METHODOLOGICAL ISSUES FOR THE EMPIRICS OF CLUSTERS AND NETWORKS IN COMPOSITE KNOWLEDGE DYNAMICS: AN EXPLORATORY STUDY OF THE TECHNOLOGCAL FIELD OF GNSS

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Abstract:
This paper aims to contribute to the empirical identification of the socio-cognitive properties of clusters by proposing methodological issues based on the social network analysis. We start with the detection of a composite knowledge dynamics rather than a territorial one. Such a consideration lets us to avoid the overestimation of the role played by geographical proximity between agents, and grasp its ambivalence in knowledge relations. Networks and clusters correspond to the complex aggregation process of bi or n-lateral relations in which agents can play heterogeneous structural roles. Their empirical reconstitution requires thus to gather located relational data, whereas their structural properties analysis requires to compute a set of indexes developed in the field of the social network analysis. Our theoretical considerations are tested in the technological field of GNSS (Global Satellite Navigation Systems). We propose a sample of knowledge relations based on collaborative R&D projects and discuss how this sample is outlined and why we can assume its representativeness. The network we obtain let us to show how the composite knowledge process gives rise to a structure with a peculiar combination of local and distant relations. Descriptive statistics and structural properties show the influence or the centrality of certain agents in the aggregate structure, and permit to discuss the complementarities between their heterogeneous knowledge profiles. Formal results are completed and confirmed by an interpretative discussion based on a run of semi-structured interviews.

Key-words: knowledge, cluster, network, gatekeeper, GNSS

JEL classification: O32, R12

1. Introduction

Clusters and networks can be viewed as peculiar meso or macro structures coming from the complex aggregation of bi or n-lateral relations between firms or institutions (Cowan, Jonard, Zimmermann, 2007). In the Economics of Knowledge, clusters and networks are subject to a growing attention due to the increasing observation of collective (or at least interactive) knowledge processes in many technological fields (Cooke, 2002). Several theoretical justifications can be provided to explain this trend. In this paper, we suppose that knowledge networks and clusters come from the complex aggregation of relational strategies between firms and/or research units which face a trade-off between appropriation (of) and accessibility (to) knowledge (Antonelli, 2006; Brossard, Vicente, 2007). Knowledge processes are nowadays composite ones, that is to say that they combine many interacting pieces of knowledge coming from different sectors. Firms have thus to combine internal and external knowledge by forming partnerships in order to assure good conditions of accessibility, or to integer their internal knowledge in larger technological systems. But they have also to maintain an high degree of knowledge appropriation in order to preserve their monopolistic position on trades, which can render knowledge partnerships uncertain, due to the risk of uncontrolled knowledge spillovers. This general assumption is significant in this work because it confirms that clusters or networks are not the *panacea* of knowledge-based firms competitiveness. They correspond to peculiar structures within which firms or institutions consider that the benefits of accessibility to external knowledge exceed the risks of under appropriation of their own internal knowledge.

The second significant assumption of this work is that space matters in knowledge interactions. This is not an astounding assumption. Nevertheless, the fact that space matters does not signify that geographical proximity between firms, once again, is the *panacea* of their innovative and market performances. Saying that, we follow an emerging literature which takes with caution the univocally role of geographical proximity in collective knowledge processes (Boschma, 2005), the excessive weight associated to local knowledge spillovers (Breschi, Lissoni, 2001), the local clusters instability or life cycle (Vicente, Suire, 2007; Menzel, Fornahl, 2007), the role of distant knowledge interactions (Bathelt, Malmberg, Maskell, 2004), and the role of gatekeeper (Allen, 1977) firms play at the interface of local and global knowledge networks (Zimmermann, Rychen, 2008; Graf, 2007). If firms combine internal and external knowledge, they combine also local and distant interactions according to a set of critical parameters related to the cognitive dimensions of knowledge processes, such as their place in the knowledge value chain, their market geographical scale, and the respective absorptive capabilities of partners.

The aim of this paper is thus, theoretical considerations being admitted, to develop methodological issues in order to capture empirically the complex dimension of clusters and networks in technological fields. The first part stressed on the necessity to start from a peculiar composite knowledge dynamics rather than a territorial dynamics in order to avoid the overestimation of geographical proximity. We infer some general and testable propositions for the following parts. In particular we develop an analysis on the reasons why firms enter in partnerships according to their cognitive distance (Nooteboom, 2000) and the phase in the knowledge value chain (Cooke, 2002). The second part presents the context of study, the GNSS (Global Navigation Satellite Systems) technological field, which presents the main characteristics of a composite knowledge process crossing several knowledge fields and technological capabilities. We discuss the construction of the sample of data and the methodology of networks and clusters empirical construction. The third part presents the results coming from the matching between traditional structural properties of networks and more qualitative concerns related to the cognitive dimension of knowledge networks. Conclusions focus on the convergence with other works and on research perspectives.

2. Theoretical backgrounds: Composite knowledge dynamics in regional innovation systems

Literature acknowledges nowadays that clusters since the diffusion of Porter' ideas are not the *panacea* of knowledge-based region competitiveness (Martin, Sunley, 2003; Vicente, Suire, 2007). The role played by geographical proximity reveals ambivalences as far as empirical methodologies are developed in order to capture the complex links between knowledge processes and geographical proximity (or distance) (Boschma, 2005). One of the most convincing approaches consists in starting by the composite (and systemic) dimension of knowledge processes (Antonelli, 2006). Such a general assumption leads to focus on the knowledge relations between agents and so reconstitute knowledge networks through the aggregation of *bi* or *n*-lateral relations. In doing that, geographical clusters are not postulated, but result from the analysis of the structural properties of these networks. Starting from relations rather than places helps then to understand why and under what conditions knowledge spreads locally (or not) and so enter in the *black box* of local knowledge spillovers by avoiding the overestimation of geographical proximity (Breschi, Lissoni, 2001).

Many knowledge processes are composite and systemic because they combine interacting pieces of knowledge coming from more or less distant technological or organizational fields. Two main related implications of this property are critical to understand clusters and networks dynamics. First, knowledge processes gather agents who face a trade-off between the necessity for them to maintain proper conditions of appropriation of their internal knowledge and assure appropriate condition of accessibility to external and complementary knowledge. Second, this trade-off constitutes, under specific conditions, an incentive for agents to form partnerships. Clusters and networks appears then as the complex aggregation process of these partnerships.

2.1. Knowledge from knowledge: the appropriation/accessibility trade-off in bilateral knowledge relations

Knowledge is an input as well as an output of the production function (Foray, 2004, Antonelli, 2006), and the growth of convergence processes in many technological field had significantly raises the number and domains of technological and strategic alliances (Mowery & alii, 1996; Hagerdoorn & alii, 2000). Firms have to compete on markets by maintaining appropriate conditions of rent appropriation of their innovative activities while favoring accessibility to external and complementary knowledge. Partnerships are suitable strategies since firms anticipate that the benefits coming from the external knowledge accessibility exceed the risks of unintended knowledge spillovers (Brossard, Vicente, 2007). Two types of related critical parameters are empirically well-suited to understand how firms choose or not to form partnerships. The first one concerns the so-called cognitive distance which characterizes the knowledge bases of the respective partners (Nooteboom, 2000; Wuyts & alii, 2005), whereas the second one concerns the knowledge phases on which the partnership refers (Gilsing, Nooteboom, 2006; Cooke, 2006).

