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Cohesion and Competition of Europe: Policy Suggestions from The Perspective of Network and Entropy

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Cohesion and Competition of Europe: Policy Suggestions from The Perspective of Network and Entropy.

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This study analyzes the innovativeness of European Union in the context of European Research Area. Literature related with the Systems of Innovation, network studies, Framework Programmes and European Research Area will be used to establish a theoretical framework for a policy analysis. It forms a database from three different resources to establish a European Research and Innovation Network, appearing as a result of policy and programme implementations at the European level. The innovativeness of European Union is discussed for developing policy recommendations, benefiting from the theoretical arguments as well as from analytical studies, derived from network analysis and notion of entropy. It is observed that implementation of a relatively simple rule by European Commission, in addition to policies focusing on development of diversity and absorptive capacity of countries, which are structural holes, may make important contribution to improve the cohesion and competitiveness of European Research Area, as well as the innovativeness of European Union.

Keywords: Systems of Innovation, Networks, Innovation Union, Entropy, STI Policy

JEL Codes: C69, D85, O10

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1. Introduction

With regards to innovativeness, Europe's falling behind compared to its important rivals, or at least its lacking the desired level, is a topic that has been extensively discussed and studied in the related literature (COM (95)688, 1995; COM (96)589, 1997; Caracostas & Muldur, 1998; Fagerberg et al., 1999; Malerba, 2004; Camagni & Capello, 2013; Asheim et al., 2011, etc.). In general, targets set to increase the innovativeness of Europe, or improve its competitiveness are expressed more often than not in the programmes implemented, such as FPs. In this context, the aspiration is to increase the capabilities and the capacities of the members deemed innovative and competitive, as well as to advance swiftly those levels of comparatively lesser innovative and competitive members. Many academic studies, some of which are mentioned above, were made on the measures to be taken to realize this demand, and it seems that there are many more to come. Accordingly, rather than repetitive research, peculiar studies with an interdisciplinary approach in the area would evidently make important contributions to increasing the innovativeness of Europe.

In this sense, this study focuses on the innovativeness of European Union (EU). In order to evaluate and provide policy recommendations for increasing the innovativeness of the Union, different established academic arguments and practical implementations of EU are overviewed. Basic academic framework of this study is based on Systems of Innovation (SIs) approach. Not only innovativeness values, but also the network, labeled as European Research and Innovation Network in this study, is obtained from the practical implementations of European Commission (EC), as the database for innovativeness and network analysis is constructed using the data from Innovation Union Scoreboard (IUS), Regional Innovation Scoreboard (RIS), and CORDIS. Investigation of innovation and network relations is also supported by European Research Area (ERA); another practical implementation by EC. Results of this analysis become inputs for policy recommendations, based on academic discussion on systems of innovation for increasing the innovativeness of European Union.

In accordance with the framework outlined above, Sections 2 and 3 in this article are aimed to establish the theoretical infrastructure of the paper. Section 2 will discuss the relationships between SIs, networks and Innovation Union. Section 3 will introduce how the concept of entropy, specifically Boltzmann's and Prigogine's views, will be used in this article. European Research and Innovation Network will be established and analyzed, benefiting from the data explained in Section 4. In other words, data and methodology infrastructure of the article will be explained in this Section. Analysis and results obtained will be presented in Section 5. In short, the network containing the nodes formed by countries and regions (NUTS-2) will be analyzed; the relationship between innovativeness of countries and regions with network structure will be discussed; ERA will be examined to observe whether it has been on the intended track or not; network analysis and entropy calculations will be used to analyze the innovativeness of EU; finally policy recommendations to increase the innovativeness of European Union will be presented.

Above discussions will bring us two policy recommendations and tools to increase the innovativeness of European Union. It will be argued that a simple rule, stating a requisite to be set by the Commission in the project application process for the inclusion of a node with a low eigenvector value into the project consortium may help to increase cohesion and innovativeness of Europe. In terms of competitiveness of EU, regarding the ability of important gatekeepers to connect with global networks but low absorptive capacity of the system in terms of benefiting from those rivals, it will be proposed that policymakers of EU should focus more on the development of diversity and absorptive capacity of nodes, structural holes, to benefit more from the European Research and Innovation Network in increasing the innovativeness of EU.

2. Systems of Innovation, Networks and Innovation Union

Scholars in the field of innovation studies work intensively on the impact of the network structures over production of information and knowledge, as well as their transformation into new products/services and production/service processes (Powell & Grodal 2005). Andersen, (1996 & 1997) benefited from graph theory and simulation models within the SIs framework. Some researchers examined the geographical distribution of the innovation network or the relationship of geography with the network (Becattini, 1990; Camagni, 1991; Cooke, 1996; Marshall, 1961; Piore & Sabel, 1986; Storper, 1997; Asheim & Gertler, 2005); while some were involved with the structural characteristics of the network (Das & Teng, 2002); or with the governance of the network structure (Pietrobelli & Rabellotti, 2009; Gereffi et al., 2005; Sturgeon et al., 2008); and others were concerned with the cognitive distance among the participants of the network Gereffi et al., 2005; and with the strength of the ties among the said participants (Granovetter 1973), the production/transfer of knowledge/information and their impact on the emergence and/or development of innovations (Nooteboom, 2004). Many authors analyzed the impact of inter organizational networks on innovation (DeBresson & Amesse, 1991; Freeman, 1991; Hagedoorn, 1990 & 1993; Nooteboom, 2004; Powell et al., 1996; Soh & Roberts, 2003). As also evident from the abundance of the studies in the area, starting from the last decade, role of networks in the areas of science, technology and innovation (STI) policies have been discussed increasingly. The main idea behind this discussion is related with the emphasis on the importance of interactions among different actors, which is accepted as the most important factor for developments in STI. In other words, instead of focusing on a single actor and its behaviors; policymakers started to focus on the importance of cooperation, collaboration and communication among the actors. In fact, expectations of policymakers from network analysis were already articulated in the notable works (Freeman, 1991; Lundvall, 1992; Metcalfe, 1995; Foray & Lundvall, 1996) deemed as the building bloc of SIs approach.

Innovation processes involve the generation and application of knowledge, where the success or failure of any SIs depends mainly on how the knowledge of actors is integrated via networks (Foray, 2006), setting the structure of SIs. With these networks, actors not only achieve dispersed specific and diversified knowledge, but also obtain more opportunities to increase their internal knowledge level (Kogut & Zander, 1992; Powell et al., 1996). The reason for this, as emphasized by Allen (2001), is that the diversity among the actors of a system increases the effectiveness of the system. Since it is diversity which enables actors in SIs to evaluate and respond to the requirements of not only market, but also (actors of) system itself. Unless new knowledge is introduced into the system, regardless of whether it is produced within the system or not, the actors of the system's "cognitive distance" (Nooteboom, 1992 & 2005) start to become similar and the system encounters inertia or lock-in.

Therefore, the role and structure of network on the production and diffusion/ dissemination/ distribution of knowledge resulted from actors and their interactions, started to gain attraction in the literature (Malerba et al., 2007). For instance, Latora & Marchiori (2002) state that "the network structure can be as important as the nonlinear interactions between elements, and…structural properties of the network can be of fundamental importance also to understand the dynamics of the system". Accordingly, on networks' relations with knowledge, it can be stated that networks should contribute to systems of innovation to obtain maximum benefit from knowledge diversity, interaction intensity, and knowledge production.

From the negative side, except for some international studies, it may be accepted that intervention policies of governing bodies are not developed within the framework of network approach (Hyötyläinen, 2000). In other words, although governing bodies have been implementing policy measures to obtain utmost benefit from networks, research has shown little interest in policy questions related with networks, though these policies have a high potential to be important ingredients in the development of appropriate policies. Among others, two reasons may be stated why network analysis and policy relationship are understudied by researches. First is the lack of appropriate data and the second is, as stated properly by Carlsson (2000) and Flap et al. (1998): Network approach suffers from the explanatory power.

