INNOVATION NETWORKS AND KNOWLEDGE SPILLOVERS: EVIDENCE FROM TRENTINO, ITALY

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ABSTRACT

Based on the literature developed on ICT clusters and communities, the present paper focuses in the ICT ecosystem of the Italian region of Trentino. It traces the flows of knowledge and key actors inside the ICT community of the region. Taking into account the ICT actors traced by OPENLOC project (Proto et al, 2012), a snowball sampling was conducted, extracting data from the officially related websites of the actors inside Trentino. The relationships under investigation are the common participation in projects. The architecture of Trentino ecosystem was constructed as network of networks and communities with the help of Social Network Analysis. The analysis resulted to a representation of the "local buzz", "pipelines" and the path of knowledge transfer inside and towards the ICT ecosystem of Trentino. Finally, the key actors were identified and the value of their position, as well as, their role inside the local innovation system.

Since the 1980s, governments and supra-national institutions have established as a priority the development and upgrading of industrial clusters for strengthening regional innovation and production systems. Porter (1998) define clusters as "geographical concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries and associated institutions in a particular field, linked by an array of horizontal networks, communities and complementarities of shared interests and knowledge spillovers". The development of industrial clusters in the context of open innovation constitutes an important direction of economic policy formation worldwide (Chesbrough, 2003). It is widely argued that industrial clusters have a positive impact on economic growth of regions, the opening of markets and the reduction of costs in doing business. In an era of global innovation and production networks, the Information and Communication Technologies (ICT) ecosystems in peripheral regions need to be upgraded technologically by importing new knowledge and creating bridging ties with distant clusters or markets.

The success of industrial clusters today depends on their ability to embody all kinds of talent, knowledge and capabilities that are needed to deliver high value to customers at local,

national and international levels (Assimakopoulos et al, 2015). For example, in the European Union, the European Cluster Observatory has identified more than 2,000 industrial clusters in both high and low-tech sectors. Roughly 38 percent of all European employees work in enterprises that are part of such clusters (European Cluster Observatory, 2012). According to most recent data provided by the Observatory, the Italian enterprises that belong to knowledge intensive clusters, constitute 16.7 percent of the total number of European enterprises (EU27) in such clusters.

This paper focuses on the Italian region of Trentino, which brings together research laboratories, corporations, Small and Medium sized Enterprises (SMEs), universities and government agencies that have similar interests, products and R&D in the fields of innovation and ICT, and their applications in embedded fields. Trentino is a unique "terrain" to observe how an ICT ecosystem forms and functions, from its early development and as it continues to evolve through a range of highly-specialized resources for creating and exchanging knowledge in a series of collaborative projects.

In Trentino, knowledge is produced and circulated among the companies of the ICT community through hundreds of projects that have been funded by European Union, the Italian government and industry, and the Autonomous Province of Trento (Provincia Autonoma di Trento – PAT) over the past fifteen years. It is also important for the ICT community of Trentino to create global pipelines of knowledge with distant markets, and other European clusters, in order to develop valuable ties for the two-way transfer of knowledge, labor, and resources across large geographical distances (Bathelt et al, 2004). This two-way transfer has to be done by collaboration and networking among the companies and research laboratories of the community and its distant counter-parts, including partners, suppliers, and customers.

In this paper, the ICT ecosystem of Trentino is investigated, by identifying and mapping collaborative networks of all kinds of actors in it. The paper is divided into five sections: the first two discuss the literature and the methodology; Sections three and four present and evaluate the main findings; Section five draws the main conclusions of the study and discusses its possible implications for policy and practice.

LITERATURE REVIEW

Porter (1990) reintroduced the concept of industrial cluster at regional, national and international levels for strengthening competitiveness. Since then a lot of government policies and

programs have been focused mainly on cluster creation and development, in order to benefit from synergies, spillovers and spatial proximity of companies, organizations, academic institutions, and public and private research centers. The same concept, though, has been referred to as "agglomeration economies", dates back to 1890 and the work of Alfred Marshall. The notion of cluster can be found in several other terms, like local production systems, regional innovation systems, growth poles and industrial districts (see, for example, Becattini 1990; Cooke 2001 and 2012; Saxenian 2002 and 2006; Parrilli 2007)

The new ICT ecosystem

In order to understand the internal and external environment of an emerging ICT cluster, it is also useful to review the new ICT ecosystem theory of Fransman (2008) in the context of Schumpeter's creative destruction theory. According to Schumpeter's creative destruction theory, innovation takes place within an eco-system, while occasionally this system has to be rearranged by the appearance of a discontinuity in innovation by new technological or market conditions (Tidd et al, 2005). These emerging innovations are the "prime movers" of the ecosystem, opening opportunities for the future growth of the cluster. In our case such innovations are ICT products. According to OECD (2003), ICT goods are those that "are either intended to fulfill the function of information processing and communication by electronic means, including transmission and display, or which use electronic processing to detect, measure and/or record physical phenomena, or to control a physical process". ICT products are particular, as they involve high-technology. Concepts, methods and applications involved in ICT are constantly evolving. However, as ICT products are high technological and their production is knowledge intensive, regions that produce them have to develop networks of knowledge flows, in order to bring together expertise and resources.

Fransman (2008) depicts the ICT ecosystem (Figure 1) as a multi-level innovation system, organized in four hierarchically structured layers: a. networked elements, b. networks, c. platforms, contents and applications and d. consumption. However, these layers don't reflect the dynamics of the innovation system. In order to analyze these dynamics, Fransman (2008) introduced the concept of six symbiotic relationships that occur inside the ICT innovation ecosystem. According to the author "symbiosis exists when the members of different species live together in close interaction, with consequences that may or may not be beneficial for all parties concerned". These symbiotic relationships refer to the interactions between the four groups of actors in the new ICT ecosystem: a. the networked element providers, b. the network operators, c. the content and application

providers, and d. consumers. Each symbiotic relationship occurs in a specific context that is shaped by four sets of influences that are competition, financial institutions, regulation and competition law, and other institutions involved. Important are as well for the development of learning and innovation, the relationships that exist among the hierarchical layers, among the companies of the cluster and those of the ecosystem/cluster with other ecosystems. As ICT products are new, they result changes in the business and innovation processes, as well as, in the environment of the existing clusters (OECD, 2002).

Knowledge flows – local buzz and global pipelines

One of the key features of spatial clustering activity is the creation of local knowledge that is non-articulated explicitly among the companies of the cluster. The local knowledge is embedded in the human and social interactions among key individuals and other key actors. If this local knowledge produced in the cluster is combined with knowledge of other clusters or global "pipelines" knowledge, an added value can be created, fostering innovation both locally and globally (Bathelt et al, 2004). According to Bathelt et al (2004), there are three levels of knowledge creation: inside the companies, inside the cluster, and pipeline creation.

