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Social Networks across Spatial Agglomerations: the Paradox of High-Tech Clusters. A Critical Revision of Clusters

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Social Networks across Spatial Agglomerations: the Paradox of High-Tech Clusters. A Critical Revision of Clusters

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Resumen: This paper analyzes a fundamental gap research in high-tech clusters surveying literature in a critical perspective: the paper evidenced the taken-for-granted assumption that knowledge spillovers (KS) are unique assets conveying flows of knowledge in clusters, arguing the importance of traded interactions based on market transaction conditions which occur in clusters, even beyond spatial social networks. In the case of high-tech clusters: which is the type of interactions occurring in clusters when there is a manifested lack of local social networks? Results suggest that under analytical (versus synthetic) knowledge base in clusters, the formal and traded commercial partnerships are also interactions (assets) available in clusters, beyond the traditionally claimed un-traded KS and not being restricted to spatial conditions but to global circuits of knowledge which complement the lack of local resources in high-tech clusters. High-tech clusters surveyed do not show the high levels of inter-firm collaboration that cluster theory predicts.

Key words: high-tech clusters, co-located firms, networks, spillovers, traded vs un-traded interactions.

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1 Introduction

The study of clusters/industrial districts have evidenced the importance of local knowledge and spatial social networks (e.g. Asheim and Coenen, 2005; Hervás-Oliver and Albors-Garrigos, 2007; da Rocha, Kury and Monteiro, 2009), as well as the national and global pipelines (e.g. Eraydin and Armatli-Köroğlu, 2005; Nadvi and Hilder, 2005). Nevertheless, some recent works have pointed out contradictory results about the assumed high levels of inter-firm collaboration that cluster theory predicts (Staber, 2009), specially in the high tech clusters (Eraydin and Armatli-Köroğlu, 2005; Moodysson, 2008). Our paper draws attention to this fact.

The rationality of the un-traded or pure knowledge spillovers (KS, hereinafter) claimed in clusters¹ is that the geographical proximity provides unintentional contacts and interactions which foster the knowledge creation and diffusion and thus the technological learning among the co-located firms is achieved in a more satisfactory way. Thus, KS are a key ingredient of innovation (e.g. Griliches, 1979; Jaffe et al., 1993) sustained by the mainly informal relationships which occur within social networks. Thus, externalities *or* KS are claimed to be the fundamental benefits that a co-located firm can gain in a cluster (e.g. Storper 1995; Harrison, 1991) due to the access to local available knowledge. Externalities are defined as dense tied networks which allow and promote tacit knowledge transmission and trust (Uzzi, 1996), and a paradoxical combination of co-operation and competition in the territory (Harrison, 1991)². Grossman and Helpman (1992:16) defined technological spillovers as firms who can access information created by others without paying in a market transaction and the current owners have no effective recourse.

Nevertheless, the clusters in high-tech industries have pointed out an unanswered question which has become a paradox. There is evidence that KS occur predominantly in knowledge-intensive sectors (e.g. Audretsch and Feldman, 1996b). Nevertheless, recent works covering high-tech clusters (e.g. Huber, 2010, Moodysson, 2008) have empirically proved that there is an almost absence of local social networks but interactions occur mainly in a non-local scale. Put differently, it seems that the high-tech clusters (biotech, software and so forth) lack of local social networks, which are a core driver of knowledge spillovers. In this chain of thought, how is knowledge created in these type of clusters? Is there any relationship between the type of knowledge base observed in these clusters and the lack of spatial social networks? Is the argument about un-traded KS valid in these clusters? This paper covers this gaps by surveying literature about high-tech clusters and analyzing the interactions which occur within them. In so doing, the paper finds clear contradictions about one of the taken-for-granted assumptions in the cluster literature, i.e. the existence of local social networks. In addition, the paper addresses the interplay between the un-intended and the voluntary flows of knowledge which occurs in high-tech clusters. In so doing, the paper integrates the fragmented literature about clusters and presents implications for policymakers to facilitate the creation and diffusion of knowledge in clusters, thus opening new research avenues for the Academia. The organization

of the paper is as follows: the next section presents a critical survey of the concept of externalities, emphasizing the traded ones. Then, the third section unfolds the nature of the interactions in high-tech clusters. The fourth section analyzes the type of knowledge base in high-tech clusters and their paradox. In the last section, the paper offers an integration of the main findings and a conclusion with implications for the Academia and policymakers.

