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"Don't throw the baby out with the bath water" Network failures and policy challenges for cluster long run dynamics

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Abstract

Cluster policies have been recently called into question in the aftermath of several empirical evidences. Disentangling how market and network failures arguments play together in cluster policy design, we look for more robust micro foundations of network structuring in clusters. Our aim is to show that, in spite of this growing skepticism, new opportunities for cluster policy exist. They require moving their focus from the "connecting people" one best way that gets through the whole of cluster policy guidelines, to more surgical incentives for R&D collaborations, which favor suited structural properties of local knowledge networks along the life cycle of clusters.

Key-words: cluster policy, knowledge spillover, network failures
JEL classification: B52, D85, O33, R12

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1. Introduction

After an abundant literature on the crucial role of cluster development for innovation and growth in knowledge-based economies, cluster policies have been recently and increasingly called into question in the aftermath of several empirical evidences that challenge the relevance of these policies (McDonald *et al*., 2006; Duranton, 2011; Martin *et al*., 2011; Martin *et al*. 2013), or at least raise serious doubts regarding their actual contribution to regional growth (Falck *et al*., 2010; Brakman and Marrewijk, 2013). This paper aims to understand the reasons of such a gap between this twenty years literature that have placed clusters at the core of regional and innovation studies and the failure of policies aiming at promoting them. In doing that, it also shows that between the reoccurrence of *laissez-faire* and the *cookie cutter* dimensions of cluster policy rationales (Wolfe and Gertler, 2004), a large window of policy designs still remains if the critical parameters of clusters long run dynamics are clearly defined.

As a matter of fact, as previously underlined by a couple of scholars, clusters have been introduced in the literature on the basis of insufficient analytical and theoretical foundations. On the one hand, there is no clear identification of the market failures at play in regions that justify targeted policy mediations towards incentives for local R&D collaborations and networks development (Duranton, 2011). Following these market failures arguments, there is no evidence that can explain the relevance of clusters policies over more traditional direct subsidies and incentives for R&D at the firm level. On the other hand, there are some superficial inductive beliefs born from the *Californian dream* or the *Porter' diamond* that allow scholars and policy makers thinking that network density between co-located organizations remains the key feature – the *panacea* – of successful regions (Martin and Sunley, 2003). In that case, policies aiming at increasing R&D collaboration and knowledge circulation in regions appear as a new rationale for regional policy, based on a "networks failure" framework, but without sufficient analytical foundations on the welfare superiority of the networks-based incentives over the market ones. Moreover, whatever the supporters of failure to repair, policies are always suspected to be under efficient, due to crowding-out effects that arise when public funds substitute private R&D expenditures at the firm level (Nishimura and Okamuro, 2011), or when a group of companies in search of windfall profits can collude with local policy makers to benefit from a cluster initiative to extract resources for themselves (Duranton, 2011). In a period featured by austerity and an increasing criticism on the waste of public funds, these typical government failures challenge clusters policies, or at least their foundations regarding the expected outcomes.

Our aim is to show that, in spite of this growing skepticism, new opportunities for cluster policy design based on network failures exist. They require moving their focus from the "connecting people" one best way that gets through the whole of cluster policy guidelines (McCann and Ortega-Argilés,

2013), to more surgical and targeted incentives for R&D collaborations, conditional to a set of particular network failures that can arise along the life cycle of clusters (Suire and Vicente, 2009, 2014; Menzel and Fornahl, 2010; Crespo, 2011, Brenner and Schlump, 2011). On the one hand, by translating evolutionary principles of long run dynamics of clusters into new policy rationales (Uyarra, 2010), one can expect drawing some critical structural properties of clusters that favor short term efficiency without compromising structural change and resilience capabilities (Martin *et al*, 2013; Boschma, 2014), and turning these properties into targeted policy interventions on particular missing links. On the other hand, by limiting public-funded incentives to these particular missing links rather than a general watering of subsidies for collaboration, one can expect from these targeted incentives a better policy return and thus legitimacy.

But to do that, one has to go beyond the figure of network as a simple catalyst of innovation in regions, and then go beyond the unsuitable argument according to which network failures in clusters should be associated to a weakness of relational density into networks. The links between networks and aggregate as well as individual innovative achievements are more complex and require a more detailed and micro-founded analysis on the formation and the dynamics of collaborative ties (Balland, 2012). According to the topology of networks and their ecology of organizations, the web of knowledge flows can have highly dissimilar consequences on their ability to produce and diffuse innovations on markets, from a great capability to constantly turn burgeoning ideas into mass market standards to an excess of technological conformism and declining trajectories. Literature has recently started to identify the peculiar network failures that provoke cluster decline (Suire and Vicente, 2009, 2014; Menzel and Fornahl, 2010; Crespo, 2011, Brenner and Schlump, 2011), but without at this stage a sufficient counterpart in terms of policy challenges. Filling this gap is precisely the aim of the paper.

Section 2 proposes a short critical overview on the process that has introduced market and network failures in the production and diffusion of policy guidelines promoting cluster development. Section 3 aims at capturing the micro-foundations of local knowledge networks through the ambivalent role of local knowledge spillovers in the innovative performance of regions. Section 4 shows how the micro-motives for knowledge collaborations give rise to particular and very distinctive structural properties of clusters, which allow us in section 5 having a more detailed definition of what network failures could really be. Section 6 draws from this approach some policy implications that significantly renew the network failure-approach of clusters policies. These implications rely on conditional targeted and surgical interventions that favor cluster long run dynamics and a higher economic return of public funds.