Initially, knowledge is created within companies, through the effective division of their labor in departments or projects (Maskell and Lorenzen, 2003). However, the companies trying to balance the division of their labor build external relationships and this is the second level of knowledge creation that appears within the clusters. Inside clusters there are two kinds of companies: a. those that produce similar goods and are highly competitive among them in terms of innovation (Porter 1990; 1998), but benefit by co-location from the information about the competitive products, and b. complementary companies interlinked with supplier-customer relations. So, this localized learning, the so-called local buzz, plays an important role in the process of growth and innovation and finally results in the production of new knowledge, economic specialization and urbanization of economies (Bathelt et al, 2004). The local buzz inside the clusters consists of continuous updates in information, learning, knowledge and technologies that stimulate the conventions and other arrangements among the companies of the cluster. This buzz within the cluster can be either smoothed or blocked, depending on the social structures and informal networks among the local organizations and companies (Bathelt et al, 2004). The local buzz can be tapped by companies co-locating within the cluster and developing similar institutional structures, for example, communities of practice (Wenger, 1998). Communities of practice encourage learning through mutual engagement, shared repertoires and development of organizational routines and

conventions, as clusters are a suitable environment for their further development through cumulative and localized learning.

The third level of knowledge creation is the one of creating pipelines across clusters. According to Powell and Owen-Smith (2002), pipelines are channels that create flows of knowledge through partnerships of interregional or international spectrum. Counter to local buzz, the creation of pipelines is not automated and spontaneous, but the amount and kind of knowledge transferred through them is monitored and controlled by the degree of trust between the companies (Maskell and Malmberg, 1999). This trust has to be built in a conscious and systematic way. However, the local buzz is dependent on the creation of these extra regional knowledge flows, as the first is strengthened by the more intensive flows of knowledge inside the cluster.

The need for the creation of network pipelines is highlighted when there is a knowledge gap in the proper mix and conceptualization of internal and external cluster relations (Bresnahan et al, 2001; Humphrey and Schmitz, 2002). A concern is how a firm can balance its internal and external linkages, when it is always able to handle only a certain amount of them (Grabher, 2002). Thus, both local buzz and external pipelines offer advantages to the companies of a cluster, when the latter are carefully created and maintained. The main reason for the creation of pipelines is that often a regional innovation system is not able to offer all framework conditions, technologies and institutions needed for innovation. So, it has to co-operate with other regional or national systems in order to gather all needed resources (Cook et al, 2004). In this way, local innovation systems like clusters become open and globally connected (Carlsson, 2006; Fraunhofer ISI, 2009).

As not all necessary resources for innovation can be found in the spot, and especially those which involve tacit knowledge, personal and informal networking seems a solution to the resource problem. Through social networks and informal networking members of a cluster know where to obtain these scarce resources and how to link up with them (Assimakopoulos and Macdonald, 2003). The emergence of communication and information technologies also led towards open innovation (Tidd et al, 2005). Chesbrough (2003) convincingly argues that “open innovation is the use of purposive inflows and outflows of knowledge” to accelerate internal innovation, and expand the market for external use of technological and organizational innovation. Companies can and should use external ideas, as well as internal ideas, and internal and external pathways to market, as they look to advance their organizational capabilities in developing emerging technologies.

Trentino: What is so special about it?

The Northeast part of Italy is a very dynamic area of Italy, where people invest largely in innovation and new technologies. Especially, the region of Trentino, has some unique characteristics related to its geography, history and funding policy, that make it a special case for knowledge transfer and triggering high-tech innovation. The most advanced and innovative sectors of Trentino are two: the food processing sector and the ICT one. Geographically, Trentino is located in the passage that unites Italy with Austria and further with Germany. From 1996, it belongs to the Euroregion Tyrol-South Tyrol-Trentino, in order to promote the regional understanding and cooperation. Historically, Trentino was an agricultural region which the last fifteen years developed a significant activity in the ICT sector. Finally, the region is Autonomous Province, which means that Trentino enjoys considerable autonomy from the Italian central government by having its own elected government and legislative assembly.

Thus, the present research studies in depth the ICT ecosystem of Trentino by identifying the key actors and the flows of knowledge within the region. It is investigating the role of the province in the innovation system and the consequences of its activity. Also, it can give useful insights for the local policy makers in order to restructure the innovation system in order that it can become more efficient. Moreover, in a more wide level, this research investigates the flows of knowledge between private and public actors, universities, research centers, state and industry, in an emerging ICT community. Finally, it shows how the structure of the network can fuel innovation process in regional level and how an ICT community forms in its early stages.

METHODOLOGY

Having reviewed some of the broad theoretical considerations for ICT ecosystems and associated cluster development, in this section, the data collection and analysis for the specific case of Trentino are discussed. This is also essential for grasping the organizational and technological context in which the regional innovation and clustering in Trentino ICT ecosystem is taking place. This research has deployed a thorough mapping of all actors in the region of Trento and their collaboration networks in the community through Social Network Analysis (SNA) and visualization (Wasserman and Faust, 1994). This is done at the inter-organizational level of analysis, for all the actors that are located inside this specific region and have participated in projects from 2000 up to the end of 2014 (some of these projects have secured funding for up to 3 years, so when funded in

2014 run up to 2017). In this sense, the structured flows of knowledge creation and sharing in this particular ICT ecosystem at the early days of its critical development (2000) and up to the mid 2010s, are investigated.

For representing the Trentino ICT ecosystem as an inter-organizational network, the actors (organizations) of the ecosystem were represented as nodes and the collaborative project relationships between them as ties. Having a list of local actors producing innovation on ICT by the OPENLOC project (Proto et al, 2012), a snowball sampling was conducted for all the ICT actors in Trentino that have participated in collaborative projects. More specifically, the data of the projects of the ICT community of Trentino are publicly available and can be found in the official websites of the actors presented project by project. As a first step the partners from the consortium of each and every project published at the actors' official websites (2015) were extracted. Data from 543 projects were gathered, ending up with a project to actor matrix, which represent the actors which are participating to every project that has published its project consortium data. For mapping the relationships between the actors of the ecosystem, the above matrix was multiplied by its transpose, giving an actor to actor matrix. This means that the actors that are related to each other by at least one project are connected. The number of actors identified was 2,401, separated in research centers, universities, industrial groups, SMEs, public agencies and other kinds of organizations (see Figure 2). In a second level, the local actors of Trentino ICT ecosystem were isolated. In this way, it is possible to have an image of the "local buzz" inside the region and how the knowledge between the local actors is transferred (see Figure 3). In a third level, the role of the two biggest players in the regional ICT ecosystem (University of Trento and Fondazione Bruno Kessler) and the role of the Autonomous Province of Trento (PAT) are analyzed according to the regional policy, how it triggers the innovation process and finally the role of SME's in it (see Figures 4a, 4b and 4c). Thus, this research studies in depth the community and the ways the actors of the ecosystem interact and are interconnected, as well as how the knowledge is generated and shared inside the community.

The interest is focused on collaboration projects supported by the European Commission and by the Autonomous Province of Trento. The patterns of relationships among all these actors created by their common participation in projects were analyzed and visualized. In majority these projects were funded by European Commission and/or Autonomous Province of Trento via an array of government instruments for funding public research for a competitive future. The results therefore trace and map the cumulative development of collaboration inter-organizational networks and knowledge flows inside the community from its beginnings and up to ongoing research and development work today.