2 Traded or un-traded interactions? An classic approach to high-tech clusters

The local buzz claimed in the literature, which occurs in the trade associations meetings and training programmes, conferences, fairs, conventions, relationships between co-located competitors and interactions along the firms in the value network, i.e. customers and suppliers, is claimed to be one of the most important assets for co-located firms learning and innovation. The literature pointed out that the KS takes place mainly through local labour mobility, spin-offs and also with interactions between staff of different local firms (e.g. Saxenian, 1994). In the classical literature, the aforementioned externalities are separated into two groups, the pecuniary, rent or static externalities, those embracing economies of specialization and labour market economies; and the knowledge spillovers, which clearly represent the technological externalities (e.g. Scitovsky, 1954). In fact, the static or rent externalities, which represent about one-fifth to one-half of the observed geographic concentrations according to Ellison and Glaeser (1999), have been less studied in cluster literature which mainly addresses the KS. Carlsson et al. (2002) distinguishes between the *unintentionally* technological spillover, i.e. un-traded in the Storper's (1995) sense, and the *intentional* transfer of knowledge. This division between intentional and unintentional is fundamental. While the unintentional is mainly covered by the un-traded idea, the intentional can be referred to traded (market-based transaction) flows of knowledge. In the cluster literature the un-traded flows have been a central part of the theory. In this work we have adopted the idea of Scitovsky (1954) to label traded transactions, such as those occurring in a voluntary and pecuniary way. Thus, access to clusters resources is obtained through informal inter-firm ties and personal interactions (e.g. Camagni, 1991; Capello and Faggian, 2005). Nevertheless, there are also explicit and intended acts of collective learning in networks (Crevoisier, 2004). As such, our paper presents an attempt to cover the gap research manifested in the cluster literature which has been more focused on adopting the un-traded perspective and has conducted less effort on the voluntary and pecuniary transfers of knowledge. As Malmberg and Power (2005) pointed out, there is little evidence of formal linkages on local context. This is consistent with the idea that *KS are not the only flows of knowledge available in clusters, neither all clusters produce KS* (e.g. Breschi and Lissoni, 2001), nor all KS can be appropriated by co-located firms (Lissoni, 2001). Quoting Breschi and Lissoni (2001:976):

“...the meaning of the localized knowledge spillovers (LKS)-buzzword....has been recently used as if it could encompass any kind of localized knowledge flows...” “....LKS provides the researcher with an escape route to avoid studying the specific mechanisms through which the two phenomena (geography and innovation) are linked”.

The main problem suggested by Breschi and Lissoni (2001) is the fact that empirical papers do not distinguish pecuniary/static and KS. In fact, it seems that some externalities provided in empirical papers are knowledge flows mediated by market mechanisms (Geroski and Walters, 1995). In addition, there are contributions which assume, rather than prove, the existence of KS (e.g. Feldman and Florida, 1994; Audretsch and Feldman, 1996a, Feldman and Audretsch, 1999). For instance, in Feldman and Florida (1994) it is pointed out that tacit knowledge is exchanged across industries by informal contacts. Put differently, it can be argued that in a cluster there are different types of assets and knowledge diffusion mechanisms (e.g. Tallman et al., 2004) in a multidimensional level (e.g. Breschi and Lissoni, 2001; Grabher and Ibert, 2006) not just restricted to KS.

Therefore, the debate about interactions in clusters should also pay attention complementary to the *traded linkages* which occur on market-based transaction forms. The reason to consider these interactions is because those traded are also assets in clusters and, at the same time, it is expected that the formal and informal flows of knowledge are to some extent overlapped. Illustrating the latter idea, let's take a look at Giuliani's (2007:151) statement, in which the intertwined flows occurring simultaneously are recognized:

“.....inter-firm business relationships which can be built both through market and socio-institutional motivations. For the sake of simplicity in data-collection this question does not allow market-based relationships to be disentangled from socio-institutional relationships.”

