (Martin & Sunley, 2003), and showing that more targeted and surgical interventions are more suited for regional resilience.

2. Clusters and network theories

2.1. A (too) short history of clusters analysis

Clusters, defined minimally at this stage as localized knowledge networks in technological and market domains, are nowadays viewed as a primary concept for competitiveness and growth policies. In Europe, since the Lisbon Agenda of 2000, clusters policies are one of the main tools for leading Europe towards "*the most competitive and dynamic knowledge-based economy in the world by 2010*"[1]. From guidelines diffusion (European commission, 2008) to the creation of a public funded European Clusters Observatory (European Commission, 2009), European Commission has convinced regional and national policy makers that competitiveness is highly correlated to the absorption of the "good practices" of clusters policies. Except some noticeable critical papers (Martin & Sunley, 2003), academic literature has viewed clusters as a source of regional performance in modern economies. This is particularly true since the empirical study of Saxenian (1994) on the Silicon Valley, and the cluster theory developed by Porter (1998), were published and largely diffused. Since then to nowadays, geographers, economists, sociologist and also specialists of network analysis and management scientists have converged against the idea that agglomeration economies arise only from market forces, and toward the idea that non-market interactions can give rise to a local web of knowledge flows that improves the regional competitiveness. Clusters become a multidisciplinary focus. Economists have converged or exchanged with geographers of innovation in order to understand how knowledge spillovers arise more from strategies of knowledge exchange rather than "in the air" knowledge flows (Breschi & Lissoni, 2000). Economic geographers have converged or exchanged with network sociologists by introducing social network analysis in regional systems of innovation (Ter Wal

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

& Boschma, 2009). And management scientists did the same by analyzing local organizational networks as a source of structural embeddedness that favors the production and diffusion of knowledge (Owen-Smith & Powell, 2004).

2.2. Clusters as knowledge structures

A cluster can be defined now 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). This relational structure can be represented under the form of a network, featured by structural properties that highlight the channels through which knowledge flows and the level of embeddedness of organizations. 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 or outside strategies of innovation over knowledge partnerships. In that case, the clusters are no more than the simple result of a co-location process. But at the opposite, clusters can display a high level of density when knowledge complementarities, trust and social proximity (Boschma, 2005), lead to high level of local cohesiveness. Variability of structural properties remains with a fixed level of density. Clusters can display a distribution of degree centralities from a flat to a sloped one. 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 (König *et al*, 2010). This later is generally linked to the size of the organizations, their absorptive capacities or the openness of their model of knowledge valuation. At the opposite, 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 captured generally by a network index of assortativity (Newman, 2003; Watts, 2004; Rivera *et al*, 2010). The structure of relations will be assortative (or disassortative) when highly connected nodes tend to be connected disproportionately to other high (weak) degree nodes. Then, the level of network assortativity gives a formal representation on the way by which knowledge flows between the core and the periphery and *vice versa*.

2.3. Clusters growth

Where the nodes and the ties come from? Network theories are very useful for analyzing clusters properties. But the emergence of these aggregate properties commonly studied in physical systems has to be founded on micro-economic behaviors, including rationality, strategy and decision externalities, instead of simple and myopic behaviors (Watts, 2007). In particular, these micro-foundations are necessary to understand how new entrants join a cluster, shape and reinforce or not its relational structure. Network theories point several drivers of networks formation. Two of them are extreme and simple cases of nodes entries and ties formation.