The basic idea is that when firms form partnerships in a very upstream explorative phase, the probability that a new knowledge emerge is greater that the cognitive distance between partners is sufficiently high to avoid a redundancy effect on knowledge capabilities. Nevertheless, an excess of cognitive distance engenders misunderstandings problems due to the resulting difference in the respective absorptive capabilities of partners. Reducing cognitive distance implies thus to strengthen the relation in order to reduce this original gap. Even if this strengthening increases the risk of unintended knowledge spillovers, the fact that firms compete in separate markets and perceive a mutual advantage to open a new technological window can be a strong motive to form explorative partnerships. Firms can also form more strategic (and less R&D intensive) partnerships in downstream exploitative phases. In this case, firms with close knowledge capabilities can perceive a mutual advantage not for producing new knowledge but for enhancing the diffusion of an existing knowledge and to consolidate it into a dominant design. In these very downstream phase, knowledge exists and the purpose for firms is to increase market power, market area, using mainly marketing agreements in order to diffuse largely codified and appropriated knowledge. But due to the closeness in the respective absorptive capabilities, the risks of unintended spillovers is higher than in the explorative phases so that firms generally weaken the intensity of the relation by focusing their collective effort on marketing rather than on R&D. If explorative and exploitative phases are typical to the knowledge process at the firm level, on the partnership level, an intermediate and empirically observable phase can be added: the examination phase (Cooke, 2006, Brossard, Vicente, 2007). When knowledge is fragmented between interacting agents, the traditional exploration and exploitation phases are not sufficient to understand the knowledge value chain, from technological discovery to diffusion. Firms can also find the opportunity to integrate their respective existing and more or less codified knowledge not for opening a new technological window, but for capturing direct and indirect networks externalities on the demand side. In this phase, firms try to increase the potential tradability of their respective knowledge by taking advantages of the systemic property of knowledge. One partner can take advantage of the integration of its technology into a large complementary installed base, whereas the installed base owner takes advantage of the increasing functionalities of its technology. The cognitive distance between partners can follow a continuum, being weak when the examination phase focuses on collective definition of a technological standard, or being higher when the partnership focuses on the integration of far but complementary knowledge. What distinguishes the exploitation and examination phases concerns the necessity for firms in the later to launch an additional R&D phase in order to resolve compatibility and interoperability constraints.

2.2. Clusters and networks from relations: structural and cognitive properties

The composite and systemic dimensions of knowledge processes engender partnerships which can differ according to the knowledge phase and according to the cognitive distance and the respective absorptive capabilities of the partners. Geographical clusters or sectoral/technological/cognitive networks cannot be defined or postulated *ex ante*, but have to be inferred from the complex aggregation process of these partnerships (Powell, Grodal, 2005; Cowan & alii, 2007).

The aggregation of relations in composite knowledge processes appears hence as an appropriate mean to avoid the overestimation of the role played by geographical proximity by adding “far relations”, and mixing clustering and pipelines effects (Bathelt & alii, 2004) in knowledge trends. In doing that, it becomes possible to test hypothesis on the links between cognitive distance, technological similarities or dissimilarities, and geographical proximity beyond bilateral relations but at the level of the structural properties of networks. The emerging aggregate structure can be moreover relevant for the identification of strategies agents play in order to manage their knowledge trade-off, access external knowledge or capture knowledge spillovers, … Network reconstitution is in consequence well-suited to capture agents that play heterogeneous roles in the whole of the knowledge value chain.

Going from bilateral relations to aggregate structures permits to study the role played by geographical and relational proximities in knowledge dynamics through the relevant set of concepts of the structural analysis of networks developed in sociology, economics and management

(Wassermann, Faust, 1994; Borgatti & alii, 2002; Powel, Grodal, 2005). This methodology has been used in a run of recent stimulant papers of regional science (Bell, Giuliani, 2005; Graf, 2008; Boschma, Ter wal, 2007), in order to capture cognitive and geographical properties of clusters and networks. By starting by the knowledge trade-off, it becomes possible to understand why geographical proximity is not the panacea of knowledge networks but rather why sometimes it plays efficiently and sometimes not, according to the set of the critical parameters of the knowledge value chain (knowledge phases, cognitive or technological distances and/or complementarities, the resulting risks of uncontrolled knowledge spillovers, the resulting benefits of direct and indirect network externalities). As a matter of fact, some technological or strategic partnerships match better with geographical proximity, whereas some others can be better favored by geographical distance. In exploration phases and part of examination phases in which partnerships are dedicated to convergent technological fields, collective knowledge processes can be a centripetal force because geographical proximity favors direct meetings, reduces the gap between the partner's absorptive capabilities and then, favors a better embeddedness in technological platforms. The argument of trust is generally outlined to support the role of geographical proximity (Nooteboon, 2000; Boschma, 2005), that can remain true but hardly to verify. An other argument can be outlined if we suppose that the risks of hold-up and unintended knowledge spillovers are reduced when cognitively distant firms compete originally in sufficiently differentiated market. In this case, trust can emerge more easily because each partner can be conscious that the gain which might result from their complementarities and interoperability is larger enough compared to the risk of knowledge strategic outflows. At the opposite, these risks of unintended knowledge spillovers is stronger when firms compete in technologically close markets. This situation is typical of partnerships in exploitation phase or part of examination phases in which firms are cognitively close. Firms have to join their knowledge only in the restrictive terms of the partnership in order to gain in critical mass, capture network externalities at the demand level, or extend the market power, but with a high degree of appropriation of their respective knowledge capabilities. In this peculiar case, knowledge is a centrifugal force so that geographical distance can appear as a benchmarking strategy of knowledge production. In these alliances, pipelines (Bathelt & alii, 2004) and temporary proximity (Torre, 2008) through travels and formal meetings are better well suited in order to favor knowledge accessibility (generally in production, commercial and marketing activities) by reducing the risks of knowledge hold-up and appropriation defaults.

Geographical proximity between firms can exhibit then ambivalent effects (Vicente, Suire, 2007) on the way that they manage the knowledge appropriability and accessibility trade-off. The ambivalence is stronger that:

(i) firms can be positioning on different phases of the knowledge value chain and thus combine local and non local relations with more or less cognitively distant partners;

(ii) once relations (local and non local) are aggregated, firms can have heterogeneous strategies and heterogeneous positions in clusters and networks;

(iii) the aggregate efficiency of clusters (density of geographical relations) can be the consequence of dense inside and outside relations, as well as strong homophile or not relations.

As said before, the study of the structural properties of networks is particularly well-suited to highlight these ambivalences because it permits to identify firms' profile and position, to give some measures of networks and clusters density, and to index critical parameters of these structural properties.

The following parts aim to give empirics of these theoretical considerations. For that, we have to identify a composite knowledge process. To avoid the over estimation of geographical proximity, we have to identify a cluster based on this composite knowledge process, but with all the relevant outside knowledge relations starting from the cluster. We have to gather data which are geographically and technologically labeled in order to study the structural properties of these knowledge dynamics in their cognitive and geographical aspects. The following parts thus present the context of the study, the data, the formal results and an extended interpretative discussion.

3. Context, data and methodology

3.1. GNSS: from a cumulative to a composite knowledge process

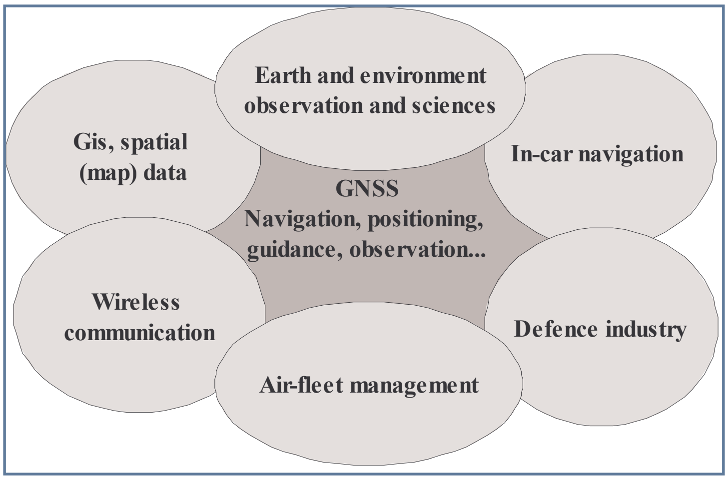

Fig1: the composite knowledge process in GNSS

GNSS (Global Navigation Satellite Systems) are technologies which present the characteristics of composite knowledge processes for at least two reasons. First (Fig.1), in the technological and symbolic paradigm of mobility (and sustainable development to a lesser extent), GNSS are technologies which find complementarities and integrative opportunities in many other technological and social contexts. In the past decades, these technologies were mainly used and developed in the cumulative context of defense industry (missile guidance) and aircraft industry (air fleet management), whereas several applications are nowadays developed in car industry, earth observation, tourism, telecommunication, safety, and so on. Second, GNSS present in addition a more vertical composite dimension, which is emblematic of the industrial organization of the general ICT sector, that's to say the complementarities between at least four levels: (i) The infrastructure level with all the spatial and ground infrastructures. (ii) The hardware level, including all the materials, devices and chipsets which receive, diffuse or improve the satellite signal. (iii) The software level, which concerns all the software applications using navigation and positioning data, and (iv) all the users and services segment, which concerns many heterogeneous agents and socioeconomic activities in which navigation and positioning technologies are introduced.