From the positive side, network analysis has started to become an important ingredient for policy development and implementation phases as increasing number of actors, blurred boundaries and roles among actors, dispersed -especially tacit- knowledge, increasing interdependencies, etc., make network analysis techniques a good candidate for a policy development and implementation tool; that is, networks “are an important component of national systems of innovation. An important function of science and technology policy is to strengthen existing innovation-related networks and to help build networks in areas where they are lacking” (OECD, 1992). Therefore, while policy analysis “is finding out what governments do, why they do it, and what differences it makes” (Dye, 2012); network analysis enables policymakers to study the structure and relational configurations. For instance, Peterson (2003) states “policy network analysis is never more powerful as an analytical tool than when it is deployed at the EU level’ and ‘few … would deny that governance by networks is an essential feature of the EU”. In this sense, reduction of the failures stemming from network, or use of network at its most, to increase competitiveness and innovativeness, necessitates development and/or implementation of appropriate policies.

In short, following the termination of FP1 in 1987, the Second (1987–1991) and Third (1990–1994) Framework Programmes (FPs) were implemented, demonstrating the characteristics of technology-push model. At around the same time, systems of innovation view started to pervade policy advisory circles (Soete & Arundel, 1993). Indeed, this approach was reflected on FP4 (1994–1998), where particular support was provided for such areas as diffusion of technology, integration of SMEs, training, and mobility. Employing a user-oriented approach, FP5 (1998–2002) was shaped specifically for solving societal problems and socio-economic challenges, as well as increasing research capacity and capacity in cutting-edge technologies. In the last two decades, the role of innovation in the context of European development has grown in importance (COM (2000)6, 2000; COM(2006)589, 2006, etc). In this context, FP6 (2002–2006) may be regarded as an important break with previous FPs. It put the emphasis on science and technology excellence and, technology push view in a somehow similar fashion to FP2 and FP3, through introducing new instruments (integrated projects and networks of excellence) and encouraging increasing the number of partners in the projects to obtain critical mass. Moreover, it also endeavored to facilitate ERA in overcoming underinvestment in R&D, fragmentation of research, and coordination problems at different levels. FP7 aimed to strengthen the scientific and technological base of European industry as well as encourage its international competitiveness, while promoting researches that support EU policies. Therefore, starting from FP6, and particularly in FP7, not only the number of participants in FP projects' network increased; but also, especially, after the articulation of European Research Area (ERA) in 2000, FP has become one of the important tools of European research and innovation policy making. Finally, leveraging sufficient additional funding for research, development and innovation, it is expected that FP8 (Horizon 2020) contributes to building/developing an economy based on knowledge and innovation across the entire Union. In this way, it will not only support the Europe 2020 strategy and other policies to be implemented by the Union, but also contribute to the targets of ERA stated as "[t]he Innovation Union must involve all regions. The financial crisis is having a disproportionate impact on some less performing regions and hence risks undermining recent convergence. Europe must avoid an "innovation divide" (COM(2010)546, 2010) between the strongest innovating regions [countries] and the others".

When the explanations up to this point are analyzed at country level, it is not difficult to say that although several rankings place EU Member States like Sweden, Finland, Germany, Denmark, and UK among the world leaders in terms of innovation performance, the rest of the Member States remain mid-range, and the aggregate performance of the EU27 lags behind that of US and Japan, despite their significant prevalence over the BRIC countries. In addition, China and India are quickly catching up with the former, displaying a particularly rapid rate of relative improvement; where, if China keeps its last five years' rate of improvement, the performance gap with the EU27 will diminish in short term (Archibugi et al., 2009). Moreover, other Asian countries, such as South Korea and Singapore, which recently became to be dubbed as the new innovation hot-spots, are also on their way; for which, the Innovation Union Scoreboard 2013 depicts South Korea besides US and Japan to have a performance lead over the EU27. Therefore, Europe began to lose its relative headway in the production of knowledge, not necessarily because Europe does less, but rather, others do more. A distribution pattern similar to these countries can also be observed among regions (as shown in RIS 2012); for which, with the intensified global competition, it is necessitated to implement "smart specialization" approaches to strengthen the existing 'hot spots' of innovation, which would give the regions the edge needed both to determine niche developmental strategies that would allow them to meet local needs, and to survive through this evolutionary phase of knowledge-based societies (Foray & Van Ark, 2007; Soete et al., 2010). By and large, Europe's underachievement, as demonstrated in the RIS 2012 and IUS 2013 data, indicates not only the low performance in growth and jobs, but also the impediments hindering the completion of ERA.

3. Entropy

As stated by Boltzman, a macrostate of a gas is described by temperature, inner energy, pressure and volume, while a microstate of a system is portrayed by momentum (px, py, pz) and spatial coordinates (x,y,z) of each point fulfilling the macrostates. There are many microstates and entropy measures the number of macrostates (or conditions) that can be fulfilled. Put differently, when entropy is 0 (zero), there is only one microstate, implying full predictability, which means there is no possibility for another microstate. On the other hand, when the entropy is higher, there are more possibilities for microstates, bringing a lower degree of predictability. From the SIs view, this situation can be explained as the existence of more possibilities for microstates, indicating higher entropy, means that entities are capable to innovate. This can also be depicted in Boltzmann's entropy formula, a probability equation relating the entropy S of an ideal gas to the quantity W, which is the number of microstates corresponding to a given macrostate. Provided below, Boltzmann's formula shows the relationship between entropy and the number of ways atoms or molecules of a thermodynamic system can be arranged:

$$S = k \log W \text{ or } S = -\sum_i w_i \ln(w_i) \qquad (1)$$

For instance, assume that there are events i (i = 1, 2, 3, …, n) occurring with probabilities w_i, $\sum_i w_i = 1$ and $0 \leq w_i \leq 1$.

If an event is realized with absolute certainty wi =1, we obtain S=0 (ln1=0). Accordingly, probabilities of wi can signify the capability of genes to change/adopt a system; or occurrence of innovation in a system. Therefore, entropy is lower when probability is less distributed; or entropy is higher when probability is distributed equally (Table 1). As a result, lowest entropy means either maximum order (all microstates in one macrostate) or maximum certainty for outcome; while, highest entropy (equal distributions of microstates all macrostates) means either maximum uncertainty of outcome or maximum possibility for innovation.

Table 1 Three Cases

	Case 1	**Case 2**	**Case 3**
Probability of w_1	0.02	0	0
Probability of w_2	0.02	0.01	0
Probability of w_3	0.02	0	0
Probability of w_4	0.02	0.02	0.16
Probability of w_5	0.02	0.08	0
Probability of w_6	0.02	0.04	0
Probability of w_7	0.02	0	0

Probability of w_8	0.02	0.01	0
Entropy (S)	0.0668	0.0590	0.0460

On the concept of entropy, Prigogine & Stengers (1984) argued that in a closed system we cannot see any exchange at all through the boundaries of the system due to lack of gradients, and consequently, the system reaches equilibrium (maximum entropy); a process which is irreversible. That is, the ability of a system's energy to perform work is terminated; as such, entropy of an isolated system never decreases due to the second law of thermodynamics, resulting in a lock-in or entropic death (Saviotti, 1988). On the other hand, Prigogine explained that sum of entropy is constituted by imported and produced entropy in open systems. In "dissipative structures", developed by Prigogine (1976) and other members of "Brussels school" as open systems, entropy is dissipated out of the system, which increases the organization of the system at the expense of increased disorder in its environment. Therefore, dissipative structures, demonstrating the ability for self-organizing by exporting entropy via fluctuations and work under the far from equilibrium, denote a system which is highly organized but always in process and the existence of which depends on the flux of inputs.