2. Market and network failures in cluster policy design: a (too) brief overview

As clearly demonstrated by McCann and Ortega-Argiles (2013), regional innovation policies have clearly shifted from market to network and systemic failure arguments, prioritizing policy efforts on increasing relational density in existing clusters, and favoring for that purpose collaborative incentives to develop innovation networks over pure individual R&D public-funded subsidies. This shift is supported and thus highly legitimated by a set of global reports from the World Bank (2009), OECD (2007) or several guidelines from the European Commission (2008, 2009). In the academic literature also, as displayed in *figure 1*, cluster policies have been subject of a still growing number of publications since the end of 1990s, with an important focus on the network and collaborative dimensions.

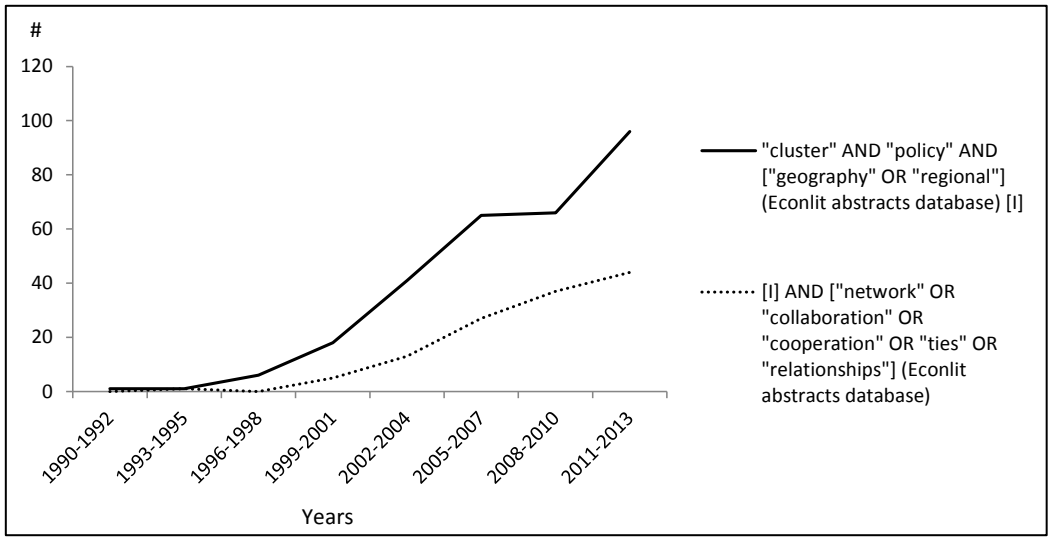


Figure 1: number of scientific papers on cluster policy introducing knowledge networks in Econlit database [1]

Recently, Uyarra and Ramlogan (2012) have proposed an extended and critical review of cluster policies through the world, detailing instruments and the nature of incentives to boost innovation in regions. Obviously, there is a certain degree of variation between all the initiatives. Nevertheless, a common pattern emerges, relying on the coexistence of policy measures dedicated to market and non-market failures in the regional innovation process. Non-market failures are considered as network or systemic failures, typified by an insufficient level of networking and knowledge exchange between co-located companies (Woolthuis *et al*., 2005). Market failures are the result of more neoclassical approaches on the inability of the market system to provide an optimal level of knowledge production. For the latter, all the means restoring individual incentives to innovate, reducing risk of knowledge under appropriation, upgrading human capital and providing research indivisible infrastructures are

[1] Key-words are extracted only from abstracts. “geography” OR “regional” are added to avoid off-topic papers.

part of the well-known neoclassical means to boost innovation (Arrow, 1962; Scotchmer, 2004). For the former, the policy background will be found in the relational turn (Bathelt and Glückler, 2003; Boggs and Rantisi, 2003) and in the evolutionary turn (Boschma and Frenken, 2006; Uyarra, 2010) of economic geography. Considering the role of non-market interactions and the composite nature of knowledge that enter the innovation process, incentives for enhancing local knowledge collaborations and exchanges appear as a key-instrument to improve regional competitiveness

The ambivalent role of local knowledge spillovers (Jaffe *et al*., 1993; Audrescht and Feldman, 1996) is at the core of the debate between the necessities to deal with market or non-market failures in the policy design. Indeed, while knowledge spillovers are mostly unintended for the market failures partisans (Scotchmer, 2004), and thus require regulations and rules of protection as incentives to innovate for companies, they can be mostly intended for the disciples of the relational turn in economic geography (Breschi and Lissoni, 2001; Boschma, 2005), and thus require understanding the interactive mechanisms supporting the collective management of knowledge circulation. These two sides of knowledge spillovers do not necessarily contradict themselves, but depend whether or not organizations favor internal knowledge appropriation over external knowledge accessibility, or can have it both ways (Antonelli, 2005). Clearly, fieldwork analyses have often shown that reciprocal knowledge accessibility is one of the key-motives of clustered organizations, which find in their co-location the opportunities to put together separated pieces of knowledge in a complex and flexible adjustment process (Saxenian, 1994). Nevertheless, this propensity of innovative organizations to cooperate and exchange knowledge should not lead us to associate in a beatific way cooperation in clusters and innovative performance. One has to remind that successful clusters are also the ones in which firms compete through the market for knowledge and the resulting patents war for instance, even when they are co-located in a same area. As clearly shown by Iammarino and McCann (2006), location in clusters can be a source of under appropriation of the company's internal knowledge-related investments. But relocating outside clusters will reduce the ability of this same company to access new external knowledge. Accordingly, market and non-market forces interact in clusters according to the specific purpose of co-located organizations, and the pure market as well as the pure cooperative views of clusters would probably fail to capture the basis of clusters success without a clear identification of the micro-motives for organizations to shape or not knowledge relationships.

