Explaining innovation with indicators of mobility and networks: Insights into central innovation nodes in Europe

Subtheme 9. Triple Helix indicators (9.1. Indicators of mobility across Triple Helix institutional spheres (local, national, international))

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1 Introduction

In this study, we approach innovation metrics from the point of view of knowledge, and the contributing aspect of mobility of people as well as their networks, showing that the measurements can be used to bring new insights into the complexities of innovation. Our results indicate that with the coordinated use of visual and quantitative social network analysis, it becomes possible to share knowledge about regional innovation ecosystems of various scale, as well as the connections between them. The results can be used to reveal special characteristics and connections of those regions in local, national and international levels that can be utilized toward strategies, activities and policies related to innovation. More specifically, agents of change in innovation ecosystems may use the insights to target their interventions more precisely to clusters of actors or even individual actors of a particular innovation ecosystem.

The methodology is utilized toward deeper insights within the context of an innovation ecosystem called EIT ICT Labs, which is a new catalyst for ICT innovation in Europe. EIT ICT Labs is a new entity of European Institute of Innovation and Technology, and includes five innovation hubs (Helsinki, Stockholm, Eindhoven, Berlin and Paris) that execute its strategy. Mobility of people and knowledge is highly emphasized in the strategies as well as daily operations of EIT ICT Labs. The analysis and the resulting snapshots can be used to contribute towards its operations, management as well as development.

2 State-of-the-art

Innovation is widely regarded as the critical source of competitive advantage and growth in global economy. Therefore its outcome is seen as a quest for many, as are the ways, methods and approaches of the process toward it (Crossan and Apaydin 2010). In general, innovation remains under-measured at all levels, perhaps due to the complexity of innovation processes and the interrelatedness of actors in innovation ecosystems. Still, the need for innovation metrics has been widely acknowledged.

Innovation process and its results have oftentimes been described with concepts of knowledge and knowledge sharing in order to achieve economic gains and value creation: the tacit knowledge of ideas moves along the continuum toward something more explicit (Nonaka and Takeuchi 1995). “Knowledge has become the resource, rather than a resource” (Drucker 1993: 45) for companies, furthermore, knowledge is seen as an intangible asset. Therefore, this knowledge-based approach to innovation has not contributed to lessening of challenges of measurement. Measurement is still seen as one of the most difficult parts of the knowledge management (KM) activities (Chen et al. 2009) though has been approached with, for example, concepts of intellectual capital (Edvinsson 1997). For example, knowledge has been described with the characteristics that “it can be replicated at relatively low cost, and it can easily travel through firm boundaries, making it difficult for firms to appropriate the returns of their investment” (Dindaroglu 2010).

2.1 Mobility and networks for explaining innovation

Innovation research literature recognizes mobility, especially labor mobility, as an important aspect of knowledge creation and sharing within innovation ecosystems. It has been stated that: “The mobility and the consequential ability to circulate knowledge are vital parts of the national innovation ability… The mobility of individuals is used as an indicator for the exchange of knowledge and innovation potential in the economy” (Graversen 2003). Furthermore, “The mobility of highly qualified personnel is an important vehicle for knowledge flows, and indicators of this movement can help to map important linkages in innovation systems” (OECD 2002:2), and “knowledge can be transferred by the movement of human capital embodied in labor mobility" (Simonen and McCann 2008: 146). Overall, labor mobility and informal contacts between people in different organizations have been seen to provide the potential to diffuse knowledge and ideas between organizations (Lundmark 2010:24).

In this era of global competition: mobility across the competitive landscape can mean that (1) people come or leave, and (2) they bring or take their individual networks with them, operationalizing the adage, "It is not about what but who you know" (Parise et al. 2006). The success of Silicon Valley is oftentimes attributed to the flow of qualified, competitive and motivated people (Saxenian 1994). Scholars have talked about brain-drain and revolving doors (Etzkowitz 2008:22).

Lately, the importance of mobility has evolved beyond individuals to include networks and informal contacts. The role of innovation networks has been highlighted with: "collaboration is premised on information technology that increasingly occurs through a network at various levels, from local to international" (Etzkowitz 2008:22). Moreover, "[o]ne of the powerful roles that networks play is to bridge the local and the global — to offer explanations for how simple processes at the level of individual nodes and links can have complex effects that ripple through a population as a whole" (Easley and Kleinberg 2010:47). Also, von Hippel (1987) presented the concept of informal networks for knowledge diffusion, and according to Bienkowska (2007), extended social networks can be perceived as a more important aspect of labor mobility than direct knowledge gains or losses.