4. Data and Methodology

Obviously, precision of any analytical study is essentially based on accuracy of data. In this sense, data from Innovation Union Scoreboard (IUS), Regional Innovation Scoreboard (RIS), and CORDIS are cleaned and prepared for analysis. The database constructed using these three resources allowed the analysis to be used for developing policy recommendations in the following sections. Furthermore, two main approaches to entropy, by Boltzmann and Prigogine, are used for analyzing the relationships between network structure and innovativeness.

4.1. Data

Basically, CORDIS "is the European Commission's primary public repository and portal to disseminate information on all EU-funded research projects and their results in the broadest sense" . IUS and RIS databases will be used to set up a relationship between the network established by CORDIS participants and the notion of innovativeness. IUS provides the innovativeness values of many Europe countries, as well as relative innovativeness values of some important countries vis-à-vis European countries. RIS, on the other hand, gives the innovativeness values of many European regions (NUTS-2). Combining these three resources, a database was obtained for the article, allowing us to focus on and develop policy recommendations for increasing the innovativeness of European Union from the perspective of network analysis.

Inconsistencies in the raw CORDIS data obtained from European Commission were removed from the database to be able to use it in network analysis. As such, not all information concerning the projects and participants could be acquired from the raw database; some projects lacked budget information, while names of participants, or project durations were missing in others, etc. For instance, while the raw database contained 40,097 participants and 12,386 projects in FP4, a cross-check of the start and end dates of projects in FP4 yielded 41,988 participants and 12,815 projects in FP4. When data was deleted based on two criteria (program name and date), 36,320 participants and 11,108 projects were attained as input for FP4 network.

4.2. Method

A network modeled at three scales, named as European Research and Innovation Network, is formed using the database established for this article in order to analyze and discuss the innovativeness of Europe and ERA. The first scale, which will be called ‘open network’, is modeled by the network formed at the country level, in which, all nodes are participants of the FPs (both European and non-European). As a second scale, a network, called ‘closed network’ is established by setting the countries, which are mentioned in IUS 2013 document as nodes. Finally, a network, called ‘regional network’ is formed at NUTS-2 level regions.

After modeling the European Research and Innovation Network at three scales, standard measurement techniques are applied to inspect network characteristics like path length, clustering coefficients, etc., which will then be employed to explore this network in terms of innovativeness; as well as for analyzing ERA in terms of cohesion and competitiveness of Europe. For an exploration of the relationships between characteristics of network and innovativeness of countries and regions (NUTS-2), which are also nodes in the European Research and Innovation Network, innovativeness values of countries and regions obtained from IUS 2013 and RIS 2012 respectively, are correlated with network values of 6 years.

Finally, the study benefits from the notion of entropy in analyzing the innovativeness of Europe with an approach that highly diverges from the general usage and interpretation of the concept. In general, many studies focus on network entropy from the point of distribution of links among nodes. For instance, Mowshowitz (1968) developed an approach based on graph invariants such as vertex degrees, distances etc., and on an equivalence criterion to benefit from information-theoretic measures. Nishikawa et al. (2003) quantified the heterogeneity of complex networks using the standard deviation of degree. Solé & Valverde

(2004) proposed using entropy of remaining degree distribution for heterogeneity, which is also discussed by Bar-Yam (2003). Wang et al. (2006) suggested using entropy of degree distribution to measure the heterogeneity of complex networks. Wu et al. (2010) offered entropy of degree sequence as a measure of the heterogeneity of complex networks . Basically, if a network is consisted of telephone machines and lines, or web pages and links, where there are stable links among nodes; it may be meaningful to consider the role of links in terms of entropy analyses. As observed in these network examples, if there are concrete nodes and links among constituents of networks, it is meaningful to make probability calculations in line with Shannon's formula to find out the entropy of a network. On the other hand, when we talk about innovation, we cannot see concrete nodes and links among the constitutions of network. In this sense, as one of the unique contributions of this article, characteristics of European Research and Innovation Network will be linked with innovativeness values of countries from Boltzmann's and Prigogine's views on entropy. In short, based on Boltzman's view, a simple rule is set forth, and based on Prigogine's view, innovation performance of Europe vis-à-vis its rivals will be discussed in order to produce policy recommendation for increasing the innovativeness of Europe and ERA performance.

5. Analysis and Results

5.1. Network Structure

Since FP1, European Union has been promoting and supporting research and development collaborations by bringing together organizations in related fields to turn ideas into new products, services, and solutions in order to improve competitiveness. This support is based on the basic reason that knowledge is not only the most valuable resource and the source of competitive advantage (Kogut & Zander, 1992), but also is produced by combining previously unconnected knowledge, generating new knowledge; and/or by exchanging knowledge among actors. In short, it is believed that knowledge production is a social process and it can be produced by interactions of actors rather than as a creative act of a single individual or organization (Hakansson, 1989 and Hippel, 1988). Such assumptions led the researchers to analyze networks in order to understand the role of network structure for enabling exchange, combination, and the creation of knowledge (Kogut & Zander, 1992; Tsai, 2002; Tsai & Ghoshal, 1998).

A number of studies analyzed the networks established under FPs. Roediger-Schluga & Barber (2006) focused on the structure of R&D collaborations networks in the first five FPs, and found characteristics of complex networks. Breschi & Cusmano (2002) dwell on the R&D

network established during FP3 and the first part of FP4. Investigating the network with the help of social network analysis and graph theory, they found the existence of small-world and scale-free characteristics. Protogerou et al. (2010) concentrated on R&D collaboration networks in the field of Information Society Technologies (IST) during FP4, FP5 and FP6. They found the existence of small-world structure as well as preferential attachment. All these studies focus on the projects and participants as nodes to determine the network structure. However, in this article, countries and regions (NUTS-2) will be taken as nodes among which the network will be established; whereas the links will be the projects in the field of RTD.

Based on the above explanations, relationships among number of participants, average durations, cost and funding of projects are also investigated. Correlation coefficients calculated among those are shown in Table 2. As per the results, the increase in the number of participants have higher positive effects on the number of projects, as well as average durations, cost and funding of the projects. Furthermore, the increase in the number of the partners in the project is in harmony with the recommendations from evaluation studies of FPs, highlighting the importance of decreasing administrative procedures.

Table 2 Correlation Coefficient among Number of Participants, Average Durations, Cost, and Funding

	# of Participants	**# of Projects**	**Average Duration of the Projects**	**Average Cost of the Projects**	**Average Funding of the Projects**
# of Participants	1.00				
# of Projects	0.74	1.00			
Average Duration of the Projects	0.79	0.45	1.00		
Average Cost of the Projects	0.82	0.36	0.55	1.00	
Average Funding of the Projects	0.78	0.33	0.55	0.97	1.00

Results obtained for Region (NUTS-2) level and country level (open network) networks are depicted in Table 3 and Table 4, respectively. An analysis of the data shows that starting from FP1, most regions or countries enter into the network via connecting with central regions or countries. Additionally, in both types of networks we see an increase in average betweenness centrality and decrease in average closeness centrality values, which can be accepted as an indication for increasing social capital (Borgatti et al., 1998). The notion of path dependency can help explain this situation; successful project management capabilities and experience acquired in the past projects let those actors to become coordinators or participants in the following projects. Acquired experience and project management capabilities may also let them decrease the marginal cost of coordinating or participating into each additional project. Furthermore, visibility or reputation attained makes them attractive partners for the newcomers, demonstrating preferential attachment. Finally, experience in past projects may also decrease the transaction cost among partners in subsequent partnerships, which process has the potential to augment mutual trust and understanding, as well as collaborations.