Firstly, networks can evolve through purely random attachment or at the opposite through a mechanism of preferential attachment (Albert & Barabási, 2002). Random attachment means that entering nodes connect randomly to others with no particular preference for their position in the structure. The randomness of the process will give rise to a rather flat hierarchy of nodes degrees when such a process prevails (Erdös & Renyi, 1959). In terms of location decision externalities and individual strategies, this kind of process can be associated to a locational cascade (Suire, Vicente, 2009). In locational cascades, new entrants draw pay-offs from the belonging to the structure as a whole and not from targeted connections to particular nodes in this structure. Locational cascades have been largely evidenced for clusters that attract new organizations from an external audience and a geographical charisma (Romanelli & Khessina, 2004; 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 here, 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 & 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 (Farell & Saloner, 1985). It is also consistent with the relational behavior of spinoffs that tend to connect to their highly connected parents company (Klepper, 2010)

2.4. Cluster structuring

Beyond nodes entry, clusters structure themselves through ties construction and dissolution. 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 argument is grounded on the process of trust construction that grows between two related nodes, because it fosters cooperation and knowledge integration within nodes groups. 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 payoffs decrease involved. As this process goes, the clustering coefficient of the network increases, and triadic closure tends to shape a core-component in the network (Borgatti & Everett, 1999), in particular when closure prevails for highly connected nodes. The second one relates to bridging strategies and introduces the idea of a more disruptive relational behavior. Considering 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 setting bridging position provides access to new and non-redundant knowledge and new opportunities for improving innovation capabilities (Ahuja, 2000; Ahuja *et al*, 2009). In the case of clusters, these bridging strategies have implications on the overall structure since they can be a better circulation of knowledge between the core and the periphery of a network (Cattani & Ferriani, 2008).

3. Are performing clusters also resilient?

The mechanisms of nodes entry and ties formation in clusters, as well as the resulting structural properties, are critical parameters of the economic analysis of clusters functioning and performance. But does performance go against resilience, or some particular structural properties are they better suited for that clusters succeed in favoring at the same time these two features? Such a question is crucial for the clusters research agenda, as well as for regional policies that face faster technological cycles and increasing turbulences of the economic environment.

3.1. Lock-in and lock-out in clusters growth trajectories

Regional resilience is considered here in an "out of equilibrium" approach (Simmie & Martin, 2010) that opens the debate on performance versus resilience of clusters. Such a debate implies to understand the complex dynamic process through which a system of local interactions succeed in emerging as a competing and leading place in a particular technological domain, while it maintains the conditions of its renewal by adapting to patterns of technological life cycles, market dynamics and consumers evolving paradigms. The direct transposition from physical network theories clearly shows that there is an opposition, or at least a trade-off, between efficiency and resilience (Brede & Vries, 2009). The more the network is efficient, minimizing ties and maximizing reachability, the more it is sensitive to external shocks and exhibit fragility properties. Introducing behavior, cognition and agency in networks theories leads to underpass the myopic behavior of nodes and introduce relational strategies that challenge this trade-off. There is empirical evidence for arguing 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 maintaining their growth trajectories. Hassink (2007) for instance highlights the relational and institutional dynamics in West Münsterlad that explained the fruitful transition from textile industry towards medical applications and devices. Vicente *et al* (2011) provide a network approach in the case of Midi-Pyrenees region and highlight the way by which knowledge on spatial navigation historically dedicated to military and defense industry has been recombined with civilian applications, giving rise to a new market for embedded navigation systems. Such resilient processes are also observed by Cooke (2008) 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 been also introduced and recombined with new applications in promising and efficient solar technologies.

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

3.2. Regional resilience and knowledge networks structural properties

Successful clusters at a moment of time and in a particular technological field are the ones that have succeeded to going through 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 clusters purpose. Indeed, the success of many products on markets 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 leads some products to do not reach the mass market 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 (Moore, 1991)[2]. Then successful clusters are the ones that reach the imposition of well-integrated and performing complete technological systems on mass markets. As literature shows (Klepper & Simmons, 1997; Audretsch *et al*, 2008), these clusters evolve from an initial scattered structure of burgeoning organizations towards a limited number of hub organizations as far as the products grow in maturity for tending towards an oligopoly structure at the mature stage of the market. Along the life cycle of products, and specially composites ones, such a network dynamics 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).

[2] 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.