In this study, we recognize that people are not the only resource — for example Timmons (1994) has characterized that people, money and technology are resources of global networks of innovation. We see that people, their knowledge and the financial flows are networked, all contributing toward potential of innovation. Therefore, we propose using indicators and metrics that not only limit the concept of mobility to labor mobility.

2.2 Research context of EIT ICT Labs

EIT ICT Labs (http://eit.ictlabs.eu) is a new initiative intended to turn Europe into the global leader in ICT innovation by establishing a new type of partnership between leading companies, research centres and universities in Europe. It started its activities in 2010 with creating the operational as well as judicial infrastructure. The year 2011 can be viewed as its first year in operation.

EIT ICT Labs builds upon nodes representing five world class ICT innovation centres located in Berlin, Eindhoven, Helsinki, Paris and Stockholm (London, Trento and Budapest are associated partners, see figure 1). The role of the nodes is to execute the strategy of the EIT ICT Labs, by focusing on excellence in education, research, and innovation and based on the co-location of the best academic and industry researchers, turning already excellent regional clusters into world-class innovation hotspots (http://eit.ictlabs.eu/nodes/).

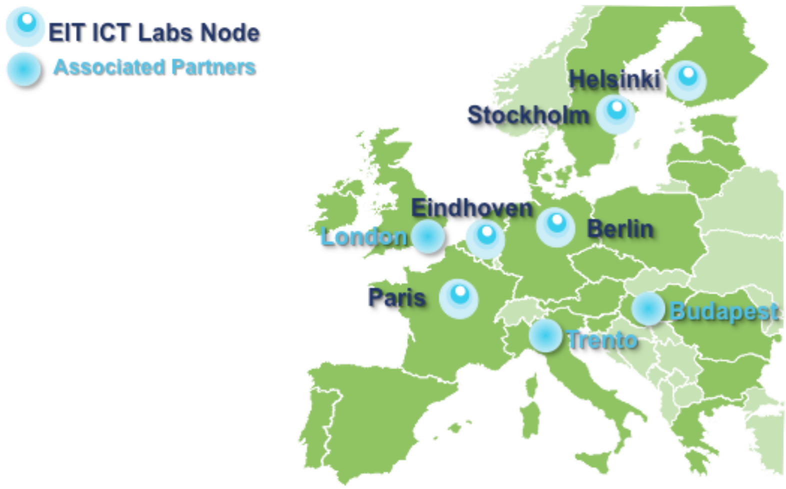

Figure 1. Five EIT ICT Labs nodes and three associated partners.

Mobility is a central theme within the operations and objectives of EIT ICT Labs. For example, one of the goals of the innovation nodes is "to build European trust based on mobility of people across countries, disciplines and organization" (http://eit.ictlabs.eu/nodes/), and at the EIT ICT Labs front page it is stated that "EIT ICT Labs community brings people together from different organizations, disciplines and organizations via mobility programs such as European exchange programs, organizational interchange and internships" (http://eit.ictlabs.eu). Therefore, using EIT ICT Labs as a case study for the analysis seems appropriate and value creating for all of the participants of this study.

The fact that the five EIT ICT Labs cities are connected is a basic assumption of this study. Firstly, some of the relationships and networks of like-minded people from these five locations were made explicit during the process of creating EIT ICT Labs, when people worked together to develop the concept and the plan for it. Secondly, with the realization of operational and judicial infrastructures as well as with the first activities of EIT ICT Labs, these people have continued to work together, and have included other people from their networks as partners. However, as often is the case in small-world networks, i.e. vast networks in which random connections create short paths between the individual nodes of the network (Milgram 1967; Easley and Kleinberg, 2010), it is assumed here that there are additional networks within these five nodes that are not visible, yet do exist, and that uncovering those could provide interesting insights for agents of change at EIT ICT Labs and those that are interested in the structure of Europe as an innovation ecosystem.