The wide range of programs sustaining clusters in the world are based on a mix of instruments and incentives aimed at repairing market and non-market failures together. Nishimira and Okamuro (2011) rightly associate the difference between both in terms of *direct* and *indirect* instruments. While *direct* instruments refer to R&D supports restoring incentives for filling the gap between private and public return to R&D, *indirect* instruments refer to a set of collaborative and networking incentives aimed at enhancing the ability of clustered organizations to intentionally manage knowledge spillovers through collaborations in order to turn potential and latent complementarities into new industries and markets. While the first instruments try to improve the innovation capabilities of each clustered organization to

increase the cluster performance as a whole, the second ones differently play, by improving the structure of knowledge flows inside the cluster, hoping a positive feedback of this structure on the innovation capabilities of the co-located organizations. Obviously, market considerations are not totally excluded from networks ones. Indeed, once again, one has to go far from the beatific view of networks and knowledge exchanges in clusters. Firstly, when public-funded collaborations arise, each firm receives subsidies to innovate, even if these subsidies are conditional upon collaborative R&D. Secondly, disclosure rules and shared property rights are clearly foreseen in the related collaborative arrangements, so that incentives for consortia substitute to pure firm's incentives to compete in the market for knowledge.

Considering the increasing weight of network failures arguments and the great tendency to foster local collaborative arrangements in the cluster policy design – with the Silicon Valley success in the sights – , it remains crucial to have a serious overview of the theoretical foundations that can sustain the importance of knowledge networks over individual incentives for regional growth. But following market failure supporters (Duranton, 2011; Martin *et al*., 2011), one has to go beyond a pure structural approach by disentangling the micro-foundations of knowledge networks.

3. Local knowledge spillovers and the micro-foundations of knowledge networks

The intended and unintended sides of local knowledge spillovers are probably the best way to reconcile market and network failures supporters, since they allow revealing the motives to shape or not knowledge relationships, while avoiding the structural and holistic arguments that constitute a strong area of disagreement between them. As a matter of fact, the researches that have pointed out the important and positive role of trust, institutional thickness, or social and cultural embeddedness in the development of networks for many successful clusters, even supported by strong and relevant empirical evidences, are explicitly criticized by the market failures supporters for their lack of micro-foundations. At the opposite, mainstream economists still struggle to link cluster performances to the complex structure of knowledge flows inside clusters, hiding behind different types of agglomeration and location externalities to capture the individual and collective benefits of firms' proximity.

Since knowledge networks at the aggregate level arise from de aggregation of pair wise ties, a way of reconciliation can be found in a dyadic approach of the formation of knowledge relationships based on the key role of intended and unintended knowledge spillovers. Organizations will shape knowledge relationships according to the way with which they manage their knowledge trade-off between external knowledge accessibility and internal knowledge appropriation. Each organization will build one or several relationships when she will feel that the expected returns of external knowledge accessibility should exceed the risks of under-appropriation of her own knowledge (Antonelli, 2005). As synthetically shown in *figure 2*, at the aggregate level, a cluster will be characterized by a *0-density*

structure, when each organization will favor knowledge appropriation over accessibility. In that extreme case, organizations protect themselves from the risks of knowledge under-appropriation and do not find opportunities to connect their own knowledge to others, giving rise to very particular clusters, typified by a very low level of relational thickness, at least at the local level, as previously illustrated by Markusen (1996) and Romanelli and Khessina (2005). At the opposite, a cluster will be characterized by a *maximum-density structure*, when each co-located organization will favor accessibility over appropriation, and decides to open its knowledge bases to all the others, expecting the same from them, in a very and probably too excessive cooperative spirit. Obvisouly, reality invites to consider *mixed structures*. In these structures, organizations will find benefits from knowledge reciprocal sharing with a limited number of targeted partners, those for whom the returns of knowledge exchanges exceed the risks of knowledge hold-up, giving rise to networks with different levels of relational density (Walker *et al*., 1997).