But are clusters producing these technologies necessarily locked-in too? The answer depends on the way by 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, ties between nodes can be rewired 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 tightly 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. At the opposite a core/periphery structure can emerge through the entry of newcomers and shapes a disassortitive web of knowledge relations along the structuring of the network. For that, the bridging strategy of nodes has to prevail over the closure one. Consequently, highly connected nodes spend a share of their relational capacity toward peripheral nodes, and the network as a whole displays now more paths between the core and the periphery than for the assortative network.

These patterns of entries (into) and structuring (of) networks 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 contributes to foster the legitimacy of social norms and conformist effects in Sociology (Watts, 2004), or technological standard and dominant design in Business Studies (Frenken, 2006). But the debate between closure and bridging is more controversial, and it is controversial for clusters studies too. Indeed, closure favors technological lock-in and so the ability of the relational structure to perform in markets. The tightly coupling between high degree organizations favor conformism and trust and so a stable and cohesive structure that prevents opportunism and promotes an efficient integration of knowledge. But closure favors network assortativity and prevents regional lock-out, since the low connectivity between the core nodes and the peripheral ones limit the re-organization of knowledge flows when external contingencies such as a market decline occur. So when preferential attachment and closure play together, 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 & Martin, 2010). For fostering adaptability and resilience, clusters have also to deal with bridging strategies in order to open more disruptive relations between the core and the periphery of nodes, preserving a minimal cohesiveness into the core, while multiplying the channels for potential or latent flows of fresh and new ideas coming from peripherals nodes (Grabher & Stark, 1997; Cattani & 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 far as the technology reaches maturity has to go with a not too low amount of entrepreneurial connections with the periphery, in order to overlap exploitation on 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 of 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 König *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 close empirical evidences 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.

4. Two simple statistical signatures of local networks resilience

The level of hierarchy of nodes degrees and the level of assortativity then 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 the age or the size, the cognitive variety and the model of knowledge promotion and valuation or organizations. But each of them can be associated to the two formers since it influences the relational behavior of clustered organizations. The most important for the empirical development of resilience studies in regional science relies on the structural and topological properties of knowledge networks. The correlation between relational behavior and individual features has to be captured in parallel.

Hierarchy and assortativity can be introduced together in a simple and appreciative model that combines these two network properties. 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 term 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 will be assortative when high degree nodes will be connected to other high degree nodes, and low degree nodes preferentially connected to low degree nodes, so that the degree correlation will be positive. And a network will be disassortative when high degree nodes will tend to connect to low degree nodes, and vice et versa, so that the degree correlation will be 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*[3]. If we note *k* the degree of a peculiar node *i*, we can then write two simple relations to characterize the network topology. By referring to a rank-size rule, we can order node degrees from the largest one to the smaller one[4] and then draw the distribution on a *log-log* scale. Such that:

$$k_i = C(k_i^*)^a ,$$

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

$$\log(k_i) = \log(C) + a\log(k_i^*).$$

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

$$\overline{k_\iota} = \frac{1}{k_i}\sum_{j\in V_i} k_j ,$$

where k_j is the degree of node *j* belonging to the interaction neighborhood of the node *i*.

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

$$\overline{k_\iota} = D + bk_i ,$$

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

If $b > 0$, the network *N* exhibits assortativity property 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 the characterize useful structural network properties.

$$\begin{cases} degree\ distribution : \ \log(k_i) = \log(C) + a\log(k_i^*) & (1) \\ degree\ correlation : \overline{k_\iota} = D + bk_i & (2) \end{cases}$$

[3] Then we focus only of 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 deals only with the relevance of public funded incentives for collaboration in an existing structure.

[4] If two nodes have the same degree, we arbitrary rank them so long as this way to do has no incidence on the slope on the power law.

Using equation *(1)* and *(2)*, and considering a network *N* with a fixed number of nodes (*n=33*) and ties (*t=64*)[5], *figure 1* summarizes this proposition, giving more details on three typical topologies and their statistical signatures.