3 Methodology

The study is based on our conceptual approach to innovation — and its participants — that is relationship-based and network-centric. Innovation takes place in the context of relationships that form a network via the linkages between firms and their human and financial resources (Russell et al., 2011) or, indeed, the institutions where people study. Mobility and connections between the actors of the network, modeled here as network nodes, are seen integral for flows of resources, including financial resources as well as flows of knowledge and ideas in their different forms. Further, we are interested in showing the flow of funding between the EIT ICT Labs nodes.

In this study, we acknowledge that with a macro-level economic approach, mobility has been seen as one mechanism toward entrepreneurial and innovative society and has been oftentimes called "labor mobility". However, we look at this phenomenon more from a micro-level perspective, viewing it as "circulation of people", i.e. people changing employers or organizational affiliations within and between European innovation hubs. For providing insights on the networks, we will utilize methods, metrics and tools of social networks analysis (SNA) (Wasserman and Faust 1994; Freeman 2009) for looking into the overall network structure, the different characteristics of the network, and the roles of the network actors.

3.1 Dataset

We base our analysis on the central innovation hubs in Europe in the Innovation Ecosystems (IEN) Dataset (Rubens, Still, Huhtamäki and Russell, 2010), a quarterly updated collection of over 140,000 records built by web-crawling English language, socially constructed data about technology-oriented companies in the information communication technology fields and the service companies (legal, accounting, advertising) that support them[1]. As of June 2011, it includes data about more than 65,000 companies (including a high proportion of startup companies), their executives and board personnel (over 76,000 records), investment organizations (over 5,300 records), and financial transactions totaling over US$ 410 billion. People included in the dataset are the press worthy employees in their respective companies (e.g. founders, executives, lead engineers, etc.), members of boards of advisors, or investors. The dataset further includes data on the background of some of the individuals including the degrees they have received from various educational institutions.

It is important to note that the dataset we use inherits both the advantages and disadvantages of socially constructed data. Some of the advantages are availability, large coverage, timeliness, and

[1] The web crawling-based process used to construct the IEN Dataset is, however, outside the scope of this article; see Rubens, Still, Russell and Huhtamäki (2010) for details.

community verification of data quality. Some of the disadvantages are potentially erroneous data and public bias (vs. the editorial bias often extant in traditional data settings). Particularly the background data for people is scarce at places.

3.2 Data analysis with visualizations and metrics

Following the process that Rubens et al. (2011) used to investigate university alumni networks referred here as Ecosystem Network Analysis, two different, yet complimentary approaches were used to analyze the data: (1) constructing a graphic representation of the network for visual investigation of patterns and (2) analyzing numerical features of the networks. Visual analysis allows both visual investigations of the patterning of the network and sharing the findings of the investigations with others (cf. Freeman, 2009). As the network gets larger, visual analysis is not able to reveal all of the interesting aspects of the network configuration. Thus, we use some of the key SNA metrics to filter out the most interesting nodes in the network for further investigation.

In this research, we use Gephi, an open interactive visualization and exploration platform for networks (Bastian, Heymann and Jacomy, 2009) for graph metrics, visualization and layout. Graph layout is processed in two stages. In the cluster-based stage we use OpenOrd layout algorithm (Martin, Brown, Klavans, and Boyack, 2011) since it produces a layout that allows to better distinguish clusters based on the interconnections between the nodes. We then apply Force Atlas (Bastian, Heymann and Jacomy, 2009) to compact the graph (nodes that are connected are pulled closer together) and to make the representation more aesthetic. The network figures are embedded in the document by using vector graphics so it is possible to look at network details by zooming in.

In addition to visualizations, social network analysis introduces a variety of quantitative indicators, from core metrics such as nodal degree and betweenness centrality (Wasserman and Faust 1994) to more complex metrics including PageRank (Page, Brin, Motwani and Winograd, 1999) and HITS for locating hubs and authorities (Kleinberg, 1998). These metrics may be used to describe both the networks as whole and their individual nodes. Giuliani and Bell (2008), for example, present a novel example on describing the cognitive roles and positions of companies in a cluster knowledge network. In this study, we use betweenness centrality.