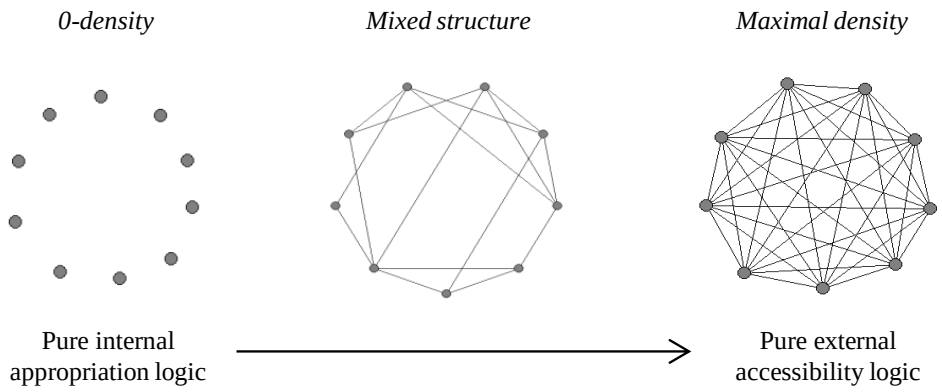


Figure 2: knowledge trade-off and clusters relational thickness

But, at the opposite to many arguments defended in clusters policy guidelines, nothing at this stage can allow linking the relational density of clusters to their innovative performance. One can just about infer that clusters can display various level of network density according to the various balances between intended and unintended local knowledge spillovers that force organizations to shape or not knowledge relationships. To have a better micro-founded view of why knowledge networks are related to clusters innovative performance, it is necessary to precisely understand why and when organizations decide to favor external knowledge accessibility without using the market system, in spite of the risks of their own knowledge under-appropriation. The "why" is related to the particular institutional ecology or demography each cluster exhibits, since the institutional form of organizations influences their propensity to build knowledge ties (Owen-Smith and Powell, 2004). The "when" is intrinsically linked to the forms of industrial organization that govern the diffusion process of innovation on markets (Suire and Vicente, 2014). As a matter of fact, the technological compositeness and

complexity of products (Frenken, 2006), as well as the demand properties from consumers (Katz and Shapiro, 1994), engender particular forms of industrial organization that can allow some organizations opening their knowledge bases and thus participating to the network densification.

As concerns the "why", economic organizations display markedly different characteristics in terms of knowledge promotion. Public research organizations for instance will be more prone to shape knowledge relationships than most of private firms, since their performance is intrinsically linked to their ability to disseminate knowledge. And as far as scientific knowledge is an impure public good, its absorption by the industry fits better with direct partnerships than with the idea that scientific finding would be totally available for the whole industry. This adherence to the norms of the open information disclosure characteristic of public science explains why the connectedness of public research organizations in knowledge networks is important for innovation in clusters (Owen-Smith and Powell, 2004), in particular in the early phase of the technological field. In the private firms' area, different types of organizations co-exist in respect of their relational capabilities but also of their model of knowledge promotion and appropriation. If some well-established companies will deal with property rights to promote their innovative activities in isolation until the market phase, some others, like many small technological firms, will also play with the patent system, but this time to signal to potential partners their wish to collaborate on the integration of their products in larger technological systems. Other companies, such as venture capital firms, will build relationships in clusters that do not only rely on financial and strategic purposes, since the monitoring of innovation projects also rests on scientific and technological advice and collaboration. Accordingly, the institutional variety that typifies each cluster in terms of knowledge promotion will have a strong influence on its relational thickness.

As concerns the "when", the way with which organizations deal with intended and unintended knowledge spillovers strongly depends of the forms of industrial organization that typify the market on which clusters are involved. As a matter of fact, most of technological fields and the resulting markets result from technological compositeness and cross-industrial interactions. Clusters will get the best performance from the capacity of organizations to combine knowledge coming from different technological and economic environments to generate new markets. This related variety assumption has been tested as a strong source of innovation for regions (Boschma and Frenken, 2011). But this related variety is not organized at random. It rests most of time on historically anchored technologies and know-how that the transversal character becomes the source of new market and applications opportunities (Cooke, 2012). Along these industrial dynamics, organizations will have incentives to adopt particular relational strategies. The technological transversality and compositeness logics will push organizations into building different types of knowledge partnerships at different moments of the technological and market life cycle. The necessity to set up technological standards on mass markets requires the existence of central organizations able to manage the integration and combination process of technologies, since the success of markets for composite technologies requires a high level of interoperability and compatibility to reach consumers satisfaction and willingness to adopt. Therefore,

organizations will favor external knowledge accessibility when they will be able to value the benefits of knowledge integration and compatibility. Once again, all relationships are not suitable. Each organization must weigh knowledge integration benefits and the risks of under-appropriation of her own knowledge on markets. For instance, competing organizations will value a benefit from reciprocal access to their knowledge bases only when they will be able to assess that cooperation for a technological standard is more profitable than isolated strategies. If direct competition is the rule between them, then geographical proximity has to go with relational distance in knowledge networks in order to avoid the weight of unintended knowledge spillovers between them (Vicente *et al*., 2011). At the reverse, in other situations, complementary organizations will find reciprocal opportunities to cooperate on knowledge. For instance, big companies owning a well-installed transversal technology will find opportunities to absorb explorative knowledge developed by young research-based companies in order to create new related markets, while the latter, far from a well-established position on mass markets, find the opportunity to integrate their more disruptive knowledge in larger technological systems (Ahuja *et al*., 2009; Balland *et al.*, 2013).