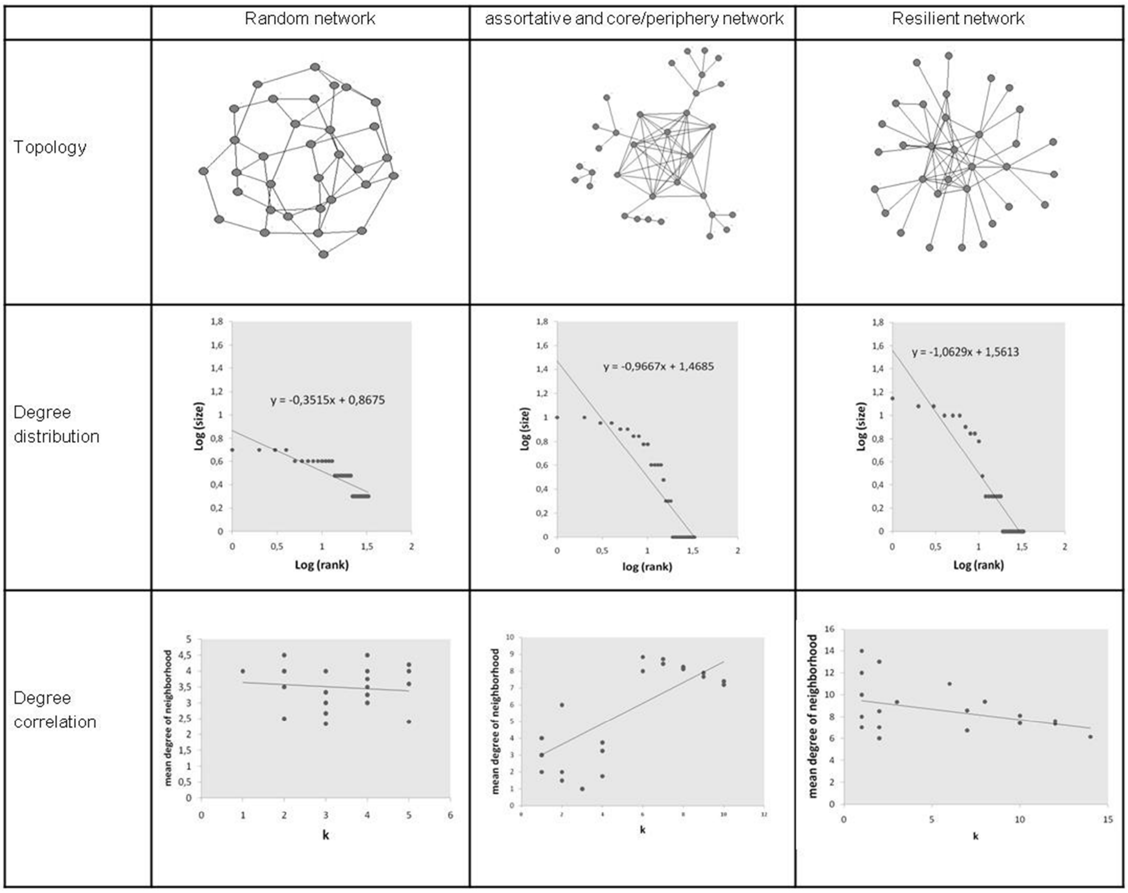

Figure 1. Networks topologies, degree distribution and degree correlation

(i) The so-called “random network” presents a relatively flat distribution of degree |a|=0,35 with a degree correlation b~0. In a physical or engineering approach of networks, such a network displays a high resistance to external shock. Due to a rather flat hierarchy within the whole network, whatever the node removed, the fluid will still find paths to irrigate the whole of the network. In a more socio-economic oriented approach, such a network displays also a strong potential of knowledge flows re-organization or direction in the structure since many paths link the whole of nodes. 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 a collective behavior that would exploit products on market by gathering efficiently pieces of knowledge.