Visualizing the Figure 2 with the help of specialized Social Network Analysis (SNA) software (Gephi, consortium https://consortium.gephi.org/index.html), 44,013 relationships between the actors were traced, represented by the edges in the network. An edge is created every time two actors are participating in the same project. The edges are undirected as it is assumed that knowledge sharing is reciprocal in project participation and it is practically impossible to distinguish inflows and outflows of knowledge in such collaborative project networks. The edges are weighted (if two nodes have a repeated cooperation, this is visualized with one edge however thicker accordingly to how many times these two actors have cooperated), so the strength of ties is visualized, in the sense that repeated relationships and participation in more than one project between two certain actors, it results in a thick(er) edge. After mapping the Trentino network of ICT projects, different centrality measures of its actors were computed, including degree, betweenness and closeness centrality, as well as the clustering coefficient. For visualizing the Figure 3, the network was filtered in order to keep in the visualization only the local actors, those which are based in the Trentino region. 158 local actors (which is the 6.58 percent of all the actors participating in projects) and 913 edges (only the 2.07 percent of the whole amount of edges) were traced, which indicates a poor cooperation between the local actors.

Finally, Figures 4a, 4b and 4c illustrate the role of the PAT inside the Trentino ICT community and how it fuels the involvement of the local SMEs in the innovation process. This was done with the help of an ego-network filter of the SNA software. It is apparent that the amount of the local SMEs connected on projects with PAT, is considerably higher than the number of SMEs connected with the rest of the key actors inside the regional ICT ecosystem.

FINDINGS

As can be seen in Figure 2 the Trentino ICT ecosystem consists of 2,401 actors (total number of nodes) and 44,013 ties connecting these organizations until today (end of 2014). A big part of the nodes (25.28 percent) are SMEs (colored green). Unsurprisingly each one of them participates in few projects, and for different projects different SMEs are selected. 19.58 percent of the ecosystem consists of large corporations and groups (colored magenta). Large multi-national groups have found fertile ground for innovation in Trentino, attracted by the emerging ICT ecosystem and the research and academic institutions present in the region, and their participation in projects is repeated facilitating cumulative learning across projects. Overall the industry, including both small and large companies, represents a bit more than the 45 percent of all the actors in

Trentino ecosystem. It is worthy to note that the vast majority of the large corporations are located outside the Trentino ecosystem.

23.24 percent of the Trentino ICT ecosystem consists of research centers (colored red) and universities (20.37 percent, colored blue). All together research intensive institutions (ie public and private research centers and universities) represent about the 44 percent of the total amount of actors in Trentino ICT ecosystem. However, as can be seen in Figure 2 research centers and universities play the foremost central role in Trentino ecosystem. In almost every project there is participation of at least one research center or/and university. This finding highlights the strong ties and participation of intensive research institutions in the local ecosystem. It is important to note the participation of the public agencies in the Trentino ICT ecosystem (7.29 percent, colored yellow), with dominant node the Autonomous Province of Trento itself, as it fuels the participation of local SMEs in the project participation.

From the outset it seems that intensive research institutions produce knowledge and propel the development of ICT innovations in Trentino. These are the largest regional research centers and university: UNIVERSITY OF TRENTO, FONDAZIONE BRUNO KESSLER, CREATE-NET, FONDAZIONE EDMUND MACH and GRAPHITECH. It is observed that they have a sum of 2,479 connections with all other actors of the ecosystem. This is about 5.63 percent of the total number of ties in the local ICT ecosystem. Thus the research institutions and the regional university together, constitute an important share of the regional emerging ICT ecosystem, playing a significant role in the production and transfer of knowledge inside it. Finally, the rest of the ecosystem (4.25 percent, colored in light blue) consists of other kinds of institutions (e.g. NGOs, industry associations etc).

The full Trentino ICT ecosystem

The Figure 2 depicts the full ICT ecosystem of Trentino region. It has to be noted the intense participation of foreign institutions in the ecosystem, as they in some cases gather more connections than the local actors. The average degree of the ecosystem is 36.662 and the average weighted degree is 40.349. Based on Figure 2, three centrality measures were computed: degree, betweenness and closeness centralities (Freeman, 1977; Freeman et al, 1991) for each and every node in the Trentino ICT ecosystem (see respectively Tables 1, 2 and 3). It is obvious the presence of the three important research centers (FBK, CREATE-NET and GRAPHITECH), the UNIVERSITY OF TRENTO and the industrial group of ENGINSOFT SPA that dominate the Trentino ICT ecosystem. The dominant actor inside the ecosystem is the UNIVERSITY OF TRENTO itself, with respect to

degree and betweenness centralities (Tables 1 and 2). It is not only the one which has participated in the majority of the research projects (degree centrality = 947), but also its betweenness centrality (645,022) is the highest in the community. High betweenness nodes are found in the intersections of more densely connected communities (Freeman et al, 1991). Actors with high betweenness perform brokering roles, in the sense that they connect otherwise disconnected nodes which yet may benefit from the exchange of knowledge and participation in collaborative projects. UNIVERSITY OF TRENTO enjoying a very high betweenness centrality has a large influence in the transfer of knowledge inside the network as well as in absorbing a lot of the knowledge form SMEs and other partners participating in collaborative projects over the years. The finding that the UNIVERSITY OF TRENTO has the highest betweenness as well as degree centrality means that in terms of knowledge transfer this specific university is an indispensable hub and conduit for the whole ecosystem. Apparently, UNIVERSITY OF TRENTO is critical for the collaboration of the rest of the actors inside the Trentino ICT community.

On the other hand the closeness centrality of this specific actor, UNIVERISTY OF TRETNO, is not the highest (1.603). According to Borgatti (2005) the measure of closeness centrality of a node expresses its average distance to every other actor in the network. A property of closeness centrality is that it tends to give higher scores to nodes that are in the center of the local communities inside the wider network. This means that UNIVERSITY OF TRENTO doesn't influence greatly the actors in distinct communities of projects. Around UNIVERSITY OF TRENTO is developed a core of actors, mainly public, which are heavily cooperating in terms of project participation. These are exclusively research centers and universities. The only two local actors that belong to this core are two research centers (FONDAZIONE BRUNO KESSLER and CREATE-NET), while the rest of the actors are national and international (see Table 1). It is obvious the great participation of foreign institutions inside the Trentino ICT ecosystem, as they have more connections with actors than the connections of the local actors. In any case and in terms of degree and weighted degree centralities this is the group of the players with the majority of connections inside the Trentino ICT community.

