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Framing the structure of global open innovation research

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ABSTRACT

This study proposes a way of mapping open innovation research structure by quantitatively analyzing open innovation research papers retrieved from Web of Science database. A total of 130 papers are retrieved in this study and 62 papers which contain keywords are chosen for research structure visualization. Open innovation research networks are quantitatively investigated by combining network theory and keyword co-occurrence. Contour maps of open innovation are also created on the basis of networks for visualization. The networks and contour maps can be expressed differently by choosing different information as the main actors, such as the paper author, the institute, the country or the author-keywords, to reflect open innovation research structures in micro, meso, and macro-levels, respectively.

The quantitative ways of exploring open innovation research structure are investigated to unveil important or emerging open innovation components as well as to demonstrate visualization of the structure of global open innovation research. The quantitative method provided in this project shows a possible way of visualizing and evaluating research community structure and thus a computerized calculation is possible for potential quantitative applications on open innovation research management, e.g. R&D resource allocation, research performance evaluation, and science map.

1. Introduction

"Open Innovation" is a term promoted by Henry Chesbrough, a professor and executive director at the Center for Open Innovation at UC Berkeley, in his book "Open Innovation: The new imperative for creating and profiting from technology" (Chesbrough, 2003). Chesbrough (2003) defined Open Innovation as "paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology". It is about harnessing the inbound and outbound flows of ideas, technology and skills across a firm's boundaries.

Actually, researches have been done since 1980s to explore how the ways toward innovation changed from a close model to a model in which firms started to increase acquisition of external technologies to advance their technology capacity (Lane & Lubatkin, 1998; Pisano, 1990; Von Hippel & Von Hippel, 1988). After 2000s, open innovation has been the most debated topic by researchers (Christensen, Olesen, & Kjaer, 2005; Dodgson, Gann, & Salter, 2006; Gassmann, 2006; Lichtenthaler, 2008; West, Gallagher, & Square, 2006), and it is now commonly accepted by academy and industry that production of knowledge itself was changing to a dynamic and interactive way of knowledge creation and acquisition.

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To understand the knowledge flow of an open innovation process, Dahlander and Gann (2010) review open innovation papers and identify two inbound processes and two outbound processes. However, in addition to understanding the inbound and outbound processes of open innovation, it is desirable to obtain a whole picture about what open innovation researches have been done so far. Therefore, similar to Dahlander and Gann (2010), this study aims to retrieve open innovation papers from Web of Science database and analyze the whole research structure of global open innovation by integrating social network analysis and keyword analysis.

1.1. Mapping knowledge evolution through bibliometric analysis

Thomas Kuhn (1962) popularized the terms "paradigm" and "paradigm shift", which Dosi later used to investigate the technology trajectory. He found that continuous innovation can be regarded as proceeding the technology paradigm, while discontinuous innovation might be the initiation of a new paradigm (Dosi, 1982). Methodologies have been proposed and applied by numerous researchers in various fields to understand the paradigm or dynamic development of the selected fields (Gupta & Bhattacharya, 2004). From literature publication metadata and information, it was evident that bibliometric analysis was the methodology used for mapping the evolution of knowledge.

For example, Kostoff had a complete and systematic study on literature-related analysis and published a series of papers based on a combination of text mining and statistics from scientific papers. He also proposed a novel and intelligible technique called the Literature-Related Discovery method for linking two or more literature concepts together (Ding, Chowdhury, & Foo, 2001; Kostoff, Eberhart, & Toothman, 1998; Kostoff, Tshiteya, Pfeil, & Humenik, 2002; Kostoff, Tshiteya, Pfeil, Humenik, & Karypis, 2005; Kostoff, Bhattacharya, & Pecht, 2007; Kostoff, 2008) mapped information retrieval research by using co-word analysis on papers collected from the Science Citation Index (SCI) and Social Science Citation Index (SSCI) from 1987 until 1997 (Baldwin, Hughes, Hope, Jacoby, & Ziebl, 2003; Ding et al., 2001) mapped ethics and dementia research by using keywords (Baldwin et al., 2003; Tian, Wen, & Hong, 2008) used the Institute for Scientific Information (ISI) database to measure scientific output in the field of Geographic Information System (GIS) by using keywords (Tian et al., 2008). Similar approaches have been made to map knowledge evolution in other fields, such as software engineering (Coulter, Monarch, & Konda, 1998), chemistry (Callon, Courtial, & Laville, 1991), scientometrics (Courtial, 1994), neural network research (Noyons & Van Raan, 1998; Van Raan & Tijssen, 1993), biological safety (Cambrosio, Limoges, Courtial, & Laville, 1993), optomechatronics (Noyons & van Raan, 1994), bioelectronics (Hinze, 1994), adverse drug reactions (Clarke, Gatineau, Thorogood, & Wyn-Roberts, 2007; Rikken, Kiers, & Vos, 1995), biotechnology (De Looze & Lemarié, 1997; Rip & Courtial, 1984), environmental science (Ho, 2007), condensed matter physics (Bhattacharya & Basu, 1998), severe acute respiratory syndrome (SARS), tsunamis (Chiu & Ho, 2007; Chiu, Huang, & Ho, 2004), and Parkinson's disease (Li, Ho, & Li, 2008).