Following this chain of thought, the notion of un-traded interactions has been pushed to the limit and in most of the literature it seems that whatever interaction occurs in clusters is just informal or unintended (un-traded) linkages. In other words, everything seems to be reduced to the “cafeteria effect” (Camagni, 1991). Nevertheless, current empirical evidence rejects this effect (see e.g. Huber, 2010; Moddysson, 2008). Despite the recognition that traded interactions are intertwined with social and personal ties (Maillat, 1989; Scott, 1988), the literature seems to be placed on the extremities of the un-traded side. Therefore, there are some claims that point to the overrated significance given to knowledge spillovers (KS, hereinafter) (e.g. Scott, 2004; Breschi and Lissoni, 2001). To be more precise, Breschi and Lissoni (2001:976) reference the KS as a mere *black box* that is based on the fact that most of the externalities which take place in clusters are just pecuniary externalities which occur in clusters on a market-base. In this chain of thought, Ibrahim et al. (2009) explicitly pointed out the differing types of KS which occur in clusters, ranging from the local individual tacit (and informal) knowledge sources received in personal interactions, to the local explicit knowledge; and the local collective knowledge, which represents the general influence of being in a particular region and the overall effect of the environment on an individual area (Lawson and Lorenz, 1999). These results are in line with Grabher and Ibert (2006) about the multidimensionality of actors and levels in clusters. The evidence suggested that the local knowledge sources, from whatever described type found in technological clusters, do influence inventors in clusters, specifically in terms of the local-buzz. The Ibrahim's work defines KS in the un-traded sense. Nevertheless, the work recognizes as a limitation the

fact that intentional exchange of knowledge does occur in clusters, beyond the notion of spillovers' knowledge leakage.

Eventually, Antonelli, Patrucco and Quatraro (forthcoming), provide empirical evidence about the pecuniary knowledge externalities. They are defined *as the indirect interdependencies among actors that take place in markets for knowledge inputs via the price system* (pp.6). They are also the outcome of intentional actions and organized transactions which occur in the local space and complement and reinforce the un-traded interactions in clusters, *shaping the dynamic increasing returns observed in technological clusters* (pp. 7). This evidence, which supported the claims made by Breschi and Lissoni, among others, points out the fact that the benefits from co-location are not *in the air*, but they are rather due to intentional actions based on price (market-mechanism) in the markets for knowledge (e.g. Arora, Fosfuri and Gambardella, 2001). The purchase of R&D in universities or RTOs, consultancy services or technology-product joint provides agreements between firms which occur in the markets for knowledge in the form of organized transactions (e.g. Zucker, Darby and Armstrong, 1998) complement rather than substitute the un-traded flows of knowledge. Put differently, the regional proximity and their social (un-traded) benefits (building trust, sharing common understandings and so forth) support and reinforce the flows of transactions (traded) between actors, as pointed out in Jenkins and Tallman (2010).

Kesidou's et al. (2009) work on the software cluster in Montevideo pointed out that quasi knowledge transactions (rather than KS) are the key flows of knowledge to innovation, specially the transactions with customers, although, it also proves the importance of local KS. In addition, the knowledge transactions are more related to the organizational aspects of the firm than the KS which are more connected to innovation. There is evidence which suggests that the traded interactions are a pre-requisite for successful informal knowledge sharing (e.g. Lissoni, 2001; Juan-Li et al., 2010). Thus, it is claimed that joint projects between organizations increase trust among employees and the informal networks are developed (e.g. Cross et al., 2002; Allen et al., 2007). Thus, it is expected that joint projects foster an alignment of norms, codes and identity (e.g. Wenger et al., 2002). In the specific case of firm and universities interactions Breschi and Lissoni (2001) are critical to the taken-for-granted assumptions and pointed out that knowledge flows mainly through pecuniary channels (consultancy, joint research, formal research and so forth). Quoting Breschi and Lissoni (2001:993) critique:

"....the so-often cited face-to-face contacts may serve only to ease the access to *information* about *who knows what and where is employed*, which is the only public good".

As such, what appears to be involuntary KS is actually well-regulated knowledge flows (Breschi and Lissoni, 2001), specifically those coming from university-firms interaction. Another interesting result from the Lissoni's work is that public labs and universities are absent from the communities in which the externalities occur. Reinforcing this point, Belussi, Sammarra and Sedita (2010) study about the linkages in the Emilia-Romagna regional innovation system evidenced that the firm-to-public research organizations (PROs, hereinafter) are much more intensive than the firm-to-firm linkages and those take the form of formal and traded R&D projects and research activities.