In terms of betweenness centrality (Table 2), a completely different image appears. It is worth pointing out that the majority of the actors with relatively high scores in betweenness centrality are local (UNIVERSITY OF TRENTO, FONDAZIONE BRUNO KESSLER, CREATE-NET, ENGINSOFT SPA, FONDAZIONE GRAPHITECH, AUTONOMOUS PROVINCE OF TRENTO, DISTRETTO TECHNOLOGICO TRENTINO). Even if some of these actors do not participate in many projects inside the Trentino ICT community, they play important role inside the

ecosystem as brokers connecting different projects between them and transferring the knowledge from the one part of the network to the other with respect to different technologies. According to Watts and Strogatz (1998), clustering coefficient measures the tendency of the nodes to create tightly knit groups characterized by relatively high density of ties. Having measured the local clustering coefficient, the tendency of the neighbors of the nodes to become a clique can be seen. For example UNIVERSITY OF TRENTO has the highest degree and betweenness centralities but also has one of the lowest clustering coefficients. At the same time, the actors which have clustering coefficient equal to one are those which participate in projects with other actors that strictly cooperate with each other. The average clustering coefficient of the whole network of Trentino ICT community is quite high (=0.875) and the average shortest path length is 2.544. Having compared this to a random graph with the same number of nodes (ie 2,401), a not so different shortest path length (=1.953) is observed. However this random graph has a much lower average clustering coefficient (=0.05), than the initial Trentino ICT community network. Combining these two sets of measurements, average shortest path length and average clustering coefficient, and comparing the two graphs (ie, Figure 2 and a random graph with the same number of nodes), it can be argued that the Trentino ICT community network demonstrates small world network properties (Watts and Strogatz, 1998).

Small world networks tend to contain cliques, or near-cliques, meaning sub-networks and tightly knit communities which have connections between almost any two nodes within them. This has as result the high average clustering coefficient of the network. In Trentino ICT community this social structure and properties are explained by the underlying structure of the collaborative network in projects that constitute sub-networks and communities. Typically, there is a high presence of high degree nodes in the network (nodes with high number of connections). These high degree nodes serve as mediators in the short path length of the other nodes of the network. In the Trentino network, the high degree nodes are a group of universities and research centers as mentioned before (Table 1). The main local actors, play as well the role of the broker inside the knowledge network and regulate the flow of knowledge inside the Trentino ICT community. Finally, they facilitate the SMEs to have fast access to all the parts of the network, which in a different social architecture for collaboration it wouldn't be possible.

The Local Trentino ICT ecosystem

The Figure 3 depicts only the local nodes of the Trentino ICT ecosystem and the edges between them. As mentioned above the local ecosystem consists of 158 nodes which share 913

edges between them. The 43.3 percent of the local nodes consists of SMEs (green color), the 20.25 percent consists of public agencies (yellow color), the 14.56 percent of other types of organizations (light blue color), the 13.92 percent of research centers (red color), the 5.7 percent are industrial groups (magenta color) and finally only the 1.27 percent is the universities (blue color). This is normal as the major and unique university institution is the UNIVERSITY OF TRENTO. Considerable is the big amount of SMEs in the local ecosystem and the low existence of industrial groups in the region. This suggests the existence of incubators and the strong empowerment of the SMEs by the AUTONOMOUS PROVINCE OF TRENTO.

Among the local actors, can be identified the key players of the Trentino ICT ecosystem. The UNIVERSITY OF TRENTO, four research centers (FONDAZIONE BRUNO KESSLER, CREATE-NET, FONDAZIONE EDMUND MACH and FONDAZIONE GRAPHITECH), the AUTONOMOUS PROVINCE OF TRENTO and an industrial group (ENGINSOFT SPA), consist the core of knowledge transfer inside the local ICT community (Table 4). As it is obvious from Figure 3, the same sub-group actors are strongly cooperating (and competing) with each other. This means that they are present in the majority of consortia, playing a key role inside the community and its current and future development. From the Table 4, also, it is evident, that the key actors mentioned above, have a sum of 3,035 connection, which constitutes the 6.9 percent of the entire amount of connections. This fact makes these institutes the core of the knowledge transfer process inside the Trentino ICT community. In the betweenness centrality table (Table 5) appears the same image with the same group of actors gathering high betweenness scores. The only difference is that instead of FONDAZIONE EDMUND MACH in this core group belongs DISTRETTO TECNOLOGICO TRENTINO. This signifies the importance of technological hubs as brokers in the knowledge transfer network, in order to facilitate the innovation procedure. This set of key actors, in terms of betweenness are connecting different project participants (national and international) being the main distributors of knowledge from the one part of the full Trentino ICT network to another (Figure 2). Finally, in the table of closeness centrality (Table 6), there are as in the previous case mostly SMEs and other kinds of institutions. These actors although they don't have a lot of connections and participations in projects, are important in the knowledge transfer inside their sub-networks and neighboring nodes.

Figure 3 and Tables 4, 5 and 6 allowed me to make two observations about the Trentino ICT ecosystem. The first is that the innovation and technological hubs of the region like TRENTO RISE and TRENTINO SVILUPPO are achieving low scores in all centrality measures tables comparing to other local actors like the university and the research institutions. Their position doesn't favor the

knowledge transfer in the regional ICT ecosystem. TRENTO RISE and TRENTINO SVILUPPO constitute innovation hubs, so they were expected to be the key players that promote the innovation process in the region by participating in the majority of the projects and achieving high scores of centrality. According to the data, they don't. This implies the need of rethinking the mechanisms of working these institutions in order that they connect different actors and transfer knowledge between them and fuel the innovation procedure inside the local innovation system. The second observation is that when the national and international edges were removed and remained only the local edges, unconnected nodes were revealed (Figure 3). These nodes are in majority research centers and SMEs which have no local partner. So, it is implied that there are actors inside the Trentino ICT ecosystem which cooperate exclusively with foreign partners or partners outside the region.

The Role of Autonomous Province of Trento

In the Figure 4a and with the help of an Ego Network filter, the ego-network of the AUTONOMOUS PROVINCE OF TRENTO was extracted. This means all the nodes that are neighboring to the AUTONOMOUS PROVINCE OF TRENTO, connected to it with at least one project. So PAT is in total connected with 241 actors which are the 10.08 percent of the total actors of the Trentino ecosystem network, with 2,219 ties which are the 5.04 percent of the total amount of ties. From the neighboring nodes/actors the one quarter (25.62 percent) are SMEs (green color), 23.97 percent public agencies (yellow color), 15.7 percent research centers (red color), 12.81 percent industrial groups (magenta color), 12.4 percent universities (blue color) and 9.5 percent other kinds of organizations (light blue color). From these actors the 37.2 percent are local actors (inside Trentino), the 31.4 percent are national (actors located in Italy but outside Trentino) actors and the rest 31.4 percent are international actors.

It is not having a meaning to calculate again the degree centrality, however measuring the betweenness and closeness centrality of the ego-network of AUTONOMOUS PROVINCE OF TRENTO, three organizations with high betweenness centralities compared to the rest of the actors of this specific ego-network could be identified: UNIVERSITY OF TRENTO, FONDAZIONE BRUNO KESSLER and INFORMATICA TRENTINA SPA. These actors in addition to the AUTONOMOUS PROVINCE OF TRENTO itself are densely connected and constitute the core of the actors included to projects financed by the PAT. This means that all the projects financed by PAT are connected with one at least of the rest of the aforementioned actors.