4 Findings and interpretation

Our analysis is, more specifically, based on a set of networks of cities, companies and their investors as well as individual employees and their educational affiliations. The core of the different configurations of the networks is constructed in the following manner. We started the construction of the network by selecting the five main nodes of EIT ICT Labs: Helsinki, Stockholm, Eindhoven, Paris, and Berlin. All of the companies that have their primary office in one of the cities were selected and connected to the respective city. Since the activities in the

Eindhoven node in practice involve also companies from Amsterdam, Delft and Twente, we have included the companies from these cities to the sample and connected them to the Eindhoven node. Similarly, companies with their primary office in Espoo or Vantaa are included and connected to the Helsinki node. Secondly, we collected all the people in the dataset for which press information has identified either a previous or an ongoing connection to one or more of the companies in the sample and connect them to the respective companies. Additionally, we added information about the educational institutions with which these people are associated through details in biographical openly available online information.

Through this selection, our sample includes 1634 individuals, 1056 companies, 280 financial organizations, and 174 educational institutions. Most of the nodes in this study are therefore companies and individuals connected to these companies. Since with our approach companies are always connected to exactly one innovation hub in which their primary office is located, the modeling for the analysis does not show the mobility of people within individual companies.

4.1 Visualizations of mobility in the context of EIT ICT Labs

To highlight the investors and individuals that work in between the EIT ICT Labs nodes, we processed the network layout in two stages: cluster-based stage and relation-based compacting stage. While networks can be constructed either as one-mode or two-mode, thus including only one or two types of nodes, we justify the inclusion of the five EIT ICT Labs locations into the network with the observation that this five-location modeling results in a network topology that follows that of geographical topology, thus supporting both visual (when laid out in an appropriate manner) and quantitative investigation of individuals' mobility and investment flows across the EIT ICT Labs nodes. The companies are clustered close to their respective EIT ICT Labs nodes, whereas individuals who work between the different nodes, their companies, and educational institutions are centralized. In all of the visualizations the persons are in blue, companies in red, educational institutions in orange, and investors in green.

With this analysis, we see that the number of patterns can be large, and acknowledge that what one reader finds most interesting may be of lesser interest to others. We highlight some of the patterns that have proven to be interesting in discussions and informal interviews with agents of change connected to the European innovation ecosystem as well as those who have an interest in its structure and dynamics. This analysis is intended to be primarily demonstrative, and we encourage readers to discover additional patterns based on their personal preferences and objectives. Since our analysis addresses mobility from various perspectives within the context of EIT ICT Labs, it is not intended to be documentary or prescriptive. Nonetheless, due to a large number of interconnected records in our dataset, several interesting patterns emerge in the analysis providing many opportunities for further research.

To start with a simplified view of the individual-based connections between the five EIT ICT Labs nodes, we created a network of the EIT ICT Labs locations and the people involved. In this case, an individual is connected to a location if the press has mentioned a connection between the company and the individual and the company has its primary office in the location.

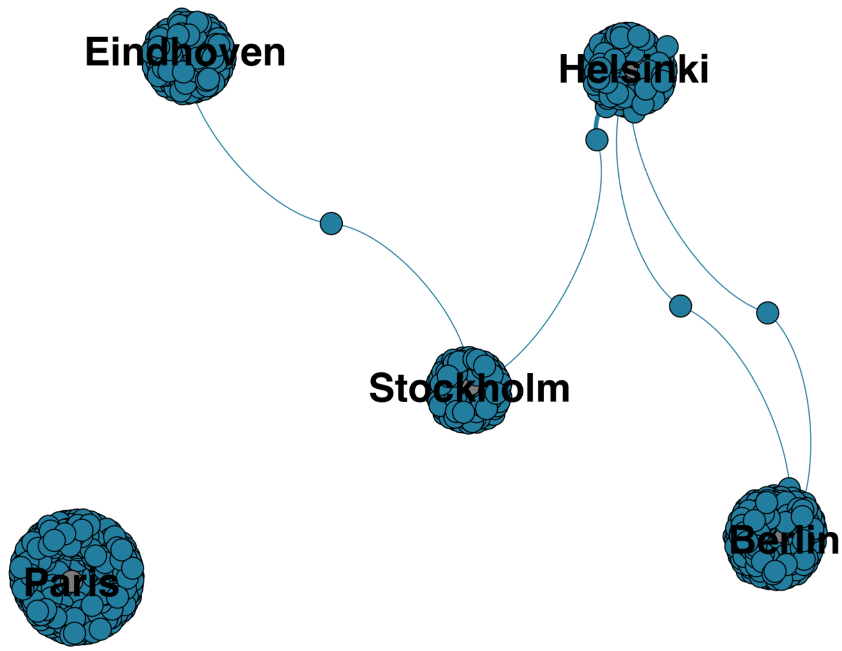

Figure 2. Mobility and people: people working in companies with primary offices in EIT ICT Labs locations