Confirming this view, Jenkins and Tallman (2010) argue that knowledge flows are more effectively conveyed between formal alliances partners, even within a cluster, because this type of channel is more productive than those between partners, based upon informal interactions (Almeida and Kogut, 1999; Gomes-Casseres et al., 2006). However, the informal relationships that exist around the formal ones moderate the transfer (Jenkins and Tallman, 2010:613). This perspective is also reinforced in several works (e.g. Trippel et al., 2009; Kesidou et al., 2009; Tsang, 2005) which stress the differing role of formal (R&D collaborations, consulting, licences acquisition or the use of shared R&D facilities) and informal linkages (recruitment of alumni, personal relationships or the mobility of labour). Thus, research collaborations (i.e., formal networks) are also important mechanisms for the exchange of knowledge. Conversely, other scholars (Tsang, 2005) pointed out the minor importance of formal linkages, while the un-traded such as the scanning of research publications, and the mobility of labor (i.e., what we would term spillovers), claim to have more relevance. Thus, instead of face-to-face contacts in which involuntarily knowledge is exchanged, the interactions are voluntarily selected and arranged in formal ways. Again, quoting Moodysson (2008:463):

“The deliberate knowledge-building activities that were illustrated with examples presented here also indicate that different types of activities provide different preconditions for the exchange of knowledge. With regard to the content of the exchange, the analytical mode of knowledge creation seems to provide better conditions for transcending formal structures than does the synthetic mode, but real incentives for activating functional relations within or across established organizations or interorganizational alliances are based mainly on perceived risks and opportunities and the degree to which the individuals are embedded in pre-established communities. These communities are, at least the specific type of scientific and industrial activities analyzed in this study, globally, rather than locally, embedded”.

Nevertheless, when focusing just on interactions it seems that the formal linkages (e.g. in form of strategic alliances) are a pre-requisite for un-traded flows to occur (Almeida et al., 2003; Owen-Smith and Powell, 2004). The formal contracts enhance the acquisition of explicit knowledge (e.g. Reurer and Ariño, 2007) and also tacit knowledge strengthens the relational mechanisms (Juan-Li et al., 2010). Put differently, the combination of formal (contractual, voluntary) and informal governance mechanisms (social, involuntary) show that local knowledge acquisition is more effective (Juan-Li et al., 2010). The logic would be as follows, for biotech clusters, quoting Owen-Smith and Powell, (2004:7):

“...formal ties among regionally agglomerated organizations are important in accounting for innovation to the extent that they signal membership in a local technological community. Such membership offers firms access to information transmitted through informal networks channels....”

Thus, accessing knowledge requires being part of the club, fact which also includes other forms of distance (in the sense of Boschma, 2005). In this vein, Deeds and, DeCarolis and Coombs (1999:216) described

perfectly the idea of *club*, pointed out in Breschi and Lissoni (2001) and Lissoni (2001), for high-tech pharmaceutical firms:

In the 'science club' membership is dependent upon the creation and dissemination of new knowledge (Dasgupta and David 1994, McMillan, Klavans, and Hamilton 1995). The informal exchange of information that occurs at conferences and seminars,.....is very valuable to new product development, but access to these information sources is limited to 'scientific club' members (della Valle and Gambardella 1993). It is the publication record of individuals, labs, and firms that are used to determine membership into the 'club' (McMillan, Klavans, and Hamilton 1995). In fact, publication record has been found to be highly correlated with the desirability of a pharmaceutical firm as an employer by Ph.D. students and Post-docs (McMillan and Deeds, 1997)

3 High-tech clusters and the paradox of spatial social networks

In the clusters of Oxfordshire and Cambridgeshire the empirical evidence proclaims that a significant number of highly skilled scientists and engineers *have no social networks*, especially in the local context. On the contrary, the non-local (global pipelines) are more abundant (Huber, 2010; Waters and Lawton-Smith, 2008; Moodysson, 2008; Boshuizen et al., 2009; Romijn and Albaladejo, 2002) than the local ones. These results are in line with those which claimed that (Bunnell and Coe 2001; Amin and Cohendet 2004; Lagendijk and Oinas 2005; Trippel et al., 2009) interactions with distant providers of knowledge are also important. Moodysson's (2008) findings reveal that local buzz is largely absent in the Swedish part of the Medicon Valley life science region, where knowledge creation appears embedded in globally configured professional knowledge communities and attainable only by those who qualify. Complementing this argument, Moodysson and Jonsson (2007) state that global knowledge collaboration is indispensable for most biotech firms in the same mentioned cluster, i.e. the local collaboration can never replace the necessary specialized knowledge found on a global arena. Similarly, Van Geenhuizen (2008) found that local/regional and global networks tend to coexist in biotech clusters in Netherlands, although it is a fact that knowledge networks trend are increasingly shaped on a global scale.