These motives to shape (or not) knowledge relationships within clusters will give rise to localized aggregate structures of interactions – called networks – that will display different degrees of density. In such a micro-founded approach, knowledge networks can be a source of regional competitiveness since they allow co-located organizations finding opportunities of reciprocal knowledge exchange and integration. The institutional demography and the composite nature of industrial dynamics at work within clusters give rise to particular micro-founded structural properties of networks that can allow clusters competing on technological mass markets, while maintaining capabilities to develop new related ones. Hence, associating network failures as a lack of density in knowledge networks, and thus designing public-funded incentives to increase this density, is still not convincing at this stage. As a matter of fact, the weight of unintended knowledge spillovers still remains, and can create at the opposite disincentives for knowledge collaborations and network densification. This is precisely when policies want to increase this density that the crowding-out effects appear, and that the organizations may have to benefit from the public resources without a real collaboration on knowledge. In order for the concept of network failures to be meaningful, one has to define in the large spectrum of mixed-structures what kind of structural properties beyond density matches with the ability of clusters to deal together with intended and unintended knowledge spillovers to reach long run success.

4. New rationales for efficient and resilient clusters : cluster life cycles and structural properties of local knowledge networks

Recent researches on clusters life cycle and the resilience of regional systems of innovation (Suire and Vicente, 2009, 2014; Menzel and Fornahl, 2010; Brenner and Schlump, 2011; Boschma, 2014; Crespo *et al*., 2014) have started to investigate the particular forms of knowledge networks clusters have to

display to maintain long run trajectories and structural change capabilities. In an evolutionary approach, these researches try to capture the causes of clusters performances, but also their capacity to resist to external shocks and sustain continuous growth in a context of growing international competition and rapid technological changes. The main idea is to detect what structural properties local knowledge networks have to display to set up technological standards on mass markets while avoiding negative lock-in though the ability of these networks to re-organize resources towards emerging and related markets (Simmie and Martin, 2010).

Faced with the relational density paradigm that waters cluster policy guidelines, these recent researches, using recent advances of network theories in business studies (Ahuja *et al*., 2012), bring into opposition some more complex forms of network structuring that better correspond to the industrial logics of technological creation and diffusion (Cowan *et al.*, 2004). For instance, from the micro and dyadic level of knowledge relationships to the structural level of networks, some papers have focused on the effects of the property of triadic closure on the innovative performance of regions and clusters (Balland *et al*., 2013; Ter Wal, 2014), or on the effects of networks centralisation (Cantner and Graf, 2006; Graf, 2011; Vicente *et al.*, 2011). Others have also stressed on the small worlds property of knowledge networks as a catalyst of innovation in clusters or cities (Zimmermann, 2002; Fleming and Marx, 2006; Breschi and Lenzi, 2013). More recently, Crespo *et al.* (2014) have proposed two related statistical signatures that at the same time summarize and encapsulate these effects on the long run innovative performance of clusters, linking these signatures to the micro-motives and incentives for organizations to form knowledge relationships.

The first one is the property of hierarchy, which directly refers to the degree distribution of networks. As clusters are considered as successful when they succeed in setting up technological standards on mass markets, the distribution of degrees within clusters will inform on the presence (or not) of some leading organizations holding transversal technologies and able to coordinate the systemic process of innovation. The degree of hierarchy in knowledge networks can be a good indicator of clusters maturity. As a matter of fact, in the lines of industrial dynamics literature, a technological field starts from a very scattered structure of burgeoning and small companies at the emergence phase and evolves toward maturity along a continuous process of ossification and oligopolization around a couple of leading organizations (Audretsch and Feldman, 1996; Klepper, 1996). This process, in its relational and network dimensions, is likely to engender the formation of core-periphery structures, in which core-organizations develop a high relational capacity, while a myriad of loosely-connected ones, more or less linked to the core, gravitate at the periphery of the network. Therefore, the degree of network hierarchy a cluster exhibits can be assessed by the slope of the degree distribution. A flat hierarchy will be associated either with a cluster in its emerging phase, or with a cluster whose network structuring has not allowed the development of central organizations able to manage the collective process of innovation. A the opposite, a sloping hierarchy will be the mark of clusters that have succeeded in establishing themselves as leading clusters through the ability of some core-

organizations to manage and organize the integration of different pieces of complementary knowledge that reinforce the potentialities for the cluster to transform new ideas into mass-market products. The empirical researches of Owen-Smith Powell (2004) on biotechs in Boston, Cattani and Ferriani (2008) on the movie industry in Hollywood, or Balland *et al*. (2013) on the European clusters in the GNSS industry provide evidences on the importance of hierarchy and core-periphery structures for clusters development.