The five individuals surfacing in between the locations in Figure 2 are all examples of mobility: a Finnish serial entrepreneur who has assisted a startup based in Stockholm, a Nokia executive who was previously a CEO of a Berlin-based company that was acquired by Nokia, a founder of a company in Amsterdam also affiliated with a company with a primary office in Stockholm, and a person who has had a position both in Nokia and in a company acquired by Nokia, originally based in Berlin.

Then, we look into the role of educational institutions as social agents in connecting the different EIT ICT Labs nodes through people. At the same time, we introduce the nodes representing companies to the visualization, creating a more complete view to the ecosystem. Orange nodes in Figure 3 represent educational institutions; individuals are blue and companies red. Several educational institutions are placed in between the EIT ICT Labs locations, indicating the central role that they have in crossing people's paths. A closer investigation of the educational institutions with top betweenness values reveals distinguished universities from both the United States and Europe.

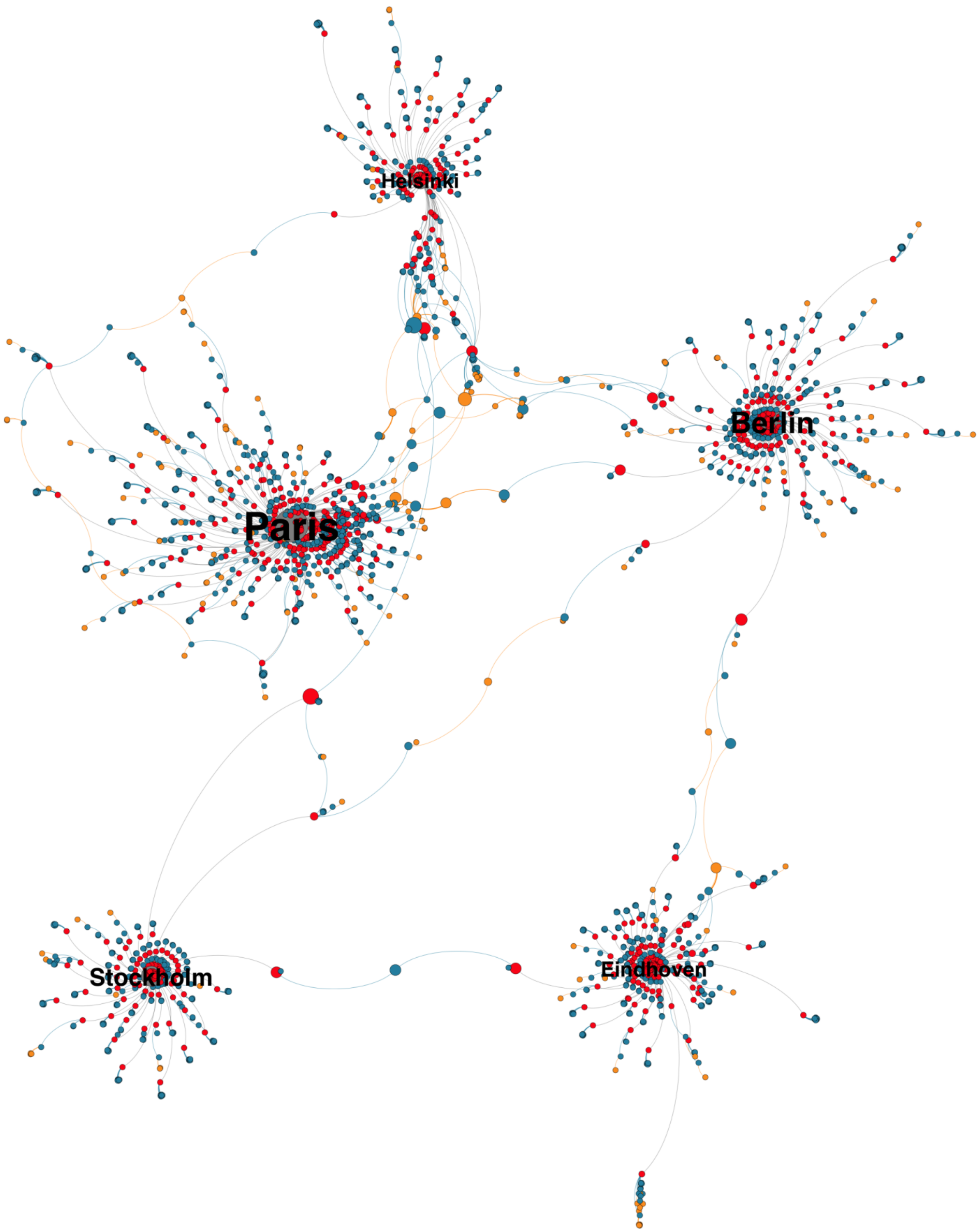

Figure 2. Mobility and Educational Institutions; University affiliations of people working in companies with primary offices in EIT ICT Labs locations

At the next stage of our analysis, we contrast the mobility of people to the flow of investments between the companies in the EIT ICT Labs locations. Companies are again connected to EIT ICT Labs locations; individuals and investors are connected to the companies with which they have investment or employment relationships. The resulting network in Figure 3 shows the majority of the connections crossing the locations are green, indicating that investors and investment organizations play a strong resource-brokering role between the EIT ICT Labs locations and, potentially, the whole of European innovation ecosystem.