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[5] In such a way that the network density remains the same (*density=0.115*), whatever the topology of the network.

(ii) At the opposite, the “core/periphery and assortative network” presents a strong slope in the distribution of degree $|a|=0{,}96$ so that the cohesiveness of the core promotes now a conformity effect, and, in a technological perspective, a high probability of the emergence of a standard. Nevertheless, its strong assortative structure ($b>0$) weakens its resilience property since the periphery is loosely connected to the core. Considering 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. In a more socio-economic oriented 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 of nodes and the peripheral ones. Then the assortative knowledge network favors the 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.

(iii) 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. To put differently, this negative correlation gives 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 at the same level than in the previous structure. Now at the same time, innovative or explorative behavior can diffuse more easily from periphery to core members, due to ability of the oligopolistic organizations to mix closure and bridging ties for overlapping explorative and exploitive phases in their relational patterns.

Figure 2 provides a more abstracted representation of these critical structural properties of local knowledge networks.

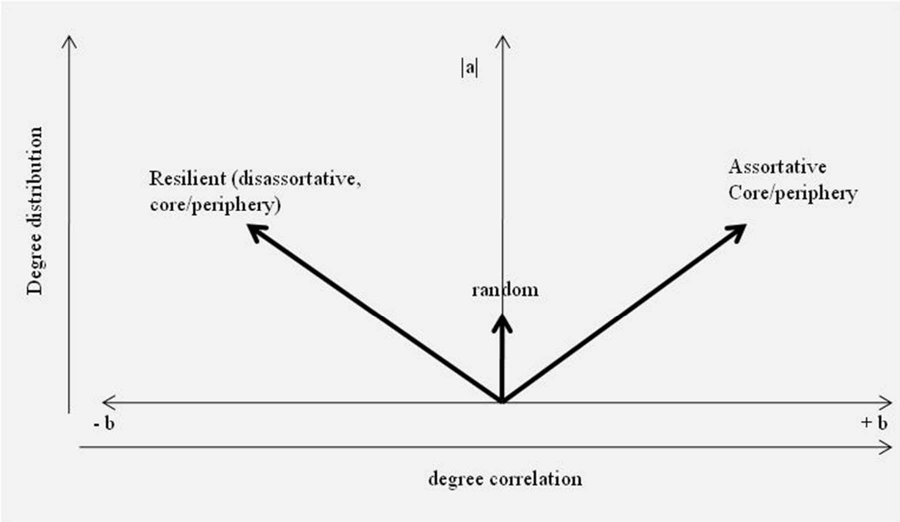

Figure 2. Statistical signature of cluster structural properties

Putting together degree distribution and degree correlation on a same layout, one can have a better understanding of how local clusters structuring and properties can play together towards aggregate performance and structural conditions for resilience. The more clusters are up-plotted on the layout, the more their structural hierarchy enable them to impose standards and dominant designs on markets. And the more clusters are left-plotted on the layout, the more the disassortative patterns of relations increases regional resilience capabilities. For physical networks, efficiency and resilience go through opposite ways (Brede & Vries, 2009). But for socio-economic networks, by considering social agency and the ability of nodes to build and maintain ties for overlapping explorative and exploitative ties, performing networks do not go necessarily against regional resilience. For that, 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. At the opposite, when closure strategy in the mature oligopolistic structure exceeds a certain threshold, then redundancy of knowledge flows and conformity effects prevail and the possibilities for regional resilience fall unavoidably.

5. **Policy implications**

The motivation for abstracting the analysis of regional resilience around only two statistical signatures of local knowledge networks can be appreciated 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. If collaborations and networks matters, regional policies can be under-productive if an unconditional index or network density is defined as a goal for supporting clusters. At the opposite, in our framework, a *laissez-faire* policy, even if it is less costly, is also an under-productive approach of regional development. Indeed, even if clusters perform at a moment of time, it could be hazardous to infer that such successful stories are necessarily long-termist ones. Between *laissez-faire* and a standard and costly increase of relational density, our simple statistical signatures provide at least nine categories of targeted policies. Basically, policy makers can concentrate their attention to only one instrument, the other one remaining fixed ($\Delta|a| \neq 0, \Delta|b| = 0 \; or \; \Delta|b| \neq 0, \Delta|a| = 0$), or can play a mixed strategy with both variables at the same time ($\Delta|a| \neq 0,\ \Delta|b| \neq 0$). *Table 1* gives an overview of the policies.