In the specific case of biotech clusters, biotechnology firms from different clusters have tried to avoid the lack of local expertise or knowledge with out-of-cluster *linkages* with organizations. In the case of Boston, there are more collaborations between local biotechnology firms and public research organizations in Boston than other regions in the US, but these same firms were also more externally connected than was the case in other regions through collaborations with public research organizations, venture capital firms and pharmaceutical corporations (Owen-Smith et al., 2002: 37–38; Powell et al., 2002: 302–303). Following other examples in high-tech industries, the case of cluster in the biotech industry in Australia (Thorburn, 1999: 252), Lombardy (Breschi et al., 2001), France (Mangematin et al., 2003), Sweden (McKelvey et al., 2003), Vancouver (Rees, 2005), Portugal (Fontes, 2005), Medicon clusters in Sweden-Denmark (Moodysson, 2008) or the ICT cluster in Cambridge (Huber, 2010), all of them, provide evidence about the

limitations of local interactions and the necessity of promoting external collaborations. In the case of Sweden, McKelvey et al. pointed out that less than a quarter of all R&D collaborations in the Swedish bio-cluster occur between two Swedish pharmaceutical giants which do not collaborate with other local firms (2003: 497). Thus, it is observed mainly an international social network beyond the local agglomeration.³ Eventually, Gilding (2008) study of the biotech cluster in Australia also find evidence about the crucial importance of the collaborations with more international partners than local and national partners. It seems that in the biotech clusters there is a general search for knowledge and capabilities not available locally (e.g. Fontes, 2005; Rees, 2005; Gilding, 2008; Moodysson, 2008; Huber, 2010). Similarly, Alecke et al. (2006) study about the high tech concentrations of the German industry found evidence for input sharing (specialized service inputs) at the county level, for labour market pooling at the more aggregate planning region level and no evidence for knowledge spillovers, confirming Rosenthal and Strange (2001) evidence about the fact that in the high tech German clusters there is only very weak, if any, evidence for spatially bounded knowledge spillovers within an industry and that there are different agglomeration forces at work at different levels of spatial aggregation. Eventually, Eraydin and Armatli-Köroğlu (2005) also found that the key importance of all different levels of interactions, i.e. local and national networking as well as global linkages, and confirmed the positive relation between intensity of local networking and innovativeness. Nevertheless, the high-tech cluster in this Turkey analysis, Ankara (machinery, electronics, defence industry and software) is the one which presents a really Weak collaborative environment whereas the more traditional ones (textiles, Denizli and Bursa) show more cooperation.

Following Narula and Santangelo (2008) study about the relationship between geographical aspects (co-location) and the selection of alliance partners in R&D, it is evidenced that R&D alliances can act both (1) as a substitute for co-location, in the case in which a firm is not interested on leaking unintended flows of knowledge, and (2) as a complementary mechanism, in which a firm engage in an alliance in order to co-operate and monitor their competitors when overlapping in similar institutional context is important to promote collaboration. Put differently, firms can engage in formal alliances or **social networks beyond spatial networks** and thus avoiding co-location in order to prevent unintended leaks of knowledge, i.e. spill-overs. In this particular case, the *private* good aspect of knowledge is more important than the *public* good aspect (Iammarino and McCann, 2006). In this vein, Polanyi (1958) or Rosenberg (1982), among others, pointed out that unlike public goods, the spill-overs of technological knowledge are not easy and rather present substantial costs. In this vein, firms do not always collocate because they wish to benefit from knowledge transfers (intended or unintended), but simply to have access to the same location-specific assets (Cantwell and Iammarino, 2003), such as well-reputed universities or skilled labour pool. Put differently, technically advanced firms prefer being proximate to universities, and are disinterested in locating close to other firms in the same industry, whereas less competitive firms prefer to locate close to rivals (Alcácer and Chung, 2007). It seems that the former try to avoid knowledge leaks and the latter are looking for them.