But hierarchy, even if it remains crucial, is not a sufficient property for the long run success of clusters. As previously said, successful clusters are the one that on a one side succeed in setting up technological standards on markets, but on the other side, in a context of rapid technological changes, that are also able to persistently maintain capabilities to create new markets. If hierarchy facilitates the first side, it is not a guarantee of success for the other side, since the main challenge for successful and mature clusters is to avoid decline when the markets for the standards they produce also decline. Literature on resilience of regional systems of innovation and clusters life cycle clearly shows that regions can sustain a long run growth when they are able to resist to external shocks, international competition and declining markets by reorganizing and reorienting cognitive resources towards new markets (Simmie and Martin, 2010; Menzel and Fornahl, 2010). The topological forms of local knowledge networks can favour or hamper such a process to occur. In particular, the degree of assortativity of network, which is a second structural property of networks that complements the former, can be a good indicator of the capacity of a cluster to overlap mature and emerging markets. The assortativity of a network refers to its degree of structural homophily (Watts, 2004; Rivera *et al*., 2010; Ahuja *et al*., 2012). A network is strongly assortative when highly-(poorly-) connected organizations tend to form relationships with other highly-(poorly-) connected organizations, and disassortative when core-organizations tend to interact more with peripheral ones. Therefore, the assortativity of clusters, which can be measured by the degree correlation of their network structures, gives a formal representation of the knowledge pathways between central and peripheral organizations. In direct relation with triadic closure and bridging, assortativity has the advantage of introducing in a same measure the uneven distribution of centralities. As a matter of fact, an assortative network will be featured by strong triadic closures between central organizations, engendering trust and limiting opportunism (Coleman, 1988), and then favouring the formation of norms and technological standards (Ter Wal, 2014). Generally defined as a naturel trend of many social networks (Watts, 2004), these effects of structural homophily can produce on the other side conformism and negative lock-in, due to an excessive redundancy of knowledge flows within the core-component of the network, and the difficulties for knowledge produced by peripheral organizations to irrigate the core of the network. Without a certain amount of bridging strategies (Burt, 1992) from core-organizations towards peripheral ones, fresh, new and disruptive ideas stay out the core-network. Therefore clusters can have difficulties reacting external shocks and exploring new market opportunities, as evidenced by Crespo *et al*. (2013) for the clusters long run dynamics in the European mobile phone industry.

5. A micro-founded approach of network failures in cluster development

The relational behaviour of organizations produces aggregate structures that can exhibit particular topological properties. Considering the failures or decline of clusters as the result of pure market failures is misleading and restrictive, since the nature of these topological forms can have strong influence of the capabilities of clusters to perform. But on the other side, considering that the density of networks is correlated to their performance is also erroneous, since an increase in relational density can also go with a weakening of the appropriative capacities of organizations, but also with an excess of redundancies in knowledge flows and a risk of conformism.

Hierarchy and assortativity can provide original and micro-founded structural properties of knowledge networks that highlight what network failures in clusters could really be. The first one, as it allows having a better understanding of how clusters can establish themselves on mass-markets through technological standards definition, can be an important source of network failures in clusters. Setting-up standards on markets requires a high level of coordination and knowledge integration of complementary pieces of knowledge. Therefore, a low level of hierarchy can explain some difficulties of clustered organizations to deal with reciprocity and intended knowledge spillovers. In a context of battle of places that requires winning the battle of standards, a lack of central coordination in clusters can be a source of competitive disadvantage. The second one, as it provides information of how mature and transversal knowledge can be connected or not to new and fresh ideas in networks, can also be a second source of network failures in clusters. In a context of fast technological change, this necessity for clusters to overlap mature and emerging technologies becomes more and more critical for their long run performance. Therefore, a lack of connectivity between core-organizations, that bring market surface and experience, and more peripheral ones, that generally provide more disruptive knowledge (Ahuja, *et al.*, 2009), engenders an insufficient level of new knowledge dissemination in clusters and some difficulties for them to turn emerging ideas into future mass-markets.

But how these two properties work together? Does a failure in one property necessarily imply a failure in the other? To put it more concretely, can a cluster dominate a market, helped by its strong degree of hierarchy, and resist the negative lock-in effects that are generally associated to mature markets (Simmie and Martin, 2010)? Literature stresses on a quasi-strict parallel between product life cycle and territory life cycle (Audretsch and Feldman, 1996; Klepper, 1996). Such a risk exists, and exists especially since an increase in hierarchy goes with an increase in assortativity along the cluster development process. In that case, the ossification and oligopolization process that typifies cluster development would generate fixity, limiting flexibility, while flat hierarchy would be more adaptive. We would be in the well-known dilemma of physicians between efficiency and resilience (Brede and Vries, 2009), according to whom an increase in centralization reduces resilience, and *vice versa*.

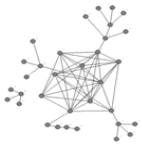
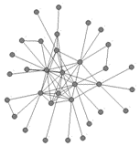
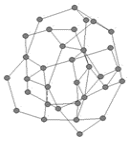
	Network (i)	Network (ii)	Network (iii)
Network graph			
Basic network statistics	Number of nodes: 33 Number of ties: 64 Density: 0,121 No isolated	Number of nodes: 33 Number of ties: 64 Density: 0,121 No isolated	Number of nodes: 33 Number of ties: 64 Density: 0,121 No isolated
Hierarchy (degree distribution)	Highly sloping distribution of degrees	Highly sloping distribution of degrees	Flat distribution of degrees
Assortativity (degree correlation)	Positive degree correlation	Negative Degree correlation	Not relevant
Cluster pattern	• Mature cluster with high level of centralization and coordination around a technological standard • Weak structural change capabilities, excess of triadic closure into the core and technological conformism • Risks of negative lock-in • Declining clusters	• Mature cluster with high level of centralization and coordination around a technological standard • Strong structural change capabilities, bridging strategies from central organizations and knwoledge flows between core and peripheral organizations • Possibilities of regional lock-out • Resilient clusters	• Scattered structure of knowledge relationships and lack of leading organizations able to manage the systemic and collective process of innovation • Emerging cluster or dominated cluster