Table 3 Network Characteristics (Regional Level)

Graph Metric	FP1	FP2	FP3	FP4	FP5	FP6	FP7
Graph Type	Undirected						
Vertices	189	223	271	281	298	309	322
Unique Edges	1195	2166	3137	4230	5187	5359	5421
Edges With Duplicates	2487	11751	14472	33291	41352	44510	60877
Total Edges	3682	13917	17609	37521	46539	49869	66298
Self-Loops	218	878	833	1987	3746	2337	3572
Average Geodesic Distance	2.14	1.92	1.94	1.83	1.79	1.82	1.80
Graph Density	0.10	0.17	0.16	0.24	0.26	0.25	0.25
Assortativity (wh)	- 0.011	- 0.017	0.003	0.015	0.035	0.018	0.004
Average Degree	19.429	38.278	44.266	67.480	77.054	77.974	81.814
Average Clustering Coefficient	0.4690	0.6323	0.6322	0.6888	0.6850	0.6761	0.6801
Power Law	3.12	2.60	2.58	2.20	2.40	2.28	2.37
Average Betweenness Centrality	108.45	102.71	127.66	117.53	117.98	127.62	130.01
Average Closeness Centrality	0.0025	0.0024	0.0019	0.0020	0.0019	0.0018	0.0018

As a result, shared characteristics of both networks such as scale-free degree distributions, relatively low average path length, high clustering, low assortativity values, etc. throughout the FPs in both networks, may be accepted to indicate the unchanging characteristics of network formation mechanisms, despite changes in FP rules. All networks show small-world characteristics, have relatively high clustering coefficients and short path lengths, meaning the structure of network supports knowledge creation and knowledge diffusion (Cowan, 2004). Analysis of participants in FPs reveals that same organizations participate repeatedly in FPs and continue to cooperate with each other. Furthermore, increasing clustering coefficients in FPs in both networks tells that creation/integration of ERA has been in line with the intended purpose.

Table 4 Network Characteristics (Open Network)

Graph Metric	FP1	FP2	FP3	FP4	FP5	FP6	FP7
Graph Type	Undirected						
Vertices	21	67	111	139	144	152	168
Unique Edges	21	96	177	339	316	416	437
Edges With Duplicates	3490	12830	20700	45013	51952	57237	74439
Total Edges	3511	12926	20877	45352	52268	57653	74876
Self-Loops	796	2297	3694	6899	7247	8158	11281
Average Geodesic Distance	1.56	2.22	2.17	1.99	2.01	1.98	2.00
Graph Density	0.44	0.10	0.07	0.10	0.10	0.12	0.11
Assortativity (wh)	- 0.011	- 0.037	- 0.009	- 0.049	- 0.023	- 0.022	- 0.016
Average Degree	10.000	7.164	8.234	13.525	14.667	17.842	18.619
Average Clustering Coefficient	0.7862	0.6008	0.5987	0.7744	0.7755	0.7466	0.7616
Power Law	0.94	2.39	2.97	2.93	2.77	2.84	3.02
Average Betweenness Centrality	6.38	41.46	65.50	69.30	73.37	74.61	84.87
Average Closeness Centrality	0.0320	0.0069	0.0042	0.0037	0.0035	0.0034	0.0030

5.2. Network Structure and Innovativeness

As discussed above, stimulation of innovation is one key concern of policymakers at all levels from local to European Union at large. Correspondingly, development and implementation of network policies may be regarded as a tool to overcome network failures (Nooteboom & Stam, 2008). In other words, connecting actors through links to provide exchange of information, knowledge, etc. can be seen as an appropriate policy within the framework of systems of innovation approach (Carlsson & Jacobsson, 1997). Therefore, in addition to the networks explained in the previous section, as a third type of European Research and Innovation Network, closed network is established with the countries listed in IUS 2013 and participated into FPs. To assess the effect of project participation on innovativeness value; correlation values obtained between number of projects and innovativeness values both at the country and NUTS-2 region levels are calculated. According to correlation results, about half of innovativeness values of nodes (country and region) can be explained by number of projects they participated.

Innovativeness and clustering values of countries in three types of networks are correlated in order to analyze the relationships between innovativeness and clustering values of nodes (country or region). A negative correlation is found between innovativeness and clustering values at the regional and country levels (for instance, correlation coefficients between innovativeness values and clustering values in 2011 are -0.4266 with 00183 (p value); -

0.6226 with 0.00008 (p value); and -0.43965 with 4.268 (p value) for closed, open and regional scale networks respectively). Important gatekeepers at country level in FP7 (Germany, France, Italy, and United Kingdom) are determined to detect the countries filling structural hole and playing critical roles in providing connections between closed and open networks. Then, the innovativeness values and number of FP7 projects of countries are correlated with the important actors stated in IUS 2013 (Brazil, Canada, China, India, Japan, South Korea, Russia, United States of America, and South Africa). According to the results, average correlation coefficient is 0.4431 (for each year, p values are found lower than 0.01137). Based on above findings, it may be articulated that collaboration with important rivals is significant for increasing the innovativeness of Europe. Furthermore, with regards to the role of the most important gatekeepers (Germany, France, Italy and United Kingdom), it seems they are the main actors not only in terms of knowledge production, but also for knowledge transaction between closed and open networks.

As stated above, starting from FP1, average degree value of nodes increases; indicating the capacity of countries is increasing in terms of maintaining links with others. The increase in average degree of nodes not only provides links between previously disconnected nodes, but may also bring about difficulties for finding appropriate links or ways to reach partner, information, knowledge, etc. For instance, Choi et al. (2001) in the field of supply networks, and Rycroft (2007) in biotechnology sector, found out that increased connectivity was not linearly related with an increase in efficiency, which is measured by delivery time and product development time, respectively. However, it is found that there is positive correlation between innovativeness and degree values of nodes in three types of network (for instance, correlation coefficients between innovativeness values and degree values in 2011 are 0.4483 with 0.01 (p value); 0.5690 with 0.0005 (p value); and 0.6801 with 0,01 (p value) for closed, open and regional level networks, respectively).

As stated earlier, the increase in the number of project partners is compatible with the recommendations from evaluation studies (Expert Group, 2010), emphasizing the significance of curtailing administrative procedures. On the other hand, this may potentially have a negative effect on project performance, as the increase in the number of partners in a project will probably decrease the interaction probability among the partners, at the expense of the time required to trust each other. For instance, Lundvall et al. (2002) argued that successful innovation is an outcome of interactive learning processes based on close relationships between actors, implying that it is established on strong ties among the actors. Ruef (2002) and Powell et al. (1996) discussed the importance of number of actors in enabling the combination of different information, knowledge, resources, etc. On the other hand, Tatikonda & Rosenthal (2000) assert negative effects of project size on innovation, though they could not provide a strong empirical support for their argument. Furthermore, the role of different source of actors in innovation is widely discussed by authors such as Nooteboom (2000), Ruef (2002), etc., among others. In general, it is presumed that diverse partners bring the newest information, knowledge, and resources into the project, increasing the success of novelty. Therefore, correlations between average project size (number of participants) and innovativeness value between the years 2006-2012, were made to assess their relationships. As per the result (-0.6494), there is an inverse relationship between the project size and innovativeness value.

Moreover, the role of different types of actors in innovation is also analyzed. Accordingly, between the years 2006-2012, the number of cooperation by each country with others is calculated in order to analyze the notion of participant diversity in projects. Contrary to the inverse relationship between the project size and innovativeness value, a positive correlation is found between innovativeness and diversity of partners, with an average correlation coefficient of 0.4105 (for each year, except for 2006, p values are found lower than 0.0572).