From the thickness (weight) of the edges it is observed that most close cooperation of AUTONOMOUS PROVINCE OF TRENTO is the one with INFORMATICA TRENTINA SPA. This is justified as INFORMATICA TRENTINA is the instrument of the public sector and more specifically of the PAT, to provide global solutions in the field of ICT. Having visualized (Figure 4b) both the ego-networks of AUTONOMOUS PROVINCE OF TRENTO and INFORMATICA TRENTINA SPA, it is noticed that the actors connected with both of them (their union) are 270 (11.25 percent of the full Trentino network) and the ties 2,523 (5.73 percent of the full Trentino network). This means that the INFORMATICA TRENTINA SPA adds only 29 actors to the ego-network of AUTONOMOUS PROVINCE OF TRENTO which added 300 connections more (0.33 percent of the network). However, except of the frequent cooperation of these two actors in projects (sometimes they cooperate exclusively between them), in projects including SMEs they are involving the rest of the key actors of the local ecosystem. This means that if these two actors are deleted from the ecosystem then there are no isolated nodes in the ecosystem (Figure 4c). Finally, although AUTONOMOUS PROVINCE OF TRENTO doesn't constitute a key knowledge broker in the region of Trentino, its funding activity turns out to be important for the involvement of the local SMEs in the knowledge transfer and innovation process. This implies that PAT constitutes an important supporting actor in the local ICT ecosystem, as it facilitates financially the knowledge transfer and triggers the regional innovation process orientated to the ICT sector.

EVALUATION

The analysis of the ecosystem of the Trentino ICT community enabled the identification of all the key players inside this ICT ecosystem and the ways that these actors are connected with each other, including the case of AUTONOMOUS PROVINCE OF TRENTO and its role in supporting the innovation process in the region. In the description of the ecosystem it is noted that the actors that are partners in projects of the Trentino ICT community network have formed a dense network of collaborative project ties for the past fifteen years. There is a significant brokerage by the nodes close to the core of the community which is dominated by research centers and the UNIVERSITY OF TRENTO. All the rest of local actors are centered around the UNIVERSITY OF TRENTO and the above group of core actors. This strong cooperation among them demonstrates the influence they have in the community. This densely connected core mainly consists of research centers, one university and the AUTONOMOUS PROVINCE OF TRENTO, which unsurprisingly inspire trust

to the rest of the actors of the network, as well as a small group of industrial groups, both national and international.

As mentioned above, a dominant player in the ecosystem was distinguished, that is by far superior in the quantity and quality of its connections to all other actors, through its leadership (central position) and participation in most of the projects. This also enables it to broker knowledge flows inside the cluster. It is the unique university of the region (UNIVERSITY OF TRENTO) that participates in the majority of the ICT projects launched within the Trentino region. UNIVERSITY OF TRENTO is the central connector as the knowledge it generates diffuses directly to the majority of the nodes of the ecosystem. The most important finding however about this specific actor is that it is strongly connected to the rest of the key actors of the Trentino ICT ecosystem, so it also receives directly the knowledge they generate from their projects. Moreover, UNIVERSITY OF TRENTO is important for the rest of the actors inside the community in order to cooperate and communicate among them. Several groups of actors inside Trentino ICT community are seeking for knowledge generated by groups of other actors connected to the UNIVERSITY OF TRENTO. In this way, UNIVERSITY OF TRENTO also plays the role of knowledge broker transferring both the tacit and explicit knowledge form one sub-group of actors to the majority of others.

As both the variation in the betweenness centrality of Trentino community actors and centralization of the network are very high, it is evident that the knowledge created through projects needs such brokers in order to diffuse emerging knowledge in the entire network. The majority of the network nodes are SMEs. A small sub-group of these SMEs can reach more easily the whole network (high closeness centrality) and in the same time play central role in the projects of neighboring companies. This means they can be more influential in terms of knowledge transfer to the close groups of companies with which they are cooperating directly. While UNIVERSITY OF TRENTO and other actors are central in a different way, these SMEs can be connected even to isolated distant actors. This small group of SMEs scores high closeness centrality and can constitute local opinion leaders inside their localized network diffusing the knowledge they create by their participation to projects more easily than the rest of their neighborhood. Their role inside the ecosystem is important because they fuel the regional growth and the transfer of knowledge inside the local community. The social architecture of cooperation in projects of the Trentino ICT community looks a lot like to a small world as the clustering of the network is high. This means that the private companies are cooperating in projects with each other and their direct connections are also connected with each other creating cliques connected with the central actors of the network by key brokers.

In industrial ecosystems, key players, like UNIVERSITY OF TRENTO or FONDAZIONE BRUNO KESSLER, accrue a network advantage because of their central position and connectivity in the entire network. As it is obvious from the network of actors in Trentino ICT community, the contacts of the actors of the network provide knowledge opportunities and perspectives that can be beneficial to the key players of the network. This specific network consists of the dense clusters and communities of the clusters and communities of actors represented by participation in public – private funded projects. The knowledge generated by these projects is common among all the actors constituting a community of actors participating in a project. However, the knowledge created by every project can potentially flow in the entire network of the community via key brokers. Thus, the small central community of organizations (starting from the dominant actor of UNIVERSITY OF TRENTO) bridges the structural holes and provides network connectivity with additional benefits to all. Key players in Trentino ICT network are able to access knowledge from different communities and projects across the region and beyond. This seems important for central actors for sustaining innovation activity in the years to come as these key players are more probable to trace opportunities and use their knowledge from one part of the wider network to another.

CONCLUSIONS

ICT industry is a special category of industry as it needs highly specialized tacit knowledge for the production of high technological products. These are not only products sold to the final consumers but also governments and other industries that participate in global value chains spanning multiple geographies, sectors, cultures etc.

The present research is the first that deals with Trentino applying Social Network Analysis techniques in order to map the flows of knowledge that trigger innovation in the local ICT industry. The main conclusions that derive from this research in local level are three:

First, the existence of a core of influential public actors (with most important the UNIVERSITY OF TRENTO) shows that the public rather than the private sector drives the development of the Trentino ecosystem, coordinating and influencing the flow of knowledge within and towards the community. The few local industrial groups (and the foreign ones) are important actors for the ecosystem, as they are able to guarantee market expertise and importing new knowledge to the community. Then, the intense participation of international/foreign actors in the knowledge transfer can indicate the existence of structural holes in the Trentino network, and

further the existence of opportunities for cooperation for the local actors. This conclusion is strengthened by the existence of research centers that cooperate exclusively with foreign actors. Finally, the supportive role of the PAT in the ecosystem by funding a big amount of collaborative projects, fuels the local innovation system and the growth of the region in the field of ICT. This substitutes somehow the low participation in projects of the local innovation hubs and includes the local SMEs in the innovation process.

As the collection of data included all the actors and all their participations in projects (conducted not by interviews but data was collected by the official website of every actor), this study draws sound conclusions on emerging ICT communities. In a more theoretical level it shows the creation of an ICT community in its early stage and the importance of the strong cooperation of research institutes, public sector and industry for fueling the innovation process of a peripheral region. Additionally, it underlines the need of the development of the innovation hubs to growth poles inside local ICT ecosystems and the importance of the state/public funding in order to support the regional innovation system. This can bridge the existing structural holes empowering the local buzz and developing the pipelines of knowledge created from within and towards a region.

REFERENCES

Assimakopoulos, D., & Macdonald, S. (2003). A dual approach to understanding information networks. *International Journal of Technology Management*, *25*(1), 96-112.

Assimakopoulos, D. G., Oshri, I., & Pandza, K. (2015). 1. Management of emerging technologies for economic and social impact: an introduction. In *Managing Emerging Technologies for Socio-Economic Impact*.