Table 1: Structural properties and patterns of clusters development

Nevertheless, human agency cannot be associated to atoms behaviour. Opportunities exist for hierarchical networks to maintain resilience and structural change capabilities. For that, growing hierarchy has to play with disassortativity. *Table 1* discloses these possibilities. For a fixed number of organizations and ties between them (and thus a same density), and besides clusters that do not succeed in ossifying their relational structure (*network (iii)*), a cluster can grow in hierarchy while maintaining a negative degree correlation. *Network (ii)*, for a same level of hierarchy than *network (i)*[2], is characterized by a negative degree correlation, meaning that in spite of a high level of centralization of its relational structure, its core displays a weaker level of triadic closure and finally a greater openness of central organizations towards more peripheral and loosely-connected ones. These networks are whose organizations have reached a high degree of centrality along the technological cycle while maintaining a high proportion of links between the core and the periphery. They are better able to resist shocks and market cycles, since their matrix of knowledge interactions and flows limits conformism situations and allows a better overlapping between exploitation of mature markets and

[2] More details on network simulations can be founded in Crespo *et al*. (2014)

exploration of new and related ones. Consequently, in a context of rapid technological changes, these clusters are better suited to rest on well-established organizations to turn emergent knowledge from peripheral ones towards future standards on mass-markets. Contrariwise, the excess of assortativity of the *network (i)* will lead to a confinement and a overembeddedness of knowledge flows into the core of the network, and some difficulties to anticipate shocks and market declines. Assortative clusters can be successful networks that may well develop into unsuccessful ones due to an excess of ignorance from their core-organizations of the emerging novelty in their periphery (Woolthuis *et al*., 2005). Among others, the empirical investigation on the renewal of the Silicon Valley during the 1980s by Saxenian (1990) supports these findings. She shows us how networks restructuring between core-organizations of the semi-conductor mature industry and burgeoning organizations providing innovative and fast-changing components and applications has led the Valley to develop, and control later in the 1990s, the worldwide computer industry.

6. Don't throw the baby out with the bath water: from "one size fits all" to surgical cluster policies

Should clusters policies based on subsidies for collaboration be rejected, as suggested by market failures supporters (Duranton, 2011; Martin *et al*, 2011)? Would direct instruments such as individual subsidies for R&D result in a higher economic return than indirect network incentives? The above analysis calls for more moderation, and invites to not reject the arguments of network failures supporters. But it also invites in dealing with network positive effects more in depth than what was made in policy guidelines, in which the fuzziness argument of clusters relational density was recurrently supported. By relating the concept of network failures on the two micro-founded statistical signatures of knowledge networks outlined above, it is now possible to capture the topological properties of long run successful clusters. These latter are suited to design better targeted cluster policies, based on possible missing links identified from cluster preliminary diagnosis. Such a renewed approach of cluster policies goes beyond the "one size fits all" and "cookie cutter" dimensions of traditional approaches of public intervention (Wolfe and Gertler, 2004; Tödtling and Trippl, 2005), since it substitutes a generalized and unconditional increasing of collaborations for more surgical and certainly less costly collaborative incentives.

As a matter of fact, based on the outcome of clusters diagnosis, a wide range of interventions can be implemented. In an extreme but important case, *laissez-faire* can be a perfectly suited policy for clusters that have historically succeeded in structuring good properties for knowledge flows. These clusters are the ones that along their growth have achieved the right combination between a core of a couple of hub companies able to coordinate separated pieces of knowledge to compete on mass-markets and a sufficient openness towards new entrants, at the frontiers of technological domains. In this kind of clusters structuring, the positive effects of transversality and knowledge recombination

allow them maintaining explorative capabilities and enduring new market opportunities. Typically, applying traditional cluster policy toolbox for these successful clusters engenders negative policy returns. In that case, the crowding-out effects associated to public subsidies could be at their maximum, since the organizations will try to capture public resources for collaborations that they would in any case have built. If market failure-based interventions still remain relevant, network-based-ones can be unproductive if they consist in giving money to organizations that could be willing to support themselves the risks and the benefits of collaboration.

At the reverse, some clusters can display more salient network failures. Two cases can be distinguished:

- Firstly, at a given level of network hierarchy, the public intervention can focus on the level of network assortativity within the cluster. Such a ties-oriented policy design can be suited to repair a lack of connectedness between core and non-core organizations, targeting subsidies towards a higher level of collaborations between central organizations or local incumbents, well-established on markets, and new entrants such SMEs, start-up and spin-offs, which gravitate at the periphery. Without weakening the core, this kind of public intervention reinforces the capacity of clusters to maintain explorative capabilities besides their experience of mass-market exploitation. Compared to less risky traditional cluster policies aiming at supporting mature and well-experienced knowledge networks, this surgical policy intermediation could allow clusters avoiding an excessive reinforcement of their core and better adapting to unstable market demands (Boschma, 2014). Conversely, policy makers can draw from its cluster diagnosis an insufficient level of cohesiveness into the core-structuring of the cluster. This level can be the mark of an inability of the central organizations to coordinate themselves in technological domains in which technological and strategic interoperability and compatibility are the rules (Vicente *et al*., 2011; Balland *et al*., 2013). In that case, the surgical intervention has to focus on incentives for collaborations that target at some links that miss in cluster to win the battle of technological standards.