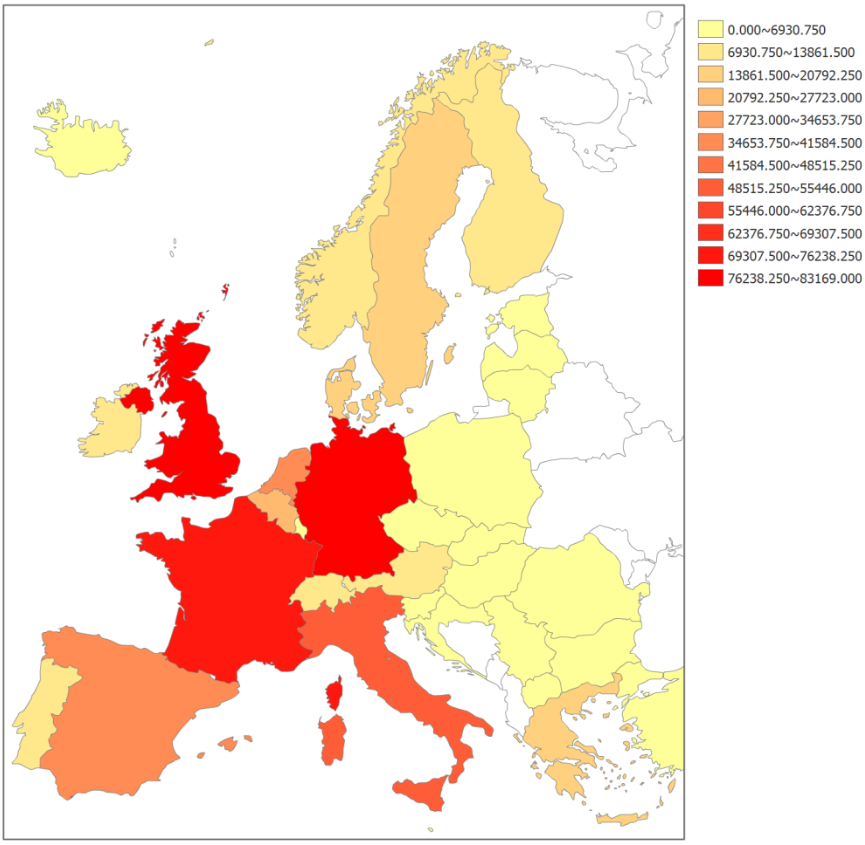

Figure 1 Number of Projects (National)

As a visual cue for the analysis of network relationships discussed, heat maps at the country and region (NUTS-2) scales are generated and analyzed. Heat map of each country or region is determined according to the number of total projects the country or region in question participated throughout all FPs (Figure 1 and Figure 2). These two tools of analysis reveal some interesting findings. Accordingly, if two nodes, countries, or regions, previously participated into a project, they show an inclination to participate into new projects. Moreover, there is also a tendency to participate into new project with the previous coordinator.

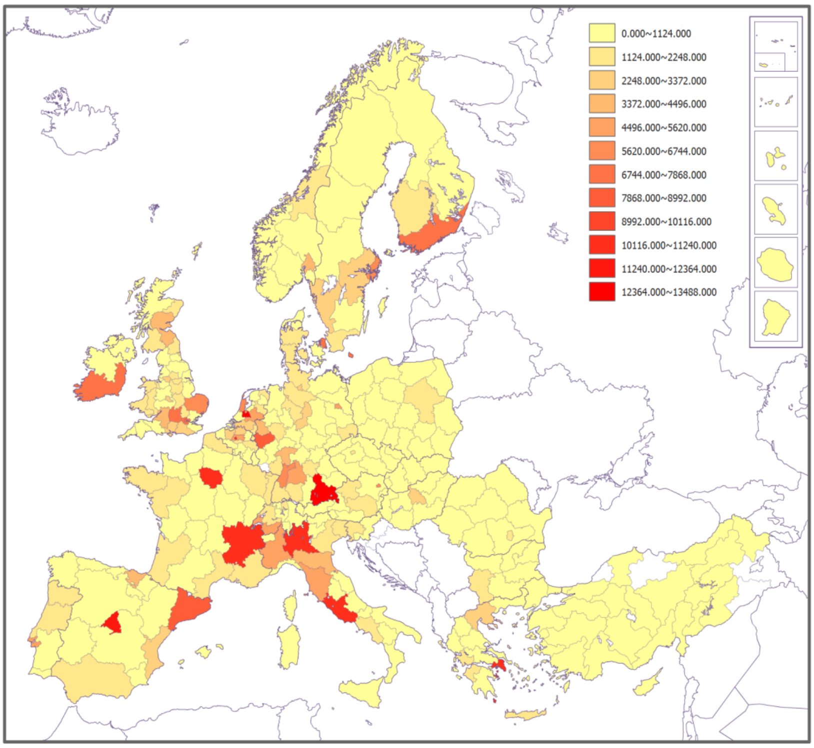

Figure 2 Number of Projects (Regional)

5.3. European Research Area

ERA can be understood as integrated countries/regions collaborating within network while competing for markets. In line with the above discussion, ERA should be designed/ developed/ implemented for creating synergy, competition, and cohesion, instead of creating conflicts, among actors. As such, to what extent ERA is complete and how it supports European Research and Innovation Network is analyzed. A negative correlation is presumed between the spatial distances of the project partners and the intensity of the interaction among project partners, as it is assumed that the increase in the distance between two partners will decrease the probability of those to be partners in a project (Hoekman et al., 2007). In brief, the findings reveal that:

1. Regions (NUTS-2) and countries prefer collaborating with those nearby, rather than those far away; implying geographical distance is still an important factor in the selection of partners for research activities.

2. There are scale free (hierarchical) structures among nodes, indicating nodes prefer to collaborate with nodes that have more links, instead of periphery nodes or lagging nodes. From the other side of the coin, this situation suggests that periphery nodes or lagging nodes could not enter the network of excellence and disparities among those will increase (Clarysse & Muldur, 2001).

3. Regions (NUTS-2) prefer to collaborate with domestic partner(s) instead of those across borders, entailing institutional infrastructure (norms, values, etc.) and national policies such as tax, labor, funding, etc., are still important factors in selecting partner(s) for research activities.

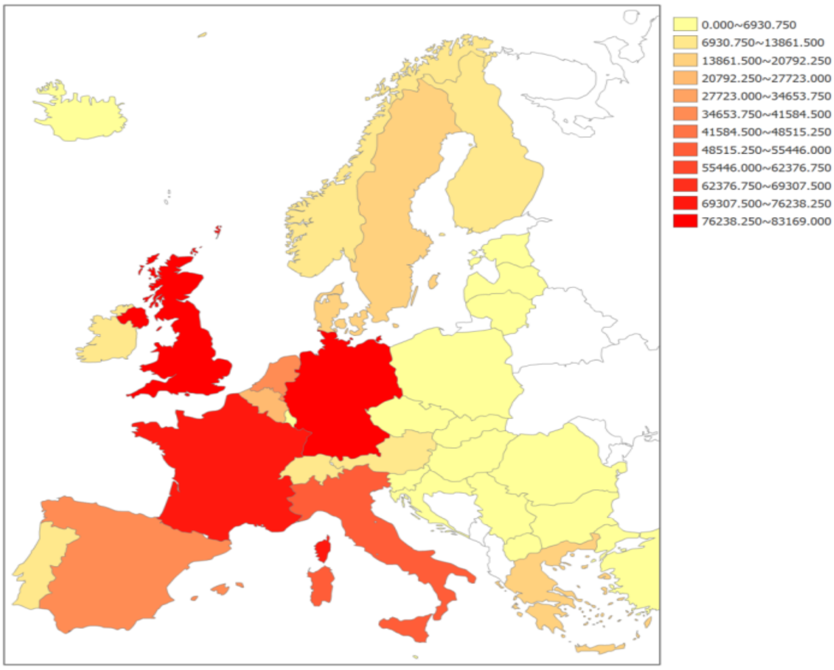

Figure 3 Distance vs. Intensity (Country)

As shown in Figure 3 and Figure 4, the importance of distance increases from east of Europe to west in both networks. West of Europe, as well as some parts in north of Europe give much more importance to the notion of distance. These nodes are also important actors for the competitiveness and innovativeness of Europe. As a result, ERA is not complete yet; as proximity is still an important factor for nodes in their selection of partners. Moreover, with regards to the third finding above, it is assumed that if the increase in number of nodes is higher than the increase in self-loops value, showing the existence of project participant in the same regions more than once, regions can be said to prefer collaborating with domestic partner(s) instead of those from across borders. Results show that while the number of partners increases 0.70 folds from FP1 to FP7, the increase in self-loops is 15.38 folds from FP1 to FP7.