GNSS field is a world-wide technological field which combines clusters and pipelines, gathers a limited number of firms in the satellite and spatial infrastructure segment, several actors in the hardware and software segment, and a plethora of application-based firms. Silicon Valley in US, Bavarian cluster, Roma cluster and Midi-Pyrénées cluster are the main identified local structures which support an high density of GNSS firms. For reasons of tractability, we focus only on the knowledge relations starting from (and inside) Toulouse (Midi-Pyrénées), in order to study how composite knowledge processes combine local and non local relations, with a concern (i) of exhaustiveness in the data collect process, (ii) of complete network visualization (see below). Of course, comparing and interconnecting clusters could be also relevant in order to have an overall view of the technological field, but this is not the purpose of this paper which focuses and contributes more modestly on the renewal of cluster analysis.

3.2. The sample

Project name	Content of the project
SITEEG	Collect real-time information on traffic and pollution.
SSA-CAPYTOL	The applications ground / board for aeronautics
TRANSCONSTROL	Control the transport of dangerous materials.
TELEMED-AERO	Telemedicine in air transport
TSARS	Application of satellite transmission technology in risk management.
OURSES	Development of the ICT in rural and mountainous areas by setting up new satellite technologies.
FILONAS SDIS 31	Location system & communication for firefighters
Géo Marathon	GNSS application to track runners
SPSA	Supervision and GPS positioning for watering systems
LIAISON	Localization solutions using A-GPS tchnology combinated with Telecom networks
Sinergit	Provide traffic information in real time for motorists, professionals and managers of the road
GPS bus	Improve the management of public transport service delivered to users.
WI AERO	Tracking and management of mobile equipment used in major industrial centres.
AIR NET	Location system, identification and management of airport vehicles
CIVITAS MOBILIS	Using satellite navigation for reducing pollution in public transport
AVANTAGE	Guider disabled people to a specific destination with an optimal way.
BINAUR	Facilitate the mobility of visually impaired person with satellite navigation systems
Egnos bus	modelling multipath GPS in urban areas
Terranoos	Geo-referencing of the flora in the Pyrenees using the GPS and Egnos signal
TONICité	Digital guide for tourism in the city
Fil Vert 2006	Location of bike in a bike-cycling
Astro +	Using telecommunications, Earth observation and satellite navigation for rescue missions.
PYRENEO	Digital guide for tourism in mountains
ACRUSS	Analyse the behaviour of drivers with GNSS signal.
Geo-urgences	Optimize supervision in real time Hospital Mobile Units
CTS-SAT	Develop a new automatic transport module for person, guided by satellite
Safespot	Communication between vehicles and road infrastructure for road safety
3D Shop	Guidance in stadiums via mobile phone, 3D simulation

Table 1: GNSS collective projects of the sample

Data for the construction of knowledge networks come from a peculiar matching of several sources and a sequential process of data aggregation. First, an intensive desk work had permitted to gather all the main regional firms involved in the GNSS technological field, from space and ground infrastructures to applications and related services, and from big firms to SMEs and research units. In doing that, we have thereby constructed a sample of 27 knowledge collective projects in which these firms are involved (see table 1), which permitted by a "snow-ball effect" to gather other firms which bring complementary pieces of knowledge in the composite knowledge dynamics, inside and outside the region (see table 2). All of these projects are partly public funded, at the regional, national and European level. A complementary dataset of more than 200 strategic alliances in the GNSS industry has been constituted from an extraction of SDC platinum database in order to have a extended view of the worldwide network organization and knowledge value chain in this industry, and to have supplementary data on partnerships concerning the firms of our regional sample (mainly the alliances of the big regional ones). Second, we have completed this methodology by making semi-structured interviews (about 10 interviews of entrepreneurs and policy makers) in order to complete information and to have a better understanding of the knowledge value chain of this composite knowledge dynamics. These interviews are particularly well-suited for the interpretative discussion of the formal results (see below)

	firms		*total*	public research or standardization institutions		*total*	**total**
	local	non-local		local	non local		
Infrastructure (satellite, telecommunications)	3	17	*20*	2	7	*9*	**29**
Hardware (material, semi-conductors, chipsets, sensors, …)	9	6	*15*	0	0	*0*	**15**
Software (GIS, maps and all natigation and positionning software)	14	9	*23*	3	1	*4*	**27**
Uses and services (all users and GNSS dedicated services)	17	13	*30*	5	5	*10*	**40**
total	**43**	**45**	***88***	**10**	**13**	***23***	**111**

Table 3: basic characteristics of the sample

Such a methodology implies comments relating to its limitations and advantages. First, starting from projects is certainly on one side a non exhaustive way to capture all the relations between firms. More or less formal bi-lateral relations can be forgotten, but the advantage is that our analysis rests thereby on a clear definition of what knowledge relation is, and avoids the vagueness of the nature of the relations we can perceive when we try the capture relations through only interviews. In particular, the density of relations can be approximated with objectivity by using an index referring to the number of projects in which firms are pair wise involved, rather than a density of relation captured by a "weak, medium, strong" indicator in questionnaires which can be subject to caution due to the heterogeneous perception and subjectivity of interviewed entrepreneurs on what a knowledge relation is. Moreover, our sample pushes aside the partnerships of the defense industry which are difficult to capture. Nevertheless, our sample is representative (and close to be exhaustive) of all the partly public funding collective projects in the 2004-2008 period. Second, starting from projects is strongly dependent to the public funding which can be regional, national, European, and thus implies a funding dependant geographical scale of projects. Nevertheless, this limitation can be transformed into a convenient advantage since all these three scales of funding are present in our sample of projects in the GNSS industry. The aggregation of these projects and their transformation into a unified network structure permit thus to have a representative view of the embeddedness of regional firms into to the European GNSS knowledge dynamics and avoid to tend to over-focus on the regional dimension as in most clusters analysis. Third, starting from projects, in particular when projects are large scale ones, can engender on the other side an excess of relations because each partner is supposed to interact with all the others in the project, even if the density of relations can be actually differentiated, or inexistent in extreme cases. Nevertheless, this limitation can be over passed since these projects are consortia in which each partners can have a privileged access to the knowledge of the other project' partners, due to the steady stream of partners meetings. Because we are more interested in knowledge accessibility (and complementarities) rather than knowledge flows, knowledge projects seems relevant for our study.

3.3. The methodology

We use UCINET 6 software (Borgatti & alii, 2002) and Netdraw visualization tool in order to draw and study our network and its structural properties, its cognitive and geographical dimensions. We proceed in three steps. First, the weighted relations matrix is used to draw the network including spatial and knowledge value chain attributes (described in the table 3). Second, we present a set of formal results concerning all the relevant for our purpose and interpretable structural properties of the network. These properties concern mainly statistical properties of cohesion and accessibility, centrality properties and ego-network analysis for analyzing firms' profiles. Third, we complete formal results with an interpretative discussion based on interviews, in order to illustrate and confirm the main obtained results.

4. Formal results

4.1. The network

Figure 2 displays the GNSS network coming from the matching of the matrix of relations, the geographical attributes and segment/cognitive attributes.