4. Types of knowledge and the paradox of high-tech clusters.

Thus, the specific type of knowledge created in clusters and industries (*analytical* versus *synthetic*⁴) is an important moderator (Moodysson 2008) of the type of interactions and ways in which the knowledge will be created and diffused. Following Asheim and Coenen (2005: 1176) an analytical knowledge base refers to industrial settings, where scientific knowledge is highly important. In this case the firms typically have their own R&D departments but they rely also on the research results of universities and other research organisations in their innovation process, using frequently the research or scientific base (mainly University–industry links). In addition, the knowledge inputs and outputs are in this type of knowledge base more often codified than in the other type. On the contrary, a synthetic knowledge base refers to industrial settings, where the innovation takes place mainly through the application of existing knowledge or through new combinations of knowledge, shaping a pattern mainly based on incremental innovation in response to the need to solve specific problems coming up in the interaction with clients and suppliers. In this case, among other the traditional clusters can be placed. In the former type there is a high presence of radical innovation and the codified knowledge is prominent through publications and patents, whereas the latter present a dominance of tacit⁵ knowledge due to more concrete know-how, craft and practical skills.

Addressing clusters which are mainly based on synthetic knowledge (see examples in Asheim and Coenen 2005), such as food cluster in Rogaland, it is evident that the linkages of the industry with RTOs such as the ‘Norconserv’ (the Norwegian Institute for Fish Processing and Preservation Technology), the Norwegian Crop Research Institute, the University in Stavanger or even out of the cluster linkages with Norwegian Institute for Fishery and Aquaculture Research in Tromsø. Similarly, the electronics cluster in Horten companies (Asheim and Coenen, 2005) has even grown out beyond the cluster and the national innovation system, in an increasing collaboration with firms and R&D institutes on an international level. The latter example shows by itself some absence of local buzz and most probable traded linkages rather than spontaneous or un-traded, especially with national and international public and private partners. To illustrate the last idea we use a biotech cluster analyzed in Moodysson’s work (2008:463) which shows that the local buzz does not occur in the Medicon cluster in Sweden.

“As an example, colleagues are usually not just colleagues; their professional relations develop into friendship relations. Concomitantly, friendship relations are unlikely to develop if there is no organizational structure within which meetings (interaction) can take place. People in a region or local area (like a science park or university campus) seldom exchange knowledge as a result of just bumping into each other, and it is unlikely that durable friendships are established just as a result of collocation”.

Complementary, Doring and Schnellenbach (2006:388) offers a similar view:

“Start-up firms in sectors such as biotechnology tend to settle in close proximity to renowned researchers in this area and seek to establish *formal relation* with these individuals in order to appropriate KS” (italics and the black words mine).

The two pillars upholding the localized-knowledge-spillover argument are the assumed dimensions of (1) public-good and that of the (2) tacit nature of knowledge, which therefore implies that locally spilled-over knowledge is freely available (i.e., pure knowledge externalities) but requires for its effective transmission geographical proximity or, more specifically, informal observations or face-to-face contact. Then, which is the role played by spillovers in the different type of clusters? Answering this question implies first to point the different knowledge bases in clusters. Therefore, tacit knowledge is much more difficult to exchange or trade, and thus tends to be sticky and geographically less mobile (e.g. Malmberg, 1997). In industries where the tacit aspect is considerable, *ceteris paribus*, the propensity to geographically concentrate is higher (Cantwell and Santangelo, 1999, 2000; Iammarino and McCann, 2006) than in sectors where the knowledge being exchanged is codifiable. In fact, this is exactly one of our paper’s results. The high-tech clusters revised have basically analytical knowledge which transfer and diffusion is less spatially restricted than that of synthetic knowledge, being the latter mainly present in med and low-med tech clusters. This paper does not contradict nor minimize the importance of local knowledge and the cluster idea, especially due to the fact that the paper is focused on the interactions dimension of the spillover concept⁶. Nevertheless, the empirical revised evidence suggests that in high-tech clusters with analytical knowledge the non-local transactions can even be more active than the local one and thus the social *spatial* networks are rather overwhelming by the social non-local ones. As Criscuolo and Verspagen (2008) suggest the marginal cost of transmitting *codified* knowledge across geographic space does not depend on distance, the marginal cost of transmitting *tacit* knowledge increases with distance, and this facts seems to affect the creation of social networks and thus way the type and conditions of interactions which occur in clusters.