Degree distribution correlation	$\Delta\lvert a\rvert = 0$ (1)	$\Delta\lvert a\rvert > 0$ (2)	$\Delta\lvert a\rvert < 0$ (3)
$\Delta b = 0$ (A)	Laissez faire	Reinforce the up part of the hierarchy of knowledge networks	Reinforce the down part of the hierarchy of knowledge networks
$\Delta b < 0$ (B)	Promote structural heterophily and disassortativity	Reinforce the up part of the hierarchy of knowledge networks Promote structural heterophily and disassortativity.	Reinforce the down part of the hierarchy of knowledge networks Promote structural heterophily and disassortativity.
$\Delta b > 0$ (C)	Reinforce the structural homophily and assortativity.	Reinforce the up part of the hierarchy of knowledge networks Reinforce the structural homophily and assortativity.	Reinforce the down part of the hierarchy of knowledge networks Reinforce the structural homophily and assortativity.

Table 1. Policies supporting regional resilience

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

- Firstly, for clusters that home a part of highly connected companies and that can be considered by policy makers as having reached a mature oligopolistic structure, diagnosis of clusters lead policy makers to play on the level of assortativity of the knowledge networks. In that case, $\Delta|a| = 0$, and policies are *type-1* and *ties-oriented* ones. Besides a *laissez-faire* policy (*1.A-policy*), two instruments are available for policy makers. On the one side, they can interpose to resolve the insufficient level of connectivity between recently newcomers or burgeoning SMEs and the core of mature organizations. In that case, a re-allocation of public funded ties from an excessive cohesiveness of the core to a better core/periphery connection (*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 assortivity between core members and between peripheral members, so that fresh and new ideas produced in the periphery have difficulties to irrigate the core-component of the cluster. On the other side, 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. Now policies are *actors-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 fits with clusters that do not succeed in building an oligopolistic structure of organizations and display in the 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 that case, windfall payoffs for central organizations will decrease the policy efficiency. On the contrary, clusters diagnosis can highlight an excess of isolation of organizations and then policies aim to reinforce the down part of the degree distribution. Decreasing the slope of the degree distribution does not mean reducing the degree of leading organizations of clusters, but at the opposite, increasing the one of the newcomers or isolated ones. 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 *actors-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 an increasing capacity of clusters to overlap mature and emerging knowledge domains, and thus more open structures of knowledge interactions (all *type-B* policies). At the opposite, 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 toward regional resilience. They provide simple but targeted tools for applying distinctive surgical policies. Policies for regional resilience have to be re"place"d and contextualized (Bristow, 2010). Indeed, according to the particular situation of clusters in terms of structural properties and market position, the simple increase of 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). At the opposite, they invite to consider particular targeted incentives for bridging potential missing links in cluster long run dynamics.

6. Conclusion

In spite of its high level of abstraction and complexity, the science of networks applied to regional science gives promising perspectives for static as well dynamic analysis of clusters. Here we have tried to show that it was possible to reduce this complexity around two simple statistical signatures of knowledge networks. Degree distribution and degree correlation highlight the critical structural properties that increase the performance of clusters in 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 more 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 introduction of degree distribution and degree correlation in a simple model of network structuring confirms that a window of parameters exists for which clusters can display performance in a short run and resilience in a long run. Capturing more precisely this window requires probably some model refinements. But at this stage, such a framework furnishes new perspectives to highlight empirical evidences 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 constitutes also 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 declining growth trend.

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