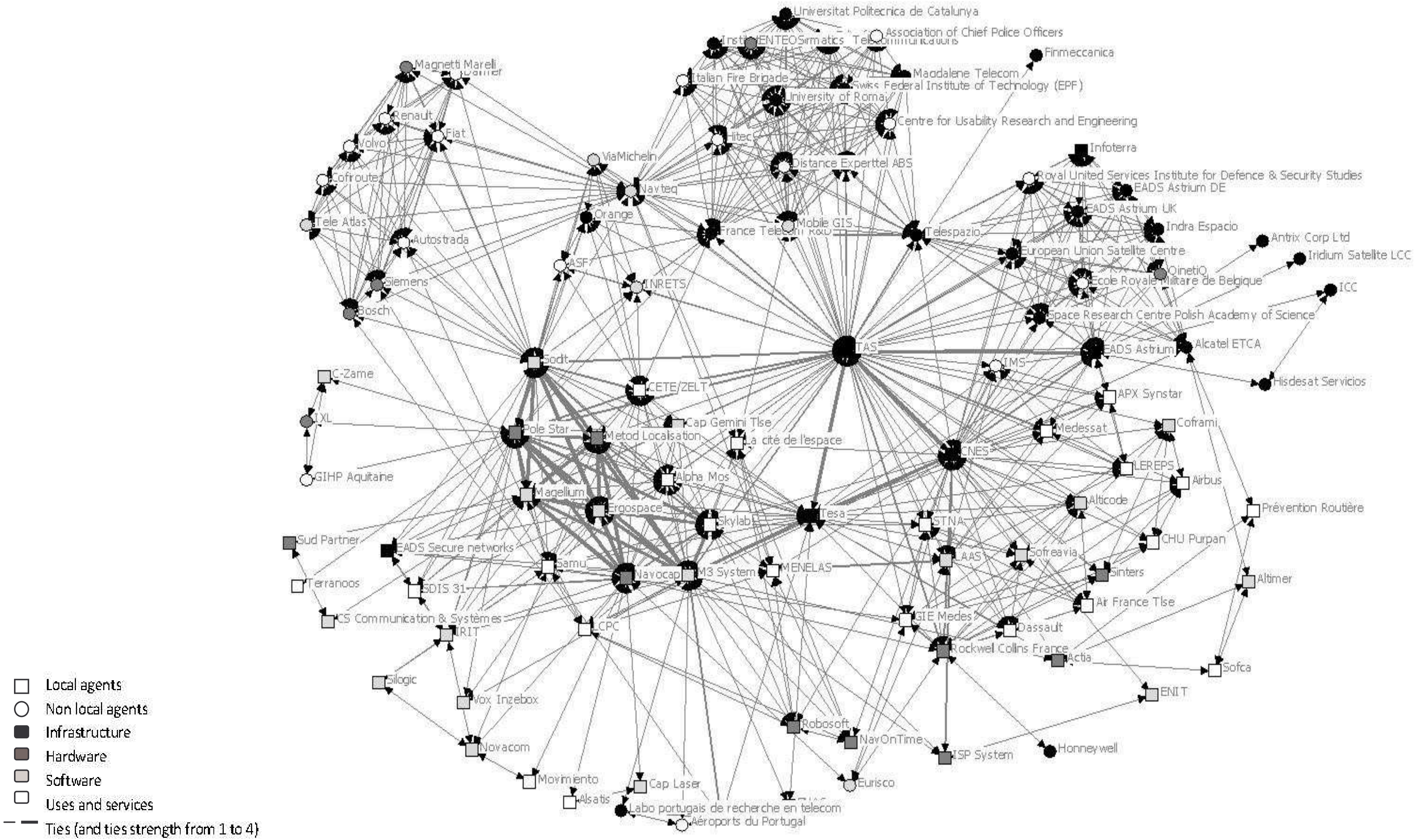

Fig 2 : GNSS network with ties weight and spatial and cognitive attributes of nodes

4.2. Descriptive statistics on relations including location and cognitive attributes of nodes

A first run of observations of the GNSS network can be extracted from statistical results linking ties (relations) density and attributes of nodes (agents). This "homophily" hypothesis supports the traditional idea in sociology that "close" agents tend to interact more than "distant" agents and thus the relational density will be stronger that agents present same characteristics or attributes. Here we distinguish geographical and cognitive or segment attributes, in order to have a distinctive view between what concerns geographical homophily and what concerns technological homophily.

Geographical categorical auto-correlation (join-count statistics, 10 000 iterations)					
	Expected	Observed	Difference	P >= Diff	P <= Diff
Local/local	141.337	243.000	101.663	0.000	1.000
Local/non local	321.472	120.000	-201.472	1.000	0.000
Non local/non local	176.191	276.000	99.809	0.000	1.000

Table 4 : statistic test on geographical homophily hypothsesis

Table 4 summarizes the geographical homophily statistics. This table shows that (observed) relations between firms inside the cluster are denser than if relations were randomly computed, whereas the number of relations between "insiders" and "outsiders" are weaker than the one obtained "by chance". This result supports the not surprising idea that geographical proximity facilitates contacts and knowledge relations opportunities, and thus, the GNSS network is not a random structure but a cohesive structure typical to clusters. Nevertheless, the relations between insiders and outsiders, even if they are weaker than the random structure, assure the cluster accessibility and openness, typical to the "small world" aggregate structure (Watts, 2004). The fact that relations between outsiders are greater than random relations is due to the size effect of the European collective projects of our sample and the hypothesis we state that all outsiders are pair wise connected.

Relational contingency in the knowledge value chain [index (cross frequency observed/expected values under model of independence)]				
	Infrastructure	Hardware	Software	Uses and services
Infrastructure	2.43 (196/80.58)	0.86 (41/47.75)	0.88 (68/77.60)	0.99 (118/119.38)
hardware	0.86 (41/47.75)	0.78 (20/25.58)	1.20 (53/44.34)	1.01 (69/68.22)
Software	0.88 (68/77.60)	1.20 (53/44.34)	0.92 (64/69.28)	0.86 (95/110.85)
Uses and services	0.99 (118/119.38)	1.01 (69/68.22)	0.86 (95/110.85)	0.66 (110/166.28)

Table 5 : statistic test on "segment & cognitive" homophily hypothesis

Table 5 presents more interesting results since it focuses on the indexes of cognitive and technological homophily, all geographical considerations being apart. By comparing observed relations frequencies (actual relations) and expected ones (random relations), we can have a first general observation, but clearly incomplete, on the composite knowledge dynamics, i.e links between nodes coming from different segments of the knowledge value chain. An index greater than 1 in the diagonal of the matrix suggests a strong homophily and thus the lack of knowledge "bridges" between nodes, whereas the number of knowledge "bridges" increases as far as the index moves from 1 to 0. For instance, in the infrastructure segment, the high index suggests the strong homophily of the segment, partly due to the multiple relations of exploitation EADS Astrium, one of the world wide major satellite company, had build with the others satellite company in the world, in order to develop an efficient constellation of satellites. At the opposite, users and GNSS-based services segment displays a weak homophily (as for hardware and software in a less extent), due to the necessity for these nodes to integer knowledge coming from the other segments in more or less upstream phases of the knowledge process. The other cells out of the diagonal display indexes close to 1, which it suggests that “knowledge bridges” are close to random ones and confirms thus that the GNSS technological field exhibits the properties of a composite knowledge process. The relative high index between hard and software suggests a not surprising high level of coordination between the two segments. This result is typical to the traditional industrial organization of the ICT sector, in which complementarity, compatibility and interoperability play a critical and imply relations.

These first results are very general but give an overall view of the geographical and technological organization of our sample by exhibiting a spatial clustered structure and a composite knowledge process. Now we have to improve the analysis by focusing on the structural properties of our GNSS network. In particular, it could be interesting to identify the influence and power some nodes play in the knowledge dynamics, as well as the heterogeneity (and complementarities) of their profile.