Therefore, the paradox is obvious: despite the fact that the industrial district literature has been mainly based on non-technological clusters⁷, there is evidence that KS are predominantly in knowledge-intensive sectors (e.g. Audretsch and Feldman, 1996b) and most of the literature assessing empirically KS is based on high-tech clusters (in the Silicon Valley, see Benner, 2003; in the Norcom wire-less cluster, see Dahl and Pedersen, 2005; software in Munich, see Grabher and Ibert, 2006; Motor Sport see Henry and Pinch, 2001; Telecommunication industry, see Ibrahim et al., 2009; software industry see Kesidou et al., 2009; Brescia mechanical cluster see Lissoni, 2001; wireless communications cluster see Østergaard, 2009). On the contrary, the literature has also embraced the KS in low and med tech clusters but mainly in a story-telling manner (e.g. clusters about the Terzia Italia). In addition, it is necessary to consider the point that, challenging the existence of social local networks in clusters (as Huber 2010 did), can be partially misguided in the sense that the aforementioned works treat KS just as informal interactions, but spin-offs and labour mobility, along with formal interactions, are also occurring in clusters and need to be added to

the debate. Thus, Almeida and Kogut (1999) and Casper (2007) suggest that the mobility of the science and engineering labour pool in a region increases the localized spillovers.

5 Discussion and conclusions

Therefore, when addressing high tech clusters in the literature, it is noted that some of the traditional taken-for-granted assumptions may be questioned and thus new conjectures should be adopted, specially referred to high-tech clusters, such as the existence of assets beyond the un-traded interactions on the global pipelines. Table 1 shows an attempt of classification from the literature revision.

Table 1 Summary of the revised assumptions and attempt of new classification

Clusters dimensions	Traditional assumptions in clusters	Perspectives for high-tech clusters
Spatial level of analysis	Meso and local network (Boggs and Rantisi, 2003 “relational turn”)	Meso, local and non-local network (e.g. Moodysson, 2008)
Policymaking target	Meso: clusters or RIS.	Meso, clusters and need to shift towards “club/networks” (Breschi and Lissoni, 2001). Also important global networks
Cluster knowledge and access by firms	Restricted to the co-located firms (i.e. geographic distance which automatically implies social network and sense of belonging)	Restricted and market-based. Even beyond spatial networks Networks of communities of practice, based on social ties and personal interactions; usually required previous formal relationships (co-joint projects, similar University, etc.); Networks of communities and mainly formal contracts or co-joint projects.
Distance	Being there (distance is necessary, but not sufficient, e.g. Boschma, 2005) but sociably interacting; Geographical; social; cognitive	Social interaction can be local and global. Geographical; cognitive; social. Also distance is not necessary (Jenkins and Tallman, 2010) specially on global circuits (Huber, 2010). Location and non-location possible (Lyons, 1995; Bunnell and Coe 2001; Amin and Cohendet 2004; Lagendijk and Oinas 2005); necessary global pipelines (Huber, 2010; Waters and Lawton-Smith, 2008; Moodysson, 2008; Boshuizen et al., 2009; Romijn and Albaladejo, 2002 Bunnell and Coe 2001; Amin and Cohendet 2004; Lagendijk and Oinas 2005; Trippel et al., 2009
Externalities	Knowledge spillovers	Knowledge spillovers and also traded knowledge
Knowledge property	Semi-public and club; basically common pool	Club (local and global) and mainly private
Vertical/horizontal interactions	Interactions which build trust and reputation reduce opportunistic behaviour,	Interactions and exchange of knowledge, mainly defined and regulated in contracts, although usually complemented by informal interactions and social capital
University-industry	Overwhelming by user-producer interactions mainly based on synthetic knowledge; possibility to tap into local social structures (Ostergaard, 2009)	Analytical knowledge dominance and frequent purchase of consultancy, R&D outsourcing and contracts (Mansfield, 1995; Zucker et al., 1998a,b; Almeida and Kogut, 1999)

The purpose of this paper is to present a paradox regarding high-tech clusters: the paper criticizes the taken-for-granted assumption that knowledge spillovers (KS) are the unique assets conveying flows of knowledge in clusters, arguing the importance of traded interactions based on market transaction conditions and also

pointing out the evidence about the lack of social networks in high-tech clusters in which analytical knowledge is the most important one. Thus, the paper contradicts the assumption that externalities, as un-traded interactions conveying flows of knowledge, are the unique valuable resource in clusters, without taking into account the voluntary or intended (traded) ones which occur at the local and non-local level transcending the spatial networks. Put differently, the networks' scope usually goes beyond local clusters, regarding high-tech clusters, and the knowledge exchange occurs within and across spatial social networks.