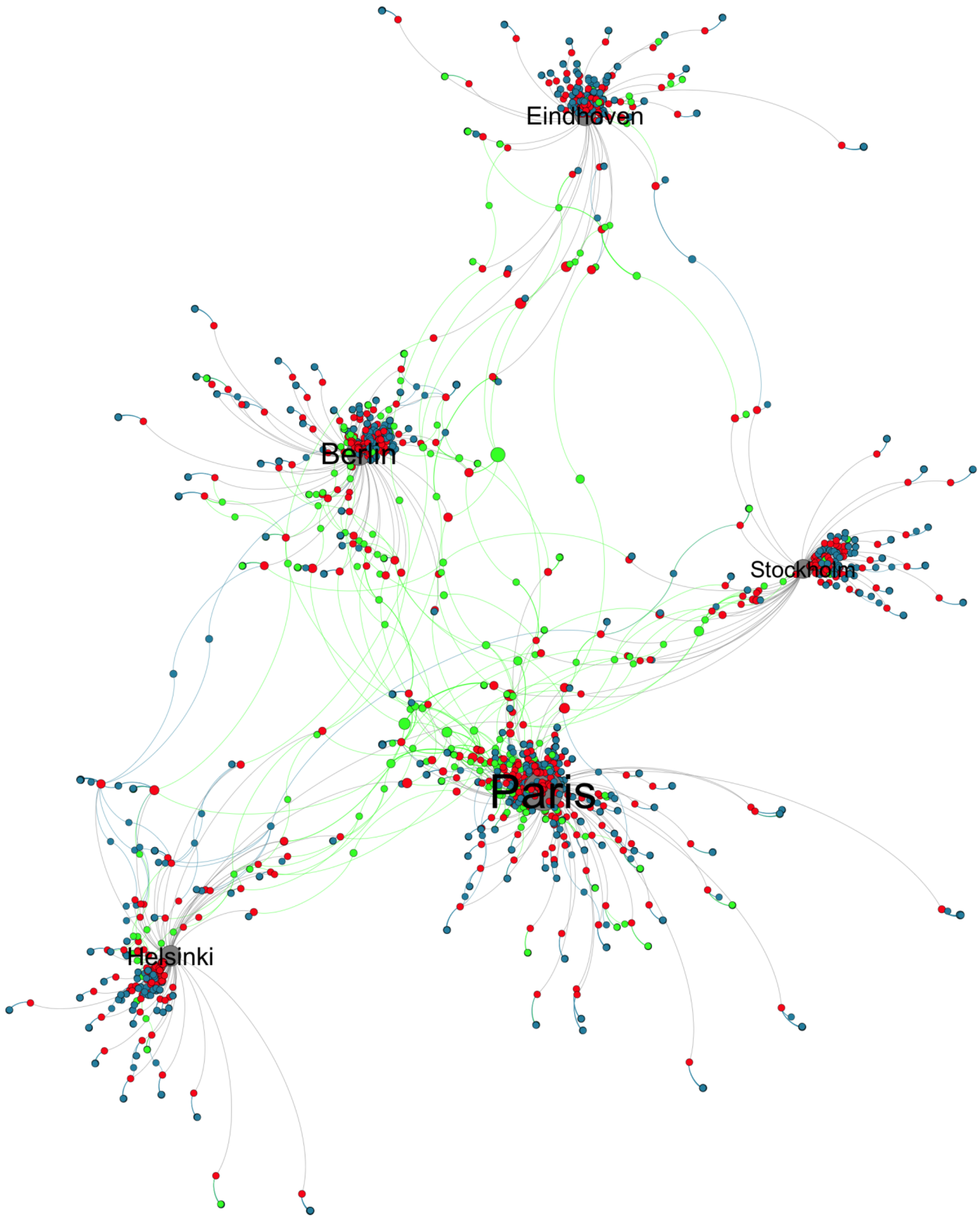

Figure 3. Mobility and financial flows: investors contributing to the companies having their primary offices in EIT ICT Labs location

4.2 Metrics of EIT ICT Labs

The modeling approach used here for constructing the networks enables the use of betweenness centrality in pointing out investors, individuals and educational institutions that operate in between the five EIT ICT Labs nodes under investigation. Betweenness centrality represents the number of times that a given node is included in the shortest path between any two nodes in the network (Wasserman and Faust, 1994). Thus, as the modeling brings investors and individuals in between the EIT ICT Labs nodes through the companies, their betweenness centrality value is increased if they are connected to companies from different EIT ICT Labs nodes. Thus, with this kind of modeling, we are able to use betweenness centrality as a metric for actor mobility in an innovation ecosystem.

Figure 4 shows the betweenness centrality for the top 50 investors, companies and persons in the network of locations, companies and investors. Whereas we give specific values for the betweenness centrality, we urge the reader to focus on the distribution of the values. The distribution brings up 30 investors with betweenness centrality value more than 10,000; the top value for investors is 608,309[2]. At the same time, there are 5 individuals that have a betweenness centrality value more than 10,000; the top value for persons is 76,590.