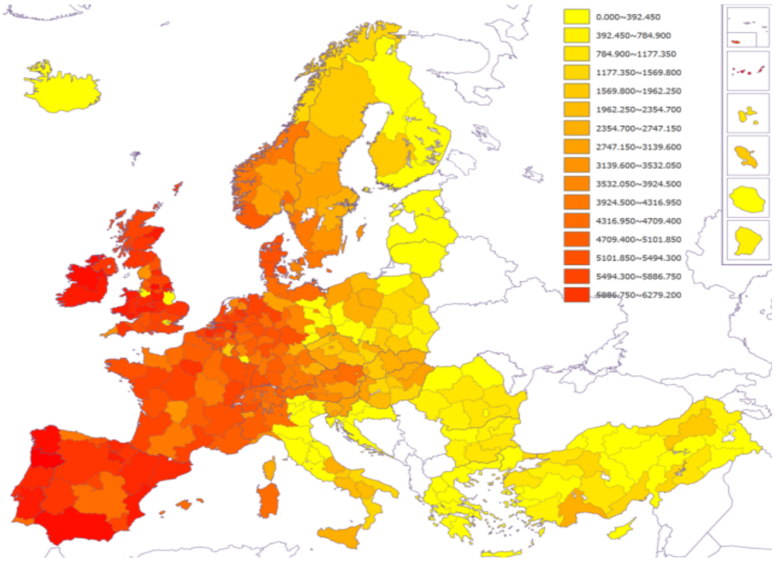

Figure 4 Distance vs. Intensity (Region)

Therefore, ERA can be considered a useful tool, as expected, for removing artificial barriers related to geography and borders. Moreover, it helps to establish networks among organizations, excellent regions, countries, which are important ingredients for increasing the competitiveness and innovativeness of Europe on a global scale. However, it also adds up to the increase in discrepancies among organizations, regions and countries, which undermine the social sustainability of the system due to unintended negative consequences of innovation policies. Thus, this dual structure, increasing competitiveness and discrepancies, should be accepted as the result of intended outcomes of program and policies related with ERA.

In terms of ERA, positive correlation between number of projects and innovativeness value of nodes, as explained above, can be regarded as indicators for the existence and/or development of ERA, which targets European integration at regional, national and continental levels in accordance with Lisbon Agenda, which aims to improve European competitiveness by developing collective innovation and research capacities/capabilities of Europe as a whole. From the view of European Commission, this dual structure will be eradicated over time. The basic assumption is that those lagging regions will increase their knowledge base, innovativeness, competitiveness, etc. over time, with the help of funding. However, findings show a clear tendency of preferential attachment. That is, nodes prefer to collaborate with nodes having more links instead of periphery or lagging nodes. Therefore, as one of outputs the of article, it can be said that improving the knowledge base, innovativeness, competitiveness, etc., is necessary but not sufficient; periphery or lagging regions/ countries are still to pass a threshold to become attractive partners for FP projects or European research network. Accordingly, the related literature also underlines the difficulty of entering into scale-free network due to preferential attachment, and into small-world type of networks due to the difficulty of attaining access to cliques. As exemplified in (Uzzi & Spiro, 2005; Fleming et al. 2007; Schilling & Phelps, 2007), cliques have strong ties with each other, making it difficult to introduce new information/ knowledge or persuade members of cliques to implement new mechanisms. Furthermore, as mentioned above, it is found that the value of average degree rises, implying the capacity of regions (NUTS-2) and countries increases in terms of maintaining links with others. When the increase in number of unique and duplicated links among the nodes are analyzed, the increase ratio of duplicate values is observed to be much higher than that of unique values, demonstrating that vertices (regions and countries) primarily prefer to establish links with the existing nodes, instead of new ones.

This situation has positive and negative sides, depending on the vantage point. While it may be regarded as the establishment of a skeleton of FP programs or declining transaction costs among the partners with the contribution of EU; this may also be seen as a situation in which the same actors doing the same thing with different tools receive the support, or even the research activities of research organizations are financed with few yielding well-known reference companies in the world as an outcome. Put differently, while this process increases the sustainability of the structure; at the same time, it has the potential to reduce the opportunities to be provided by the newcomers. As such, it may be speculated that this relatively semi-locked network (or the notion of path dependency), teaming up with previous partners, may not only lead to redundancy but also trigger the risks of lock-in (Leonard-Barton, 1992). That is to say, it is difficult for the latecomers, which may be an organization, region or a country, to form a hub because of the network structure, which may hamper the re-orientation of relations in the network towards more productive research areas.

5.4. Network Structure, Entropy, and Innovativeness

In line with the discussion on Boltzmann's entropy in Section 3, the possibility to achieve innovation is lower when inputs of innovation are concentrated in a single country, organization, or region (Case 3 in Table 1), while higher if they are distributed among the countries, organizations, or regions (Case 1 or 2 in Table 1). Inputs of innovativeness measurements such as human resources, research systems, firm investments, etc. with different values are distributed differently among countries in IUS 2013. For instance, the value of "firm investments" (composed of business R&D expenditure and non-R&D innovation expenditure) for the year 2012 is 0.287 in Italy and 0.417 in Belgium, indicating the probability of finding a firm investing in R&D and non-R&D for innovation is higher in

Belgium than Italy. As explained above, distribution cannot be rearranged; in accordance with evenly distribution of probabilities among nodes in Case 1 of Table 1. On the other hand, existence of competition among countries does not permit concentration of probabilities depicted in Case 3 of Table 1. This leaves only one alternative, which is the real-life like distribution of probabilities, observed in Column 2 of Table 1, upon which policies can be developed.

Several researchers, including Ahuja (2000), Powell et al. (1996), Leoncini et al. (1996), and Ter Wal & Boschma (2011) argued that links in networks are important means for exchanging information, knowledge, resources, etc., which are important components for novel combinations (Nelson & Winter, 1982) as well as innovation. In this framework, the position of an actor is also argued to be an important factor in determining its innovativeness (Schilling & Phelps, 2007). As discussed by Singh (2005), by influencing the structure of network, policymakers may increase not only information, knowledge, capability, etc. of actors, but also the capacity of actors to innovate.

When the relationship between the structure of the network established by FPs and innovativeness values are analyzed, the correlation results given in Table 5 are obtained for the three types networks. In Table 5, innovativeness shows the highest correlation with the eigenvector value denoting a node's importance in a network based on the node's connections, and next, with the degree values in country networks, either open or closed, in regional network. As per the discussions above, it is not meaningful to expect the redistribution of links among the countries for obtaining high degree values in order to make positive contributions to the innovativeness of countries. On the other hand, eigenvector value may be taken into consideration as a tool for policy intervention. That is, the inclusion of a node with a low eigenvector value into the project consortium not only enables the establishment of consortium with the rest of partners as preferred by the members of consortium, but also supports the existing degree distribution, which contributes to the competitiveness of Europe.