4.3. Centrality and power: who influence the knowledge dynamics and where are they?

Because relations are not randomly distributed in the geographical space as well as in the technological space, the resulting differentiation of relations will display a differentiation in the influence or the power agents play on the others. Many empirical analysis of clusters stressed on the role central firms play in the local knowledge dynamics. Good examples are the structural role of Hewlett-Packard in the Silicon Valley (Saxenian, 1994), the existence of hubs in technological districts (Markusen, 1996), or the role played by “fashion leaders” in ICT cluters (Vicente, Suire, 2007).
Network analysis proposes three main methods that permits to capture the position of nodes in the aggregate structure. These methods, which differ on their definition of the relational influence of nodes, are built on the concept of centrality. For the sake of clarity of the presentation, we present for each method the only top twenty central nodes.

Table 6 presents the results concerning the closeness centrality index based on path distances, that is to say the index that measures how close an agent is to others. The index increases as far as a node is closer to more nodes than any other node. The basic idea of this index for our purpose is that the more an agent is central, the more he is favored in knowledge accessibility because he is able to reach other agents at shorter path lengths than others. Without any surprise when we look at the network, TAS (Thales Alenia Space) display the stronger index of closeness centrality. This influential position is due to the fact that TAS is involved in many collective projects of the sample. Tesa and the CNES, two research institutes, are also central, following by the set of GNSS start-up located in Toulouse (see discussion below). The most surprising is that one of the major world-wide company of space and satellite industry, located in Toulouse, EADS Astrium, presents a closeness centrality index weaker than the one of at least three outsiders (Navteq, Telespazio and France Telecom R&D).

Top twenty closeness centrality index	
TAS	71.429
Tesa	57.592
CNES	57.292
M3 System	56.122
Sodit	55.838
Pole Star	54.187
Navocap	53.922
Skylab	53.140
Magellium	52.133
CETE/ZELT	52.133
Ergospace	51.887
Samu	51.887
Metod Localisation	51.643
Alpha Mos	50.926
Cap Gemini Tlse	50.926
Navteq	50.691
Telespazio	50.459
France Telecom R&D	49.774
EADS Astrium	48.889
Rockwell Collins France	47.826

Table 6: closeness centrality

	Top twenty centrality degree index	
	Nrmdegree	Share
TAS	18.349	0.055
Sodit	11.009	0.033
CNES	10.780	0.033
M3 System	10.780	0.033
Pole Star	10.092	0.031
Navocap	8.945	0.027
Tesa	8.257	0.025
Magellium	7.339	0.022
Ergospace	7.110	0.021
Skylab	6.881	0.021
Navteq	6.881	0.021
Metod Localisation	6.651	0.020
France Telecom R&D	5.963	0.018
EADS Astrium	5.963	0.018
Telespazio	5.734	0.017
CETE/ZELT	4.817	0.015
Rockwell Collins France	4.587	0.014
Mobile GIS	4.128	0.012
Samu	3.899	0.012
Hitec	3.899	0.012

Table 7: centrality degree

Table 7 presents the results concerning the degree centrality index (normalized), i.e the more a node has relations with others, the more he has opportunities to access external knowledge (even if for our purpose this position increases the risk of knowledge outflows and unintended spillovers). The results are close to the formers, whereas they change a little in table 8 when we suppose the betweenness centrality index. In this case, the relational influence is drawn from the ability of nodes in the network to posit themselves between other nodes, in order to carry out influence by broking knowledge diffusion between other nodes or by establishing themselves as a “leading” intermediary of the composite knowledge process. In this vision of influence and centrality, TAS keeps its “leader” place but one can observe the increasing influence of its direct local competitor compared to the closeness and degree approaches.

top twenty Freeman node betweenness index		
	Betweenness	nBetweenness
TAS	4746.757	40.322
Sodit	1296.387	11.012
CNES	1115.467	9.476
M3 System	1092.777	9.283
Pole Star	1032.198	8.768
Navocap	979.011	8.316
EADS Astrium	909.067	7.722
Tesa	863.173	7.332
Navteq	777.885	6.608
Magellium	462.535	3.929
Actia	399.244	3.391
Rockwell Collins France	311.468	2.646
Samu	292.713	2.487
Telespazio	283.827	2.411
Alcatel ETCA	232.089	1.972
Skylab	231.398	1.966
France Telecom R&D	193.144	1.641
LCPC	122.816	1.043
LAAS	85.839	0.729
Ergospace	81.179	0.690
IRIT	69.004	0.586

Table 8: betweenness centrality

4.4. Ego-network analysis, the heterogeneous "broker roles" of key agents

The above results give a first view on which agents play a critical role in the network and structure of the composite knowledge dynamics, but without any considerations on the "qualitative" features of this structural role. The basic spatial and knowledge attributes conferred to the nodes can help to improve the results by computing the so-called "broker" roles agents plays in the network. The different brokering strategies we can computed are particularly suited to corroborate the implications of the trade-off between knowledge accessibility and appropriation. Firms or research units (have to) develop strategies of network embeddedness in accordance with their knowledge management strategies, which depend on their place on the knowledge value chain, the main segment on which they operate, their location and their absorptive capabilities. All of these critical parameters delineate how agents posit themselves in networks in order to increase their accessibility to external knowledge while maintaining proper conditions of internal knowledge appropriation. These knowledge management strategies can be captured by identifying a set of agents' profiles. The complementarities between these profiles give at the aggregate level a relevant insight of how the network perform.

The study of ego networks are suitable for analyzing these profiles. Ego networks are networks starting from one node with all its connections at some path lengths. An agent who not has no direct or indirect relations with an "ego" is out of the ego's neighborhood. Ego networks analysis fit thus with the examination of the knowledge profiles of an agent, taking into account his behavior in his neighborhood composed of heterogeneous agents. Gould and Fernandez (1989) provided a set of measures of these profiles by proposing a typology of mediation behaviors agents plays in their group: the so-called "brokerage roles".

Ego-network analysis								
Brokerage (main brokers & weighted and un-normalized brokerage scores)								
Spatial analysis of brokerage				**sectoral and knowledge analysis of brokerage**				
	nodes	*coordinator*	*gatekeeper*		*nodes*	*coordinator*	*gatekeeper*	*liaison*
local nodes	TAS	255.666	609.833	**infrastructure nodes**	TAS	111.000	408.084	585.500
	Magellium	41.629	0		France Telecom R&D	7.300	34.133	45.667
	EADS Astrium	4.667	48.333		EADS Astrium	98.000	49.167	4.667
	M3 System	146.943	32.000		Tesa	0	19.500	171.333
	Pole Star	42.095	46.167		CNES	0	115.000	211.833
	Navocap	110.629	11.667		Telespazio	42.000	36.333	12.000
	Tesa	280.000	11.500					
	Sodit	3.095	88.667	**hardware nodes**	Pole Star	0	14.000	83.643
	Samu	53.186	0		Rockwell Collins France	0.667	8.000	41.000
	Rockwell Collins France	31.667	18.833		Navocap	0	9.000	71.943
	CNES	271.833	150.167					
	Skylab	59.333	0	**software nodes**	Ergospace	1.583	4.254	1.769
	LAAS	4.000	5.667		M3 System	1.583	30.577	94.269
	IRIT	19.167	0		Navteq	6.000	45.333	227.633
	CETE/ZELT	0	25.667		Sodit	15.583	54.720	93.869
	LCPC	0	18.000					
				uses and services nodes	Skylab	13.333	15.000	14.000
outside nodes	France Telecom R&D	63.267	39.500		CETE/ZELT	2.000	8.250	22.500
	Navteq	311.267	54.667		Samu	0	7.792	16.352
	Telespazio	90.000	21.333					

Table 9: Ego-network analysis

Table 9 presents these brokerage roles in the GNSS network. As said before, we stress merely on the main "brokers" for the sake of clarity. Recall that nodes of the sample are marked by two kinds of attributes. Agents are featured by their location (inside or outside Midi-Pyrénées) and by their main place in the set of GNSS segments.