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

Becattini, G. (1990). 4 The Marshallian industrial. *Industrial districts*, 37.

Borgatti, S. P. (2005). Centrality and network flow. *Social Networks*, *27*(1), 55-71.

Bresnahan T, Gambardella A, Saxenian A. (2001). *"Old economy" inputs for "new economy" outcomes: cluster information in the new Silicon Valleys.* Industrial and Corporate Change, Vol. 10, pp. 835-860.

Carlsson B. (2006). Internationalization of innovation systems: A survey of the literature. *Research Policy*, Vol. 35, pp. 56-67.

Chesbrough H.W. (2003). *Open Innovation: The new imperative for creating and profiting from technology*. Boston: Harvard Business School Press.

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

Cooke P, Heidenreich M, Braczyk H.J. (2004). *Regional Innovation Systems.* Second Edition. London and New York: Routledge.

Cooke, P. (2012). Transversality and transition: Green innovation and new regional path creation. *European planning studies*, *20*(5), 817-834

European Cluster Observatory, http://www.clusterobservatory.eu/index.html [accessed on 12/04/2015].

Fransman M. (2008). *The new ICT Ecosystem: Implications for policy and regulations.* Cambridge: Cambridge University Press.

Fraunhofer ISI: Koschatzky K, Baier E, Kroll H, Stahlecher T. (2009). *The spatial multidimensionality of sectoral innovation – the case of information and communication technologies (ICT).* Working Papers Firms and Region, No. R4/2009.

Freeman, L. C. (1977). A set of measures of centrality based on betweenness. *Sociometry*, 35-41.

Freeman, L. C., Borgatti, S. P., & White, D. R. (1991). Centrality in valued graphs: A measure of betweenness based on network flow. *Social networks*, ; ,bjh,o m;:¡*13*(2), 141-154.

Grabher G. (2002). *Cool projects, boring institutions: temporary collaboration in social context.* Regional Studies, Vol. 36, pp. 205-214.

Hamphrey J and Schmitz H. (2002). *How does insertion in global value chains affect upgrading in industrial clusters?* Regional Studies, Vol. 36, pp. 1017-1027.

Maskell, P., & Lorenzen, M. (2003, April). The Cluster-and other current forms of Market Organization. In *Regional Studies Association International Conference on 'Reinventing Regions in the Global Economy'in Pisa*.

Maskell P and Malmberg A. (1999). *Localised learning and industrial competitiveness.* Cambridge Journal of Economics, Vol. 23, pp. 167-185.

OECD. (2002). *OECD Information Technology Outlook.* www.oecd.org [accessed on 12/04/2015].

OECD. (2003). *A Proposed Classification of ICT Goods*, OECD Working Party on Indicators for the Information Society, OECD, Paris.

Parrilli, M. D. (2007). *SME Cluster Development*. Palgrave Macmillan.

Porter M.E. (1990). *The competitive advantage of nations.* New York: Free Press.

Porter M.E. (1998). *Clusters and competition: new agendas of companies, government and institutions.* In On Competition (pp.197-287). Boston: Harvard Business School Press.

Powell W and Owen-Smith J. (2002). *The new world of knowledge production in life sciences.* In The Future of the City of Intellect. California: Stanford University Press.

Proto, A., Tani S., Buhnemann J, Gaus O. and Raith M. (2012). "Knowledge Networks and Their Impact on New and Small Firms in Local Economies: The Case Studies of the Autonomous Province of Trento and Magdeburg", *OECD Local Economic and Employment Development (LEED) Working Papers*, 2012/02, OECD Publishing.

Saxenian, A. (2002). Silicon Valley's new immigrant high-growth entrepreneurs. *Economic development quarterly*, *16*(1), 20-31.

Saxenian A. (2006). *The new Argonauts: Regional advantage in global economy.* Boston: Harvard University Press.

Tidd J, Bessant J, Pavitt K. (2005). *Managing Innovation: Integrating technological market and organizational change.* 3rd ed. West Sussex, England: John Wiley & Sons Ltd.

Wanger E. (1998). *Communities of practice: learning, meaning and identity.* Cambridge: Cambridge University Press.

Wasserman, S., & Faust, K. (1994). Introduction to social network analysis.

Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks. *nature*, *393*(6684), 440-442.

APPENDIX

Figure 1 – New ICT ecosystem (Fransmann, 2008)