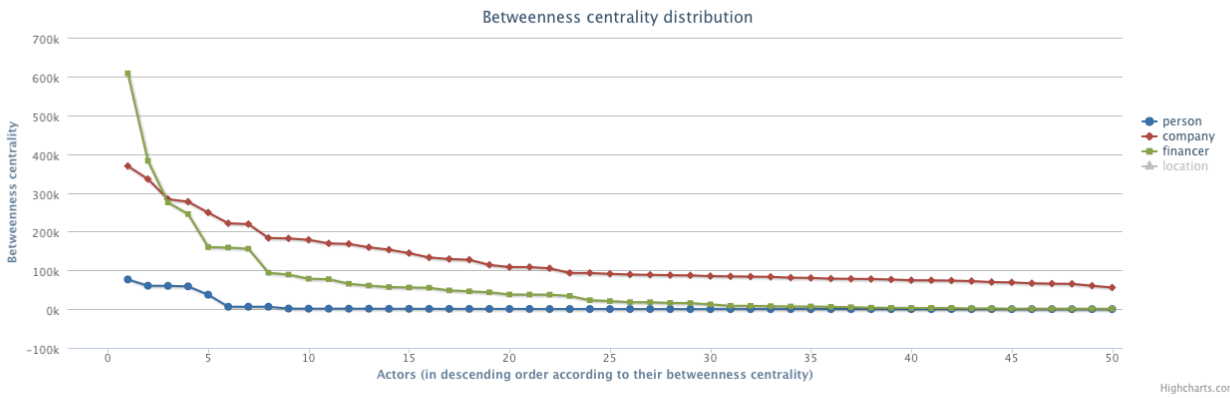

Figure 4. Mobility metrics: the distribution of betweenness centrality values for financial organizations, companies and individual people

While a large number of educational institutions are represented in this innovation ecosystem (N=174), educational affiliation data is missing for a high proportion of individuals included in this dataset. We are reluctant, therefore, to make a direct comparison of betweenness centrality values of educational institutions for individuals to or investors. The characteristics of the distribution are, however, interesting and may be used to indicate the number of educational institutions that can potentially become players in the initiatives operating between the EIT ICT

[2] We follow the convention of representing betweenness centrality values without normalization. To give context to the values that may seem enormous to a reader, it is useful to note that the number of shortest paths for the investor network, for example, is 8,847,650. In practice, however, there are less possible shortest paths in the network because the modeling we use does not allow all possible connections. Two companies are, for example, never directly connected to each other.