The Left side of the table presents the spatial analysis of brokerage. Following Gould and Fernandez (1989), nodes exhibit a salient "coordinator" role when their "betweenness" position in neighborhood is strong with the members having the same spatial attributes, while they exhibit a salient "gatekeeper" role when their "betweenness" position leads them to have a privileged control and access to members endowed by the other spatial attribute. Coordinator and gatekeeper are not substitutable nor complementary roles, their respective salience depends on the above computed centrality of nodes. For instance, we can observe that even if the two main worldwide companies TAS and EADS Astrium exhibit logically a geographical gatekeeper behavior, their respective ratios between the two roles show that TAS is more concerned by the role of coordination inside the region. The above identified system of SMEs (Magellium, M3, Pole Star, Navocap, Sodit) exhibit an interesting path with SMEs more concerned by local coordination and others by insiders-outsiders geographical intermediary. The two main research units exhibit as well an interesting path, with a high level of local coordination for the two units and the role of gatekeeper mainly assigned to the CNES, which is historically embedded in the Space European research networks. At last, the three central outsiders nodes (FT R&D, Navteq and Telespazio) observed above reappear here logically as the three main outside gatekeepers, i.e firms that play a salient intermediary role between local and non local interacting agents.

These results (and so the used methodology) show clearly that it would be irrelevant nowadays to analyze clusters independently of the technological and organizational environment for at least two reasons. (i) Firms embedded in local networks are besides embedded in larger ones: knowledge flows and knowledge accessibility play on these two connected dimensions. (ii) Non local firms bring knowledge from outside (and also capture from inside), and, as important knowledge "conveyors", participate powerfully to the local knowledge dynamics. Consequently, even if we have identified a GNSS cluster in the Midi-Pyrénées Region, the aggregate efficiency of this local structure does not only depend on the inside relations, but either on the way the cluster connects itself through a subset of nodes to geographical larger pipelines.

In addition, the right side of the table brings more information on why the singular cluster-pipeline structure is typical to the actual GNSS composite knowledge dynamics. Following the same Gould and Fernandez indexes, but on the level of the knowledge segments of the GNSS technological field, we find heterogeneous profiles of firms and research units, i.e different ways to manage the knowledge trade-off. Notice that we have added a profile – the "liaison" role – since we have more than two features in the sectoral and knowledge attributes of nodes. A firm or a research unit of one of the segments will have a liaison profile within its neighborhood if it "brokes" relations between two distinctive groups or agents of the other segments. The results we obtain improve deeply the analysis and highlight gradually the coexistence of different profiles in the composite knowledge dynamics. First, if we look at the infrastructure segment, we can have a better understanding of the behavior of the two main companies of our sample. The spatial gatekeeper role of TAS is confirmed either by the weight of its knowledge gatekeeper and liaison roles, while EADS, its competitor on the worldwide market of satellite systems does not play a significant role of liaison and plays a strong role of coordinator in the space industry (the reasons of these two differentiated strategies will be discuss below). At the research units level, Tesa and the CNES display noteworthy a radical switch in their role. If they assure a high level of coordination at the local level, at the opposite they adopt a actual behavior of interface at the knowledge level, with an high index of liaison (and gatekeeper in a less extent). Once again, we find the above-mentioned SMEs, in the hard and software segments, with for each one a striking index of liaison and a weaker level of coordination. This is not a surprising result since each of this segment appear as an intermediate segment between the infrastructure (the satellite signal for navigation and/or positioning) and uses and services (the use of this signal for dedicated services). More generally, the high mean score of liaison (and gatekeeper in a less extent) of agents in all the segments is really characteristic of the fact that GNSS is a composite knowledge dynamics combining knowledge coming from different segments and thus coming from different cognitive bases. Recall that GNSS technological field is typical to knowledge processes in ICT sector, i.e processes in which the innovative capabilities of firm are not the guarantee of market success. Firms which succeed are not necessary the most innovative ones, but firms which gather or can have access to complementary knowledge resources in their economic environment, in order to find new opportunities of technological interoperability and to enhance the integration of their knowledge in large technical systems or platforms.

If we cross the geographical and knowledge levels, the agents' profile becomes over clear: two very different profiles emerge for the two competing worldwide companies TAS and EADS Astrium. The first one develop an intensive strategy of interface at the geographical and technological levels, while the second develop a clear coordination in the satellite industry with a weak level of relations inside the regional cluster. These distinctive strategies furnish a relevant illustration of the links between the role of geographical proximity or distance and the phase of the knowledge value chain. As a matter of fact, if we follow our theoretical considerations, TAS seems to concentrate this effort on explorative and examination phases, by forming partnerships between more or less cognitively distant partners, by positioning itself centrally in networks of composite knowledge, and by reducing the resulting knowledge gap between absorptive capabilities by a strong local strategy of coordination. EADS Astrium does not develop an equivalent strategy. At the opposite, its high level of coordination in the space infrastructure segment traduces a concentration effort in the collective exploitation of the satellite constellation, so that it prefers to maintain an high level of knowledge local appropriation by insuring a weak level of local coordination (and avoiding thus the risks of unintended knowledge spillovers) and a weighty role of geographical gatekeeper. The combination of geographical and knowledge levels exemplifies either the role of the research units in the geographically situated knowledge processes. Tesa and the CNES, because research institutions do not face knowledge trade-off in the same way than firms, combine a high level of local coordination with an high level of interface and intermediary between knowledge segments. That's why their centrality above-mentioned appears as a critical value of the knowledge circulation in the knowledge value chain and thus one of the major condition of the cluster viability and efficiency. At last, the core of local SMEs we have identified exhibits also a particular profile of the knowledge trade-off. Even if they do not belong to the same segments, they play close gatekeeper and liaison roles in the knowledge value chain and the related indexes reveal a positioning on the upstream phases of knowledge exploration and examination. That is a behavior typical of technological SMEs. This behavior is associated to a strong level of local coordination which is due to at least two reasons: (i)

The gap between knowledge absorptive capabilities is reduced by the geographical proximity as far as these SMEs are embedded in the upstream phases of the knowledge value chain; (ii) When we look at the sample, these SMEs are in majority embedded in collective knowledge projects which are supported and funded by local institutions.

5. Interpretative discussion

From descriptive statistics of the GNSS network to the measures of centrality and the definition of the heterogeneous knowledge profiles of the main agents of the network, we have a quantified example of (i) the necessity to start from knowledge processes rather than places, in order to capture the idea that the knowledge trade-off implies local and distant relations, (ii) the role played by "outsiders" in the composite knowledge process of GNSS, and (iii) the heterogeneous and complementary roles central (or not) agents plays in the composite knowledge process. Nevertheless, this quite mathematical and statistical approach of network analysis based of formal relations can reveal some limitations since it does not permit to capture more informal and "holistic" aspects of relations. Social relations, friendship but also conflicts can play an important role in the structure of the network and we propose to capture these aspects in order to improve, confirm or infirm the analysis by an interpretative discussion based on a run of semi-structured interviews.