Table 5 Correlation Coefficients of Average Network Characteristics and Innovativeness

Closed Network	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Degree	0.4729	0.3248	0.3429	0.4069	0.4483	0.4392
Betweenness Centrality	0.2499	0.0213	0.2240	0.2593	0.3916	0.4507
Closeness Centrality	0.4668	0.3365	0.3482	0.4296	0.4609	0.4497
Eigenvector Centrality	0.4763	0.3238	0.3348	0.3912	0.4336	0.4167
Clustering Coefficient	-0.0307	-0.2151	-0.2730	-0.3759	-0.4265	-0.4755
Open Network	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**

Degree	0.5967	0.5873	0.5807	0.5638	0.5690	0.5455
Betweenness Centrality	0.4371	0.4054	0.4138	0.3793	0.3896	0.3739
Closeness Centrality	0.5694	0.5519	0.5476	0.5383	0.5453	0.5246
Eigenvector Centrality	0.5810	0.6078	0.6143	0.6047	0.6037	0.5694
Clustering Coefficient	-0.6782	-0.6573	-0.6328	-0.6154	-0.6226	-0.5905
Regional Network	**2007**		**2009**		**2011**	
Degree	0.5916		0.6445		0.6801	
Betweenness Centrality	0.4131		0.4043		0.4262	
Closeness Centrality	0.6474		0.6409		0.6734	
Eigenvector Centrality	0.6135		0.6637		0.6949	
Clustering Coefficient	-0.0617		-0.2423		-0.4396	

The last statement is also supported by Demetrius & Manke (2005), who suggest "[w]hile robustness is defined as the resilience of the network against changes in the underlying network parameters, network entropy characterizes its pathway diversity". As such, in an unweighted and undirected network (like networks established in this article), topological entropy can be calculated using a formula derived from Kolmogorov-Sinai (KS) entropy, according to whom, topological entropy is positively correlated with the largest eigenvalue of the network. In this framework, the largest entropy value among all nodes in FPs is found and correlated with the innovativeness value of Europe. Correlation coefficient between them is -0.052, meaning that they are almost uncorrelated. Next, the most relevant eigenvector value with Demetrius & Manke (2005) argument is investigated and it is found that average eigenvector centrality is the most correlated value with innovativeness value, which is -0.8379. This indicates an inverse proportion between average eigenvector centrality and innovativeness value: a decreased average eigenvector centrality yields a higher innovativeness value. The emergence of a network structure results not only from the characteristics of nodes and sectors, but also from the interactions among the constituents of the institutional infrastructure, as discussed by Kogut (2000). In this sense, the position and links of the node determine its eigenvector value. As such, similar to the approach above, it is not meaningful and possible to demand from nodes (countries or regions) to change the links they have; instead, a policy developed upon eigenvector may be implemented in a manner that allows the nodes with low eigenvector values to be taken into the networks. In the case of such an implementation, the eigenvector value pertaining to both the countries with previously low and high eigenvector values will change accordingly.

To decide on the appropriateness of this change, eigenvector distribution of each node in the network is considered. It is found that eigenvector values of nodes are in accordance with the power law value of the network (correlation coefficient is 0.7888 with $p=0.03$). Furthermore, there is an inverse relationship between innovativeness value and power law value, indicated with a correlation coefficient value of -0.5247. As an emergent structure, we cannot trade-off innovativeness of Europe with the characteristics of network, implying that instead of deciding who will establish a network, a simple rule may be added to the application process, which may bring about a more democratic distribution (or lower power law value) and more innovativeness.

Another interesting finding is the relationships between European Research and Innovation Network and entropy of the system, mentioned above. Based on discussions by Prigogine & Stengers (1984), it can be stated that entropy of an isolated system never decreases due to the second law of thermodynamics and thus, we observe a lock-in or entropic death (Saviotti, 1988). In this sense, average degree value of countries consisting of non-members, candidates and EFTA members is 969.71 between the years 2006-2012, meaning European Research and Innovation Network clearly maintains its links with outside. However, this statement is no more than "stating the obvious", in terms of the relationship between entropy and European Research and Innovation Network. The critical point here is an analysis of the relationships between European Research and Innovation Network and degree values of important rivals, stated in the Innovation Union Scoreboard 2013 (IUS) report. Essentially, the changes in the innovativeness value of Europe, stated in IUS 2013, and in degree values of each important rival from successive years (2006-2007, 2007-2008, etc.) are calculated. In this framework, it is assumed that a positive correlation value will be obtained if the relationships between European Research and Innovation Network and important rivals have positive effect on innovativeness on Europe, or vice versa. Correlation results obtained between innovativeness value of Europe and degree values of important rivals are given in Table 6.

Table 6 Correlation Coefficients between Changes in Average Innovativeness Value of Europe and changes in Degree Values of Important Rivals

Countries	Brazil	Canada	China	India	Japan	South Korea	Russia	United States
Innovativeness	0.87	0.78	0.02	-	-0.99	-0.99	0.06	-0.89

According to IUS 2013, United States, Korea, and Japan have performance lead over Europe; while Brazil, Canada, China, and Russia have performance gap with Europe. The obtained results given in Table 6 are consistent with IUS 2013 statements, demonstrating positive correlation between Europe, and Brazil, Canada, China, and Russia; and negative correlation between Europe, and United States, Korea, and Japan. Put differently, when its relations with three of its rivals are considered, the existing policy and implementations in Europe have not proved as beneficial as expected.

5.5. Policy Recommendations

Dual structure (competition and cohesion), resulted from implementations related with ERA, should be considered when ERA policy is determined and/or developed, if all EU rather than the successful participants only are aimed to benefit. However, the discussion on ERA based on the obtained results proved that ERA has not been completed yet (COM(2012)392, 2012); although the Commission states “ERA is at the heart of the Europe 2020 strategy and its Innovation Union (IU) policy flagship and why the European Council has called for ERA to be completed by 2014” (COM(2012)392, 2012) . Since, it is thought that one way or another, fulfillment of ERA will provide harmony among the policymakers in terms of not only their perception and implementations of SIs policies, but also elimination/ minimization of critique made above.

When the relationship between network structure established by FPs and innovativeness values are analyzed, it is found that innovativeness shows the highest correlation with eigenvector and next with degree values in country networks either open or closed, in regional network. Based on the explanations above, it is not meaningful to expect the redistribution of links among the countries in order to make positive contributions to the innovativeness of countries. As such, the Commission may decide on the duration of support, the amount of project budget, the amount of project funding, and the types of participants. However, as network is an emergent structure, even if the high clustering or low path length have positive effects on the information/knowledge dissemination/production, the Commission should not decide who will build collaborations in the project. Therefore, in terms of cohesion, eigenvector value may be considered as a tool for policy intervention. Without forgetting the emergent structure of European Research and Innovation Network and the importance of current nodes, which can be either country or region, for the innovativeness and competitiveness of Europe, a simple rule which states that in the project application process, a requisite to be set by the Commission for the inclusion of a node with a low eigenvector value into the project consortium, would both allow the free establishment of the said project consortium, and facilitate the participation of nodes with low innovativeness into the network. That is, when the sustainability of EU innovativeness is considered, how to manage increase in diversity is a question to be answered by policymakers of EU to prevent the decrease in performance of the system. This study offers to use of eigenvector calculation as a simple but effective tool for increasing the cohesion of the region or countries for achieving the target of Innovation Union, including ERA. Since participation into FP projects will increase the knowledge base of the periphery or lagging region or countries in a time. One may ask whether there is a negative side to include periphery or lagging region or countries into project in terms of overall innovation performance of EU, or leader regions or countries. As stated earlier, this rule does not prevent any partners to establish a project consortium with others. In other words, at least one node, which has a lower eigenvector value, will be included into project consortium, and the rest of project partners will be selected via free will of the applicants (project leader or coordinator) of the project.