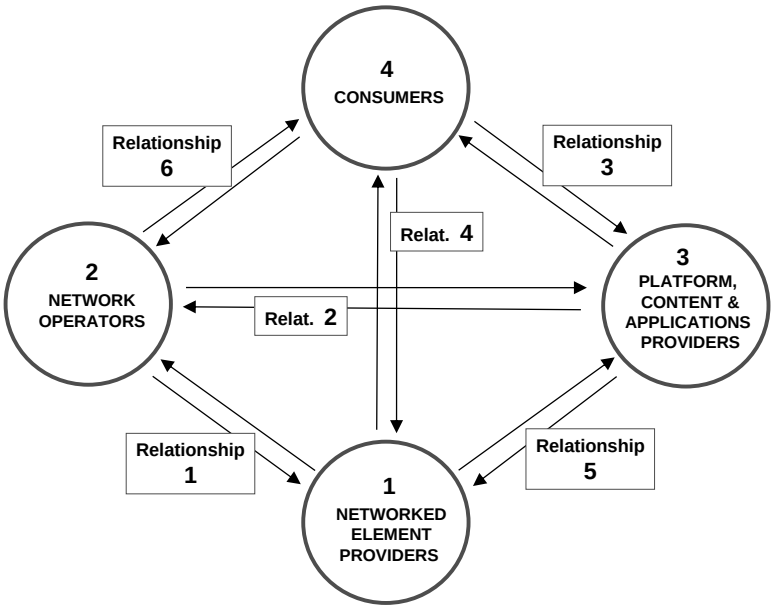

Figure 2 – Full Trentino ICT Ecosystem

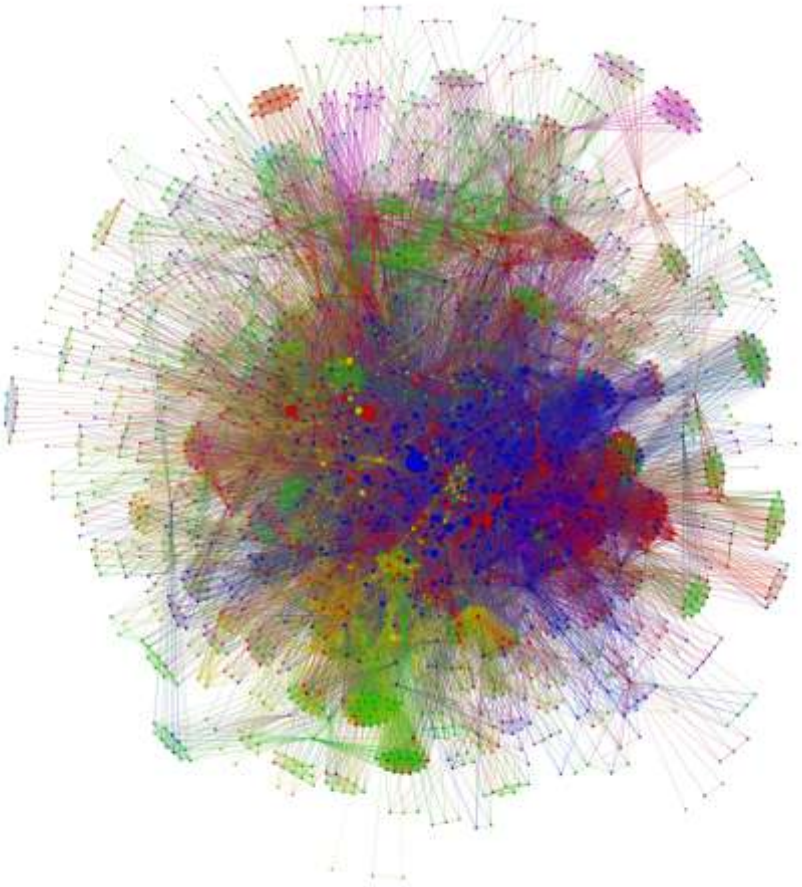

Figure 3 – Local Trentino ICT Ecosystem

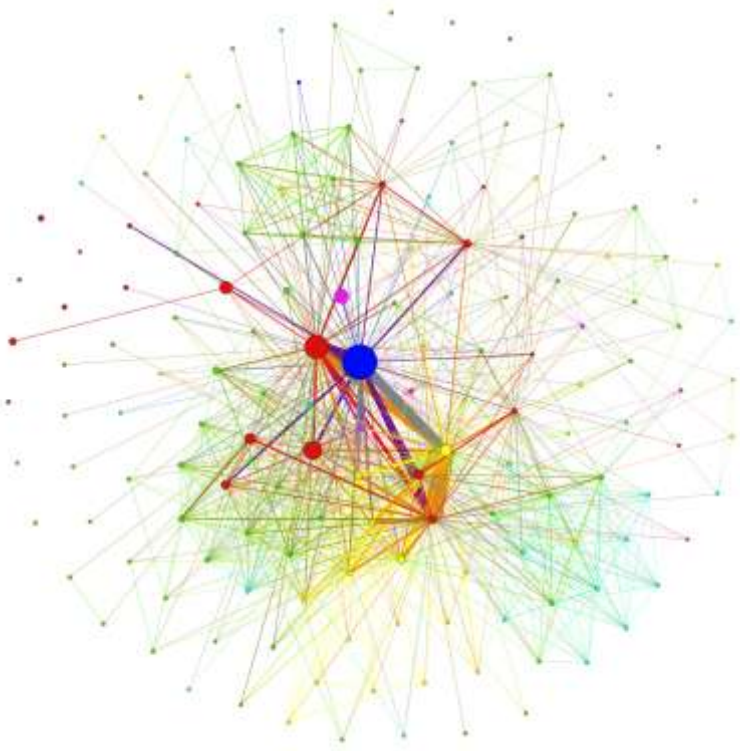

Figure 4a – Ego-network of Autonomous Province of Trento

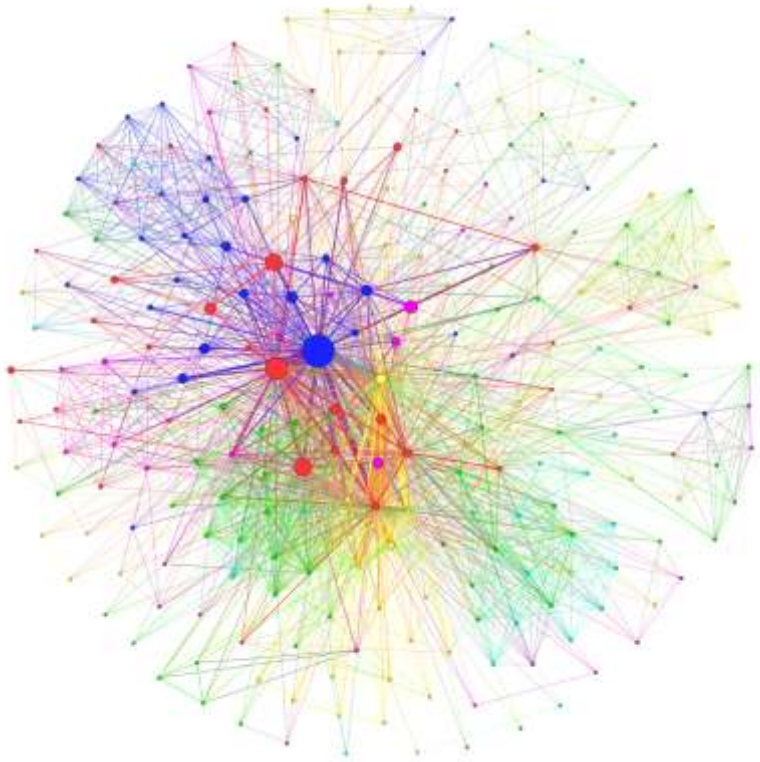

Figure 4b – Combination of the ego-networks of Autonomous Province of Trento and Informatica Trentina SPA

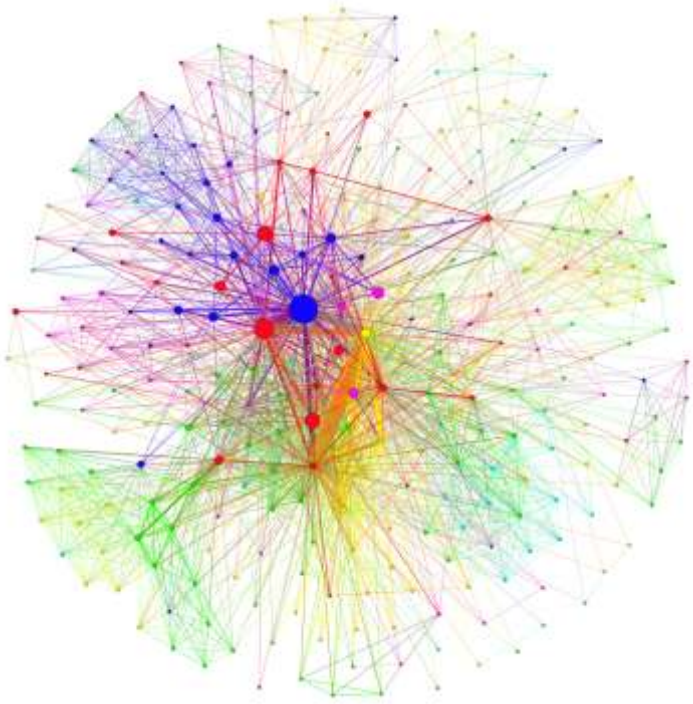

Figure 4c – Combination of the ego-networks of Autonomous Province of Trento and Informatica Trentina SPA but without these two nodes in the network.