Labs locations. Figure 5 shows the distribution for persons, companies and educational institutions or the education network.

Figure 5. Mobility metrics: the distribution of betweenness centrality values for financial organizations, companies and individual people

The top 11 educational institutions have a betweenness centrality value more than 10,000; the top betweenness value for institution is 655,028. These 11 universities are, according to the sample, acting at the moment a connectors and relationship bridges between companies and people in the EIT ICT Labs locations.

5 Conclusions

Mobility of people and other resources is generally seen to contribute towards the goals of innovation. Therefore, this paper presented a novel method for analyzing mobility with a network centric approach, looking at networks of people and money. Using the novel method, the paper explores the context of a European innovation ecosystem, limiting the analysis to five major ICT innovation hubs: Helsinki, Stockholm, Eindhoven, Berlin and Paris, and their networks with nodes of individuals, companies, educational institutions and investors.

The results of the study provide a demonstration of the Ecosystem Network Analysis method and a snapshot of the flows of people and money within that context at the launch of the EIT ICT Labs. We can see that visualisations of network structures provide partial analysis; they provide an approachable abstraction that can be used as a steppingstone for more detailed analysis. In the context of EIT ICT Labs, the visualizations showed who are currently the central figures (mostly either individuals or financing entities) in the five innovation hubs under study. Especially interesting from the collaboration and cooperation points of view are the nodes that are between the innovation hubs, showing that they already have relationships across two or possible nodes.

Once additional detailed network metrics are uncovered, the visualisations can be enriched with these metrics as visual properties. Thus, the paper shows the potential of measuring innovation with an indicator of betweenness centrality, which describes how central a node is within the network. Accordingly, as one of the major goals of EIT ICT Labs is to increase mobility, we anticipate that EIT ICT activities will increase the number of nodes with a high betweenness value. Therefore we propose that measuring and monitoring betweenness centrality within innovation networks can provide valuable and actionable insights.

6 Policy implications and directions for further research

On basis of discussions and informal interviews, we conclude that visual network analysis of a curated, socially constructed dataset of companies, people, educational institutions and investors has resulted in both new and interesting insights on the existing structure of parts of the European innovation ecosystem and its central players at its current state. We state that the resulting snapshot becomes valid and valuable when the people familiar with the context are motivated to understand their individual role in value co-creation within the larger context and can then communicate their shared vision to the results. This way, this paper can be seen to describe the process "from data to intelligence" within its special context.

Presenting these results especially with geospatial social network visualisation (in which graph nodes are laid out according to their geographical locations) helps in understanding existing connections between people in the innovation nodes. Through revealing the special characteristics and the connections within and between the regions at local, national and international levels—overall making these patterns visible—it becomes possible to look at the communities of people involved in innovation activities, and to move to discussions of actions, strategies and policies. For example, the visualizations can be used to promote and increase mobility between the locations of EIT ICT Labs.

The results provide an interesting snapshot, as they describe the European landscape of ICT related activities within the five innovation hubs through press worthy flows of people and money. As the results depict the situation in April 2011, the activities of the EIT ICT Labs itself that has been operational for only a few months have had a negligible impact. Therefore the results provide a valuable baseline measurement to be used in managing, monitoring and evaluating the impact of the future activities of EIT ICT Labs. The hypothesis, which can be further analyzed in the future, provides fascinating possibilities for follow-up research.

European innovation networks are dynamic and will change over time. From a systems perspective, policies and programs may support and enhance positive infrastructure. Policies and programs can also be used to correct and redirect weaknesses and vulnerabilities in the system. These nodes (people, companies, investors, educational institutions) are potential resources for programmatic activities. As was already mentioned, EIT ICT Labs currently involves a limited number of participants (individuals as well as their organizations), so contacting new nodes that were uncovered during this study could provide benefits for the existing participants as well as overall goals of the EIT ICT Labs.

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