On the other hand, in addition to the issue of cohesion above, there is the issue of competitiveness of EU. As mentioned, there are enough links among the nodes (regions and countries) to state that nodes are able to collaborate with others. Concerning the competitiveness of EU, with regards to the role of the most important gatekeepers (i.e. actors filling structural holes), it is found that they are the main actors not only in terms of knowledge production and diversity, but also for knowledge transaction between closed and open networks, or between EU and outside. However, when relations with three of the important rivals are considered, the existing policy and implementations have not proved as beneficial as expected from European Research and Innovation Network. Put differently, based on the finding that indicates a negative correlation between clustering coefficient and innovativeness, and a partially positive correlation between the number of projects with important rivals and innovativeness value, it may be articulated that collaboration with important rivals is significant for increasing the innovativeness of Europe. That is, instead of focusing on obtaining high clustering, which may also indicate the existence of mass, redundant links among nodes, decrease in differences, etc.; focusing on structural holes may be considered as an alternative means for increasing innovativeness of EU. Therefore, regarding the ability of important gatekeepers to connect with global networks but low absorptive capacity of the system in terms of benefiting from those rivals, it is logical to propose that policy makers of EU should focus more on the development of diversity and absorptive capacity of nodes in order to benefit more from the European Research and Innovation Network to increase the innovativeness of EU.

Evidently, which tools (or instruments) are preferred to implement the above recommendations is a critical issue. While the selection of policy tools forms a part of the policy formulation; tools turn out to be part of the actual policy implementation. Notwithstanding which policies and tools related with innovation are selected, their framework and impact are mainly determined by ultimate political objectives, which might be related with various topics ranging from economic issues such as growth, employment, and inflation, to social, environmental, defense concerns. Furthermore, selection and implementation of appropriate innovation policy tools are mainly related with causes behind the problems identified by the researchers, governing authorities, etc. The analysis in this study reveals two important causes, initiating two main policy recommendations (Table 7), stated above. One of the causes is the imbalance among nodes (regions and countries in Europe) in terms of knowledge accumulation, capacities, and capabilities, preventing the cohesion/development of ERA and impeding the innovativeness of EU. Second is the low level of diversity and absorptive capacity of nodes, especially gatekeepers, preventing the rise of competitiveness in ERA and adding to the innovation performance gap with the important rivals stated in IUS 2013, specifically USA, Japan and South Korea.

Regulatory, economic and financial instruments, as well as soft tools (Borrás & Edquist, 2013) used for innovation policies, can be considered as important means employed by governing bodies for policy intervention. Within the systems of innovation and network studies scope of the article, two instruments are selected among others to implement suggested policy recommendations. One is in the framework of regulatory instrument in accordance with the categorization by Borrás & Edquist (2013). As such, a legal regulation, which stipulates the inclusion of a node with a low eigenvector value, in projects may be used for balancing nodes (regions and countries in Europe) in terms of knowledge accumulation, capacities, and capabilities, to accelerate cohesion/ development of ERA and increase innovativeness of EU. Second tool falls into the category of soft instruments. In order to increase diversity and absorptive capacities of actors, specifically gatekeepers, vis-a-vis important rivals of Europe, stated in IUS 2013, this study considers the use of public procurement and/or public-private partnerships (PPI) for increasing the competitiveness of ERA and decreasing innovation performance gap with the important rivals, specifically with USA, Japan and South Korea. Since, specific and challenging projects requested by or implemented with public actors will increase specific knowledge and capabilities of actors, which increases the diversity as well as absorptive capacity of actors in the long run.

As a result, Barca (2009) report underlined the importance of combined exogenous and endogenous push for institutional changes in nodes (country and/or region), while innovation policy supports excellence and nourishes inequalities among the nodes; cohesion policy enables measures to decrease inequalities among the nodes. In this sense, recommendations developed in this study related with cohesion and competitiveness of ERA as well as innovativeness of EU could be seen as an appropriate input for developing institutional infrastructures in nodes (country and/or region). In accordance with Prigogine's argument, while European Research and Innovation Network, in a sense, sources a part of its order from outside by improving its ability in terms of managing links with non-EU countries, especially important rivals; at the same time, eigenvector approach enables its cohesion, increasing the absorption and diffusion of knowledge of nodes, especially lagging or periphery nodes. In this way, not only political concerns related to 'hollowing out' of globalization on innovation systems in Europe or with network failures arguments (Varblane et al., 2007) can be diminished but also global networks can be used for increasing the performance of systems of innovations at all levels.

Table 7 Aim, Instrument, Tool and Policy

<table>
<tr><td colspan="2"></td><td colspan="2">Aim</td></tr>
<tr><td colspan="2"></td><td>Cohesion</td><td>Competitiveness</td></tr>
<tr><td rowspan="2">Instrument</td><td>Regulatory Instrument</td><td>decrease in diversity among the actors</td><td></td></tr>
<tr><td>Soft Instrument</td><td></td><td>increase in the diversity & absorptive capacity of actors, which fill structural holes</td></tr>
<tr><td colspan="2"></td><td>Eigenvector Value of Node</td><td>Public Procurement and/or PPI</td></tr>
<tr><td colspan="2"></td><td colspan="2">Tool</td></tr>
</table>

6. Contributions and Future Directions

As discussed by some of the authors such as Arnold (2011), Weber (2009), Richardson (2000), the bridge between network analysis and policy development should be established and this link should be used for developing and implementing policy. That is, network analysis techniques should say more than the obvious results that can be obtained using four mathematical operations, such as the changes in network sizes, the determination of the importance of actors by adding the number of projects they participated into, etc. In this context, the methodology developed in this study, aimed to benefit from network analysis in order to produce policy recommendation, will contribute to the elimination of the valid criticisms in the literature.

It is believed that this study might provide a base for two different types of studies for integrating network studies and policy development/implementations. First is an investigation of relationship among growth, collaboration and innovation in European Union. The existing study already deals with the relationship between innovation and collaboration and a discussion on this relationship, combined with social capital and growth, will be able to contribute to the development of academic studies on trust, social capital, and innovation.

Another field of study is the analysis of network structure, position of actors in the network and performance of nodes, either national or regional. Particularly in an environment where network formation is encouraged, the examination of network structure and the impact of performance in network, etc. or vice versa, will contribute to the programs such as FPs, which support network formations.

7. Conclusion

European Research and Innovation Network, formed at three scales in this study and appeared as a result of policy and programme implementations at the European level, was analyzed benefiting from standard network analysis techniques to evaluate RTD policies, implemented by EC. At the same time, discussions on entropy were combined with the results obtained from the analysis of European Research and Innovation Network, and discussions on SIs, within the framework of EC implementations related with ERA and innovativeness of EU. In this way, not only network analysis can be used as an ingredient for policy recommendation, but also as one of the unique contributions of the study, the innovativeness of EU is discussed and policy recommendations are made by benefiting from the discussions and analyses on SIs and network studies. This process produced two main policy recommendations. Firstly, implementation of a simple rule, inclusion of node which has low eigenvector value into project consortium by EC will not only increase the cohesion process of ERA but also the innovativeness of EU. Secondly, without forgetting the emergent structure of European Research and Innovation Network and the importance of current nodes, which can be either country or region, for the innovativeness of Europe, it can be said that when relations with three of the important rivals (United States, Korea, and Japan) are considered, the existing policy and implementations have not proved as beneficial as expected from European Research and Innovation Network. In this sense, policymakers of EU should focus more on the development of diversity and absorptive capacity of nodes that form structural hole, in order to benefit more from the European Research and Innovation Network to increase the innovativeness of EU.

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