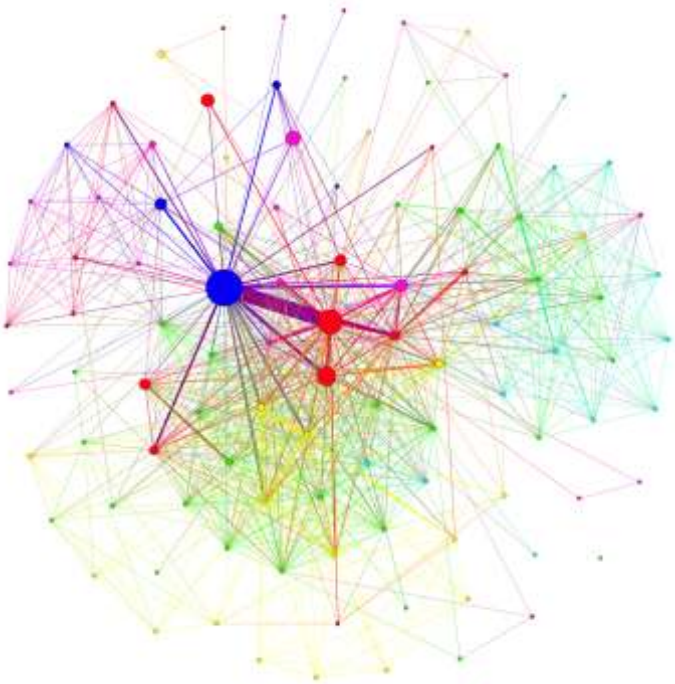

Table 1 – Degree Centrality of the Full Trentino ICT ecosystem

Node Name	Type of Institution	Location	Degree Centrality	Betweenness Centrality	Closeness Centrality
UNIVERSITY OF TRENTO	University	Local	947	645,022	1.603
FONDAZIONE BRUNO KESSLER	Research Center	Local	609	370,299	1.749
POLITECNIC UNIVERSITY OF MADRID	University	International	459	85,494	1.858
CONSIGLIO NAZIONALE DELLE RICERCHE	Research Center	National	454	115,949	1.851
CREATE-NET	Research Center	Local	443	198,308	1.840
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Research Center	International	370	38,756	1.939
SWISS FEDERAL INSTITUTE OF TECHNOLOGY IN ZURICH	University	International	340	40,736	1.920
COMMISSARIAT A L'ENERGIE ATOMIQUE	Research Center	International	320	34,403	1.948
UNIVERSITY OF EDINBURGH	University	International	318	44,610	1.949
LUNDS UNIVERSITET	University	International	317	18,480	1.996

Table 2 – Betweenness Centrality of the full Trentino ICT ecosystem

Node Name	Type of Institution	Location	Betweenness Centrality	Degree Centrality	Closeness Centrality
UNIVERSITY OF TRENTO	University	Local	645,022	947	1.603
FONDAZIONE BRUNO KESSLER	Research Center	Local	370,299	609	1.749
CREATE-NET	Research Center	Local	198,308	443	1.840
ENGINSOFT SPA	Industry	Local	118,259	315	1.952
CONSIGLIO NAZIONALE DELLE RICERCHE	Research Center	National	115,949	454	1.851
FONDAZIONE GRAPHITECH	Research Center	Local	106,599	208	1.989
AUTONOMOUS PROVINCE OF TRENTO	Public Agency	Local	95,990	241	1.908
POLITECNIC UNIVERSITY OF MADRID	University	International	85,494	459	1.858
DISTRETTO TECNOLOGICO TRENTINO	Research Center	Local	63,394	127	2.068
FRAUNHOFER INSTITUT	Research Center	International	59,749	308	1.964

Table 3 – Closeness Centrality of the full Trentino ICT ecosystem

Node Name	Type of Institution	Location	Closeness Centrality	Degree Centrality	Betweenness Centrality
FITS FOUNDATION	Other	International	3.489	1	0
HUMAN FOUNDATION	Research Center	National	3.489	2	0
R & P LEGAL	SME	National	3.489	2	0
FUNDATIA PENTRU DEZVOLTAREA SOCIETATII CIVILE	Research Center	International	3.408	4	0
INSTITUTUL DE CERCETARE A CALITATII VIETII	Research Center	International	3.408	4	0
NATIONAL CENTER FOR TRAINING IN STATISTICS	Research Center	International	3.408	4	0
CENTER FOR FORMIDLING AF NATURVIDENSKAB	SME	International	3.299	4	0
BLOOMFIELD SCIENCE MUSEUM JERUSALEM	Other	International	3.299	4	0
CIENCIA VIVA	Public Agency	International	3.299	4	0
TRAKIA UNIVERSITY	University	International	3.182	6	0

Table 4 - Degree Centrality of the local Trentino ICT ecosystem

Node Name	**Type of Institution**	**Degree Centrality**	**Betweenness Centrality**	**Closeness Centrality**
UNIVERSITY OF TRENTO	University	947	645,022	1.603
FONDAZIONE BRUNO KESSLER	Research Center	609	370,299	1.749
CREATE-NET	Research Center	443	198,308	1.840
ENGINSOFT SPA	Industry	315	118,259	1.952
FONDAZIONE EDMUND MACH	Research Center	272	51,530	1.989
AUTONOMOUS PROVINCE OF TRENTO	Public Agency	241	95,990	1.908
FONDAZIONE GRAPHITECH	Research Center	208	106,599	1.989
TRENTO RISE	Research Center	169	49,448	2.002
LABORATORY OF APPLIED ONTOLOGY	Research Center	147	54,387	2.030
INFROMATICA TRENTINA	Research Center	131	30,822	2.003

Table 5 - Betweenness Centrality of the local Trentino ICT ecosystem

Node Name	Type of Institution	Betweenness Centrality	Degree Centrality	Closeness Centrality
UNIVERSITY OF TRENTO	University	645,022	947	1.603
FONDAZIONE BRUNO KESSLER	Research Center	370,299	609	1.749
CREATE-NET	Research Center	198,308	443	1.840
ENGINSOFT SPA	Industry	118,259	315	1.952
FONDAZIONE GRAPHITECH	Research Center	106,599	208	1.989
AUTONOMOUS PROVINCE OF TRENTO	Public Agency	95,990	241	1.908
DISTRETTO TECNOLOGICO TRENTINO	Research Center	63,394	147	2.068
LABORATORY OF APPLIED ONTOLOGY	Research Center	54,387	147	2.030
FONDAZIONE EDMUND MACH	Research Center	51,530	272	1.989
TRENTO RISE	Research Center	49,448	169	2.002

Table 6 - Closeness Centrality of the local Trentino ICT ecosystem

Node Name	Type of Institution	Closeness Centrality	Degree Centrality	Betweenness Centrality
MAGNIFICA COMMUNITA DI FIEMME AZIENDA	SME	3.069	8	0
RASOM HOLZ & KO	SME	3.069	8	0
ILLE PREFABRICATI	SME	3.069	8	0
TRENTINO MOBILITA	Public Agency	3.034	4	0
TRENTINO ARCOBALENO	Other	3.034	4	0
LUCIAN SRL	SME	3.002	1	0
ASSOCIAZIONE ARTIGIANI	SME	2.981	4	0
CONFINDUSTRIA TRENTO	Public Agency	2.981	4	0
CONFCOMMERCIO IMPRESE	Public Agency	2.981	4	0
NOVAGENIT SRL	SME	2.953	11	0