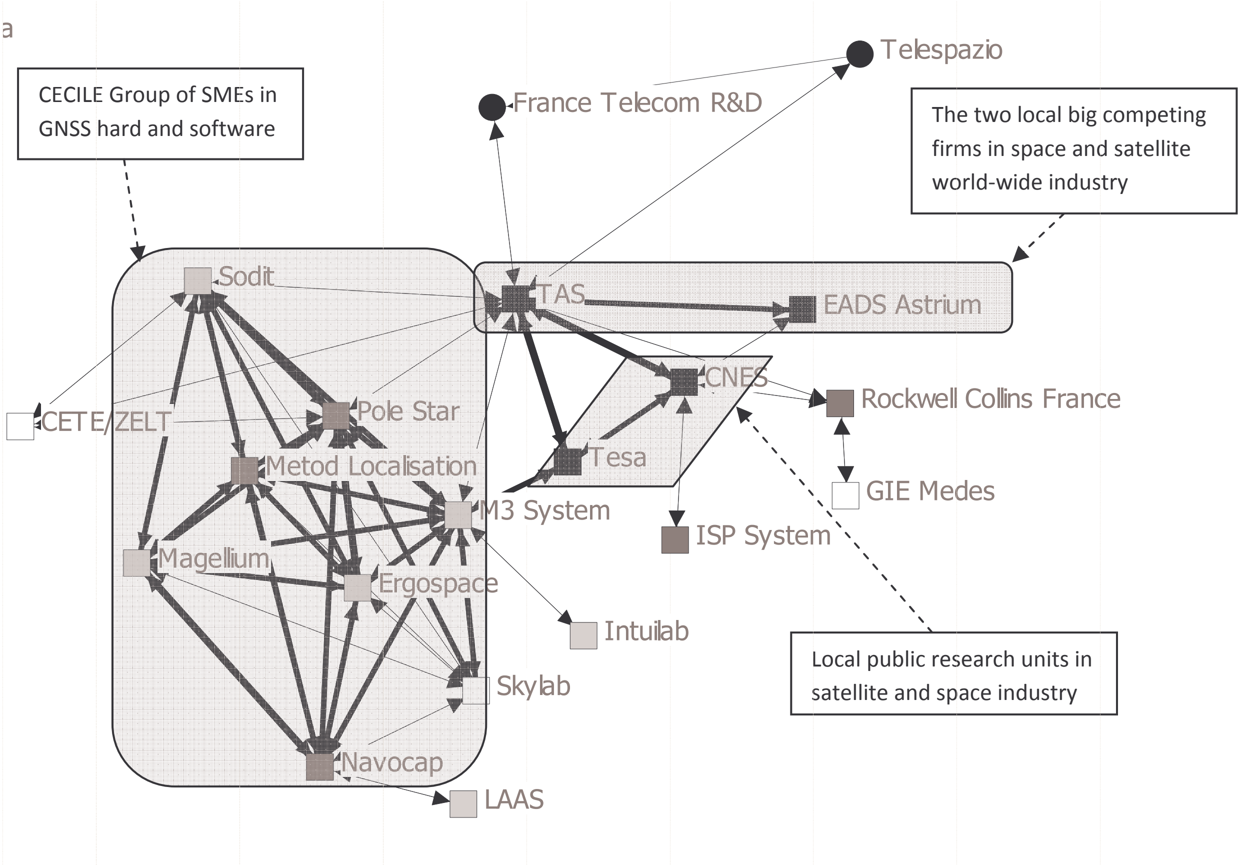

Figure 3: focus on the core nodes and relations of the sample

For that, we focus on a restricted sample. We assume only a part of the network which includes agents who have at least two pair-wise relations (see figure 3). In this sub network, the more influential agents appear an thus we obtain the group on which semi-structured interviews has been realized. This local impregnation brings further suitable explanations of (i) the core of interacting SMEs manage the complex trade-off between accessibility (to) and appropriation (of) knowledge, (ii) why the very similar local satellite companies play the opposite roles of gatekeeper and external star in the cluster, and (iii) how research units posit themselves in the network in order to improve and assure the fluidness of knowledge flows and exchanges.

5.1. Knowledge accessibility and appropriation between local firms

Visual inspection of the figure 3 shows a core group of local SMEs which are more linked than others. These firms have established at least more knowledge linkages with other firms of the sub-group. Increasing accessibility to external knowledge, this strategy can also bring unintended knowledge spillovers. We will try to understand how geographical proximity increases accessibility to knowledge, and how these firms manage their knowledge appropriation though this strong geographical proximity.

This core group of firms is composed by eight toulousian small and medium enterprises (SMEs) of the hardware and software GNSS segment. Interviews show that strong geographical proximity between these firms increases their accessibility to knowledge. Composite knowledge in this technological dynamic suppose lots of interoperability interactions, with many face to face contacts, but the distant interactions costs are often more difficult to manage for SMEs than for large firm. In addition to this pecuniary reason, geographical proximity seems to provide for these SMEs more information about the knowledge bases of the others firms. We had shown that an optimal cognitive distance provides an efficient knowledge matching. In order to realize this efficient knowledge matching, firms must have accurate information about the other sources of knowledge, firm's strategy or the project they are engaged on. This kind of information flows in the Toulousian social network. As a major actor said: "it's very easy to make R&D cooperation in Toulouse, everyone knows everyone". This local social network is composed by formal or informal meetings, animated by some "networks man" which often come from institution (agglomeration community, region), but also from industry or research centre (CNES, Tesa). The Toulousian social network is an efficient way of information flows where firms want to signal their knowledge bases and the external knowledge sources they are looking for. Another source of efficiency can be found in the professional background of the GNSS actors. A large part of them have had previous experience in GNSS toulousian large companies like Thales, Alcatel, Matra, Astrium, or the CNES and are coming from the same engineering schools.

However, GNSS downstream business, with hardware, software applications and value added services is a growing market, with highly risks of unintended knowledge spillovers. This core group is made of local firms which create and share very complementary knowledge. To talk about each other, these firms always start claiming that they are complementary. But in the same time, they haven't enough cognitive distance to avoid the risk of unintended knowledge spillovers. In order to avoid this risk, they have decided to create an association: the Cecile group, and recently a GIE[1] (TAMS). The core of the Cecile group to avoid the risk of unintended knowledge spillovers is the creation of a competency matrix. This tool delimitates cognitive fields for each firms on the basis of their capabilities. The control of the respect of this matrix is made by another firm, which makes audit control, in order to assure that cognitive field are respected. An actor said*: "Cecile is an open collaborative structure, new members can arrive, but they have to improve the knowledge base of the*

[1] A GIE (Groupement d'intérêt économique) is a formal consortium with legal statues.

group providing new competencies." Moreover, some actors tell us that geographical proximity helps us to monitor the others, and keep a good trust level between each others.

5.2. Why big similar firms became knowledge gatekeepers or external stars?

A knowledge gatekeeper*,* as previously defined, have strong links with local firms and also strong links with external firms, joining global and local knowledge dynamics. So, we are talking about knowledge gatekeeper when an actor had an active role of bringing knowledge inside the cluster and sharing knowledge outside the cluster. Visual inspection of the overall network (Fig 2) help us to identify Thales Alenia Space (TAS) as the major knowledge gatekeeper of the cluster. Strong external relations can be explained by European based big projects, like Egnos yesterday, or Galileo today. This project aims to be an alternative and a complement of the American GPS. Geo-political issues, but also technological changes provided by this kind of projects engage all big European actors of the GNSS infrastructure segment to establish strong knowledge relationship. EADS Astrium, which has got a very similar knowledge base, size, financial capacities and market than TAS, has got quite strong external links, but at the opposite very weak local relations. In fact, our analysis shows that EADS Astrium isn't a knowledge gatekeeper but an "external star" (Allen 1977). Interviews will help us to explain why TAS has got strong local relations while EADS Astrium has got weak local relations.
Strong local relations of TAS can be explained by his local partnership development strategy. TAS aims to make the Midi Pyrenean cluster a bigger and more competitive one. This strategy was revealed by many interviews, but also by the project that brought TAS: *Navigation Valley*. *Navigation Valley* aims to structure the GNSS cluster in Toulouse, to be able to support the competition with BavAIRia, the GNSS cluster of Munich, in which EADS Astrium is involved through the organizational matrix or the parent company EADS. *Navigation Valley* was a big project who aims to set up a platform for development and innovation in order to promote and enhance coordination between toulousian actors. The project provided the establishment of a simulation laboratory, experimentation and validation site, a resource centre, an expertise centre, training and research centre, and an international relations center. This knowledge platform in which TAS is more involved than EADS is the illustration of the will of TAS to improve the conditions of the collective upstream knowledge phase and improve thus the conditions of integration and interoperability of more or less distant but complementary pieces of knowledge locally developed. EADS Astrium seems to be less involved in this project, displaying a wider relational strategy with worldwide satellite company. In spite of their cognitive proximity and the risks of uncontrolled knowledge spillovers (and a defiant climate perceived during interviews), these two competing companies succeed to co-exist in the same place by a strategic differentiation on the geographical extent and the nature of their knowledge relations. Nevertheless, as join in figure 3, they succeed to cooperate when research units plays the role of betweeness actors.