The paper pointed out the importance of networks, arguing that knowledge is not in the air but embedded in communities of practice co-located and also non-located. Thus, the access to networks in which the knowledge flow is not just a matter of distance (Boschma, 2005) or social capital (Uzzi, 1997). Confirming, Staber's (2009) results, there is an explanation about the fact that many studies of clusters have not been able to document the high levels of inter-firm collaboration that cluster theory predicts. As it is stated, the empirical evidence showed that learning is not always an interactive and communicative process, but it is often a biased process. The fundamental distinction between *learning with and from others* needs to be kept in mind to keep researchers from misapplying the concept of collective learning in situations where learning occurs without a commitment of actors to share knowledge, but an imitation from others.

The results also present and highlight important insights for policymakers, as well as the Academia. Thus, following the granted assumption that the knowledge is on the air within the cluster and not looking at the specific networks, companies and their knowledge repositories, among other factors, can arguably lead to naïve policy implications (Breschi and Lissoni, 2001) and the managerial and policymaking implications can be focus on the cluster rather than the networks or epistemic communities (Lissoni, 2001) in which externalities occur, addressing the complex and intertwined nature of traded and un-traded knowledge and paying more attention to the non-local nature of interactions which also are important in high-tech clusters. As Echeverri-Carroll and Brennan (1999:47) suggest, policy makers should provide infrastructure that intensifies external networks, due to the fact that clusters grow combining a mix of local and non-local transactions (Scott, 1998). In addition, the efforts to understand how non-local firms tap into local resources with non collocation, as suggested by Narula and Santangelo (2008) or Jenkins and Tallman (2010), is an interesting less explored research avenue for scholars in clusters and should require different policies to bridge local firms into global circuits of knowledge. The thriving of more knowledge-intensive industries in the developed countries and even the increasing knowledge-intensive activities in traditional clusters should be taken into account in order to understand the changing pattern of knowledge transfer and diffusion within clusters. Clusters are crucial due to the extraordinary way in which knowledge is collectively shared and created, but the spatial phenomena requires more insight to understand the evolving forces of the globalization process. In addition, there are some questions which still remain open, offering interesting research avenues for future research. In fact, due to the fact that engaging in networks within or across networks is not only social capital dependent, it is needed more insight about the firm-level requirements to engage in networks within and across clusters. For this purpose, it would be very

interesting to import organizational literature to complement the meso-level mainstream. In addition, the paper posits an emerging debate on the formal and traded commercial partnerships and deals (with suppliers, universities, public labs., and so forth) which are also assets available in clusters and constitute important flows of knowledge, both individually or in combination and support with the un-traded KS.

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ENDNOTES

¹ We recognize differences between clusters and industrial districts, due mainly to the social aspects of the latter. Nevertheless, in this paper we use clusters and industrial districts indistinctively.

² In addition, in clusters it has been evidenced other assets such as the *milieu* (Maillat, 1989), which can be subdivided into three aspects: *culture* (attitudes, knowledge, traditional crafts, information channels, class and job mobility, high social regard for profit and risk, a mixture of confidence and competence), and *infrastructure* (land availability, communications, social services, services to firms, "local banking").

³ See Narula and Santangelo (2009) for a comprehensive description of these examples.

⁴ See Laestadius's (1998) and Asheim and Gertler (2005) to extend the idea of analytical and synthetic.

⁵ In addition, Polany (1966) distinguished between tacit and explicit knowledge, stating that the non-codifiable nature makes transfer difficult and require face-to-face (f2f) interactions. The local buzz is the proper context for these frequent contacts. Nevertheless, it is claimed that this f2f interactions are more required due to the fact that, as Cowan et al., (2000) pointed out, understanding of tacit knowledge depends on the capability to decode, and not the lack of codification. In this vain, Arikan (2009) remarks this idea stating that the larger the tacit component of the knowledge, the stronger the inter-firm exchanges.

⁶ Casper (2007) identifies mechanisms by which social networks linked to career mobility emerged and became sustainable within the San Diego biotechnology cluster. Ties between individuals are created through joint employment within the same organization. Under this rule of tie formation, ties linking individuals across organizations are only formed through mobility, for each year between 1978 and 2005, shaping the patterns of career mobility across San Diego. In this case, unlike previous studies, the focus is not in the interactions but in the labour-mobility, which is also an important source of knowledge spill-overs. Similarly, Smith et al. (2005) work about Oxfordshire pointed out that the entrepreneurship and the spatial concentration of talented workers is a different, but related, to the existence of social networks.

⁷ For instance, not exhaustively, in Italy Brenta Shoes, ceramics in Sassuolo or textiles in Prato, in Spain, footwear in Alicante, ceramics in Castellon or textiles in Alcoi, see Ybarra, 1991.