- Secondly, a cluster can display network failures that concern its difficulties to reach a sufficient level of ossification of its core, and thus an insufficient level of hierarchy. Such an actor-oriented policy, which plays this time on the degree of organizations, is particularly suited for clusters which do not achieve maturity, due to a lack of coordination capabilities of the more central organizations. In that case, public intervention aims at producing incentives for a higher hierarchy, favouring the relational capabilities of a couple of organizations. Typically dedicated to emerging clusters, this targeted policy is suited for clusters which want to reach a better place in the hierarchy of competing clusters in a particular technological or market domain. At the reverse, for clusters that have reached maturity, this particular intervention increases the risks of windfall pay-offs so criticized by market-failures

supporters. The policy maker can also observe an excessive number of isolated organizations and thus can reinforce the lower part of the hierarchy curve, by increasing the degree of peripheral organizations, and favouring the connectedness to the cluster of new and isolated entrants.

Playing together or distinctly with ties and actor-oriented policy, meaning with the distribution of links or the degree of some particular organizations, can significantly increase the economic returns of cluster policies compared to traditional interventions that rely on an unconditional intensification of collaborations. Considering that density of clusters increases their performance signifies either that knowledge accessibility and exchange only prevail or unintended knowledge spillovers have never existed, or to admit that windfall payoffs exist and organizations capture public resources without necessarily engage themselves in collaboration. The two statistical signatures of local knowledge networks we have defined allow going beyond this debate. According to the actual structural properties of clusters and their maturity degree, these two signatures favour a better targeting of public incentives and subsidies on particular missing links. And since these properties rely of a clear definition of what a successful cluster is and what the drivers of competing clusters are, they allow having a better understanding of what topological properties clusters have to display if they want together to establish themselves on mass-markets, to avoid conformism, and to maintain explorative capabilities. Coping with the rising criticism on the under-efficiency of network-based cluster policies, our analysis invites to save the cluster policy baby from the drowning. Network failures actually exist, but repairing them requires a less beatific view of networks and collaboration, and requires looking deeper into the complex links between the structural organization of networks and the drivers of innovation on the long run. With a forceful argument in an austerity context: by limiting public incentives and subsidies on particular missing links in clusters, public expenses and crowding-out effects are considerably reduced, and thus cluster policies could get their legitimacy back.

7. Conclusion

In the lines of the growing tendency to put into question the economic returns of cluster policies, this paper has tried to search micro foundations that can offer to the network failure concept some more robust analytical arguments. Indeed, on a one side, market failures-based researches have always been introduced on the basis of more or less disembedded strategic choices, with a strong focus on the role of unintended knowledge spillovers and the resulting means to restore and maintain a high level of individual incentives to innovate. At the opposite and on the other side, network failures-based researches have too often emphasized the holistic arguments such trust and shared cultural values to explain the role of local networks in regional innovation, explaining the progressive shift of public interventions towards public subsidies and incentives for reinforcing knowledge collaborations in

regions. But, in return, and according to market failures supporters, such a shift is not clearly convincing and supported by empirical evidence.

Our attempt to introduce micro-foundations into the definition of network failures allows solving, at least partially, what at first glance looks like a dialogue of the deaf. Considering that knowledge spillovers displays unintended and intended sides, as Breschi and Lissoni (2001) previously did, offers the possibility to explain how organizations manage their own trade-off between knowledge accessibility and appropriation, and thus, at the aggregate level, how networks emerge from the strategic choices of co-located organizations. This knowledge trade-off justifies the role of collaborative incentives to innovate, besides traditional individual ones, so that finally, market and network failures exist and complement each other's. But the composite nature of innovation processes and the necessity for regions to compete in the battle of places while maintaining explorative capabilities requires particular structures of knowledge networks. The recent lessons of network theories provide new insights for that purpose, and the two statistical signatures highlighted in this paper clearly show that a univocal criterion of network density can be underproductive. Our results show that hierarchical and disassortative clusters perform better than others, as recently evidenced by Crespo *et al*. (2013), since they succeed in combining a sufficient process of ossification around a couple of highly connected organizations and a high level of connectedness between these core-organizations and more loosely connected ones. This ossification process is important. Without that, the cluster cannot establish itself on mature markets. And the connections of peripheral organizations to the core are also crucial, since they constitute the matrix of knowledge flows through which fresh and new ideas can be turned into future markets.

Following our findings, we understand why all the studies on the appraisal of the role of clusters policy on regional innovation give sometimes divergent results (Falck *et al*., 2010; Martin *et al*., 2011; Nishimura and Okamuro, 2011; Broekel, 2013; Martin *et al*. 2013; Brossard and Moussa, 2014). The topological forms of the networks which result from the policy are more important than the existence or not of this policy in regions. Besides market and network failures, a kind of government failure could arise, when policy makers design policies that, by increasing relational density, tend to reinforce the core of existing clusters against the periphery, and thus sclerose creativity and resilience capabilities. In particular, the archetypal system of calls for collaborative proposal that typifies many clusters policies around the world is highly responsible of such government failures. Indeed, public fund raisers that launch these calls being conscious of the informational asymmetries between them and the applicants, they prone to develop selection routines that decrease the risks. Therefore, the more organizations are experienced in past collaborations, the more they win together the selection process. This path dependent process decreases the risks for policy makers, but by increasing network assortativity, it can explain the weak return of cluster policies evidenced by the market failure supporters.

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