5.3. The local coordination

As a matter of fact, figure 3 shows two actors who play the role of local coordinator: Tesa and CNES. Local coordinators could be seen as actors who play the difficult role to link the different segment of the GNSS knowledge value chain, but also to assure an efficient cognitive matching between actors. However, we identify in our interviews that the two structures doesn't assume the same kind of coordination. Tesa is a very local research structure bringing together several academic research laboratories, industry and institutions working on the development of hybrid systems combining telecommunications and GNSS. Tesa wants to be the *"missing link between research and the development of services to users"*[2]. Tesa tries to diffuse knowledge between the different segments, at a Midi-Pyrenean level. The Centre National d'Etudes Spatiales (CNES) is the government agency responsible for shaping French space policy. CNES is also a critical player in Europe's space program, and holds with the European Space Agency the role of European coordinators. However, they play also a peculiar role at a more local level. CNES is here a major local coordinator of the infrastructure segment, the more oligopolistic one. CNES can be viewed as a strong link between the two biggest Toulousian (and European) companies of these segments: TAS and EADS Astrium. As we had said before, TAS and EADS Astrium haven't got a lot of cognitive distance, which increases the risk of unintended knowledge spillovers. The latter should lead inertia to the knowledge dynamic of the infrastructure segment, and so of the others. In fact, they cooperate without difficulty in order to have a powerful financial impact, but never on strategic knowledge. CNES has got power to orientate cooperation between them on more strategic knowledge sharing or creating.

6. Concluding remarks

This methodological contribution of cluster empirical identification does not provide a normative approach of the analysis of cluster aggregate efficiency. Nevertheless, by focusing on knowledge processes rather than places and by stressing on the knowledge profiles and the structural roles of clustered agents, this socio-cognitive network approach leads to perceive the complex geographical and technological organization of a particular cluster. Obviously, the results we obtain concerning the role that play external agents in the knowledge dynamics of the cluster and concerning the heterogeneity (of) and complementarities (between) knowledge profiles inside the cluster must be confronted in the future with (i) theoretical researches on knowledge clusters and networks aggregate efficiency, and (ii) to more systematic empirical researches on various composite knowledge processes.

7. References

Allen, T.J. (1977) Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization, *MIT Press*, Cambridge, MA.

Antonelli, C. (2006) The business governance of localized knowledge: An information economics approach for the economics of knowledge, *Industry & Innovation,* 13(3): 227-261.

Bathelt, H., Malmberg, A., Maskell, P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, 28(1): 31-56.

Borgatti, S.P., Everett, M.G., Freeman, L.C. (2002) Ucinet 6 for Windows, *Analytic Technologies*, Harvard.

Boschma, R.A., Ter Wal A.L.J. (2007) Knowledge networks and innovative performance in an industrial district: the case of a footwear district in the South of Italy, *Industry and Innovation*, 14 (2): 177-199

Boschma, R.A. (2005) Proximity and innovation: a critical assessment, *Regional Studies,* 39(1): 61-74.

[2] Journal of Tesa, n°2, feb 2008

Breschi, S., Lissoni, F. (2001) Knowledge spillovers and local innovation systems: a critical survey, *Industrial and Corporate Change,* 10(4): 975-1005.

Brossard, O., Vicente, J. (2007) Cognitive and relational distance in alliances networks: evidence of the knowledge value chain in the European ICT sector, *Summer DRUID Conference*, Copenhagen, June.

Cooke, P. (2001) Regional innovation systems, clusters, and the knowledge economy, *Industrial and Corporate Change,* 10(4): 945-974.

Cooke, P. (2002) Knowledge Economies, *Routledge*, London.

Cooke, P. (2006) Rational Drug Design, the Knowledge Value Chain and Biosciences Megacentres, *Cambridge Journal of Economics* 29: 325-341.

Cowan, R. Jonard N., Zimmermann J.B., (2007) Bilateral Collaboration and the Emergence of Innovation Networks, *Management Science*, 53(7): 1051-1067.

Foray, D. (2004) The Economics of Knowledge, *MIT Press*, Cambridge, MA.

Gilsing, V., Nooteboom, B. (2006), "Exploration and Exploitation in Innovation Systems: The Case of Pharmaceutical Biotechnology", *Research Policy* 35, 1-23..

Giuliani, E., Bell, M. (2005) The Micro-Determinants of Meso-Level Learning and Innovation: Evidence from a Chilean Wine Cluster, *Research Policy,* 34 (1): 47-68.

Giuliani, E. (2007) Networks and Heterogeneous Performance of Cluster Firms, In *Applied Evolutionary Economics and Economic Geography*, edited by K. Frenken. Cheltenham/Northampton: Edward Elgar.

Gould, R.V, Fernandez, R.M. (1989) Structures of mediation: a formal approach to brokerage in transaction networks, *Sociological Methodology***,** 19**:** 89–126

Graf, H. (2007) Gatekeepers in regional networks of innovators, *Jena Economic Research Papers 2007-054*, Friedrich-Schiller-University Jena, Max-Planck-Institute of Economics.

Hagerdoorn, J., Link A.N., Vonortas N.S. (2000) Research partnerships, *Research Policy* 29, 567-586.

Markusen, A. (1996) Sticky places in slippery space: A typology of industrial districts, *Economic Geography,* 72: 293–313.

Martin, R., Sunley, P. (2003) Deconstructing clusters: chaotic concept or policy panacea? *Journal of Economic Geography,* 3(1): 5-35.

Menzel, M.P., Fornahl, D. (2007) Cluster life cycle: dimensions and rationale of cluster development, *Jena Economic Research Papers*, Max Plank Institute of Economics.

Mowery, D.C., Oxley, J.E., Silverman, B.S. (1996) "Strategic alliances and interfirm knowledge transfer", *Strategic Management Journal* 17, 77-91.Newman, M.E.J. (2003) The structure and function of complex networks, *SIAM Review* 45, 167-256.

Nooteboom, B. (2000) Learning by Interaction: Absorptive Capacity, Cognitive Distance and Governance, *Journal of Management and Governance* 4(1-2): 69-92.

Powell, W.W., Grodal S. (2005) Networks of innovators, in Faberger J. & alii, The Oxford handbook of innovation*, Oxford University Press*, New York, 56-85.

Zimmermann, J.B., Rychen, F. (2008) Clusters in the global knowledge based economy: Knowledge gatekeepers and temporary proximity, *Regional Studies (Forthcoming).*

Saxenian, A. (1994) Regional advantages: culture and competition in Silicon Valley and Route 128, Cambridge, *Harvard University Press*.

Schilling, M.A., Phelps, C. (2007) Interfirm collaboration networks: The impact of large-scale network structure on firm innovation. *Management Sciences,* 53: 1113–1126.

Sorenson, O., Rivkin, J.W. Fleming L. (2006) Complexity, Networks and Knowledge Flow, *Research Policy,* 35(7): 994-1017.

Torre A. (2008) On the role played by temporary geographical proximity in knowledge transmission, *Regional Studies (Forthcoming).*

Vicente, J., Suire, R. (2007) Informational Cascades vs. Network Externalities in Locational Choice: Evidences of 'ICT Clusters' Formation and Stability, *Regional Studies* 41(2): 173-184.

Wassermann S., Faust K. (1994) Social network analysis: methods and applications, Cambridge, *Cambridge University Press*, 825 p.

Watts D.J. (2004) The 'New' Science of Networks, *Annual Review of Sociology*, 30: 243-270.

Wuyts S., Colombo M.G., Dutta S., Nooteboom B. (2005) Empirical tests of optimal cognitive distance, *Journal of Economic Behavior & Organization,* 58: 277-302.

Zimmermann, J.B., Rychen, F. (2008) Clusters in the global knowledge based economy: Knowledge gatekeepers and temporary proximity, *Regional Studies (Forthcoming).*