Some studies were enhanced by combining keyword analysis with other forms of analysis. For example, morphology analysis was a conventional method of forecasting future technology and identifying technological opportunities. Yoon and Park (2004) argued that morphology analysis has its limitations because there was no scientific or systematic way of establishing the morphology of technology. Therefore, keyword-based morphology analysis was proposed. An example of thin film transistor-liquid crystal display (TFT-LCD) was studied to illustrate the detailed procedure of this keyword-based morphology analysis (Yoon & Park, 2005).

1.2. Mapping knowledge by network and keyword analysis

A social network can be made up of different forms of social actors: for example, the basic components could be people, organizations, or countries. A social network formed on the basis of social exchange can be used to understand how resources were exchanged in this network, how social actors were positioned to influence resource exchange, and which resource exchange was important (Nohria, Eccles, & School, 1992; Wasserman & Galaskiewicz, 1994; Wellman & Berkowitz, 1988). Each resource exchange is a social network relation or a "tie" maintained by social actors at both ends of the "tie." The strength of a tie is a function of the number of resource exchanges, the type of exchanges, the frequency of resource exchanges, or even how close the two connected actors are (Marsden & Campbell, 1984).

Social network analysis is an interdisciplinary research field. Granovetter (1970, 1973) proposed the theory of the weak tie after his social network research. He surveyed a total of 282 job seekers with regard to the type of ties between the job seeker and the contact person who provided the necessary information. Of those who found jobs through personal contacts, only 16.7% reported seeing their contact person often. This illustrated that social network analysis is a proxy that provides a connection between microscopic analysis and macroscopic analysis. In the late 1990s, collaboration between researchers from different fields through the use of social network analysis had been initiated, and the field became more interdisciplinary. At that time, Barabasi and Albert (1999) demonstrated that the algebraic distribution in the connectivity of a scale-free network was caused by two basic factors in the temporal evolution of the network: growth and preferential attachment (Barabasi & Albert, 1999). Watts and Strogatz (1998) published a breakthrough paper titled "Collective dynamics of 'small world' networks," (Watts & Strogatz, 1998), and a book titled "Six Degrees: The Science of A Connected Age" (Watts, 2003) which, together with other interdisciplinary works, contributed to the expansion of the "small world" concept from conventional neuroscience and bioinformation systems to any natural or human system that can be modeled by a network.

Social network analyses based on keywords have also been explored. Motter, de Moura, Lai, and Dasgupta (1999) constructed a conceptual network from the entries in a thesaurus dictionary and considered two words to be connected if they

Table 1
Sources of open innovation research papers.

Journal	No. of Papers	%
R & D Management	23	17.69
Research-Technology Management	15	11.54
Research Policy	7	5.38
International Journal of Technology Management	6	4.62
Technovation	5	3.85
Industry & Innovation	4	3.08
Journal of Product Innovation Management	4	3.08
California Management Review	3	2.31
Food Technology	3	2.31
Management Decision	3	2.31

Datasource: Web of Science.
Top 10 journals for open innovation.

expressed similar concepts. They argued that language networks exhibited small-world properties as a result of natural optimization. These findings were important not only for linguistics, but also for cognitive science (Motter et al., 1999). In addition, Marshakova-Shaikevich (2005) attempted to build a semantic map in the field of women's studies by document-clustering on the basis of lexical similarity of titles and word-clustering on the basis of co-occurrence of words in the same documents (Hori, Nakakoji, Yamamoto, & Ostwald, 2004; Marshakova-Shaikevich, 2005).

1.3. Construction of global open innovation research structure

The purpose of this research is to shed light on the effects of a combination of social network analysis and bibliometric analysis of publications in global open innovation research by using different publication information as actors in the network, e.g., keyword, author, research institute, or origin of country. The network actors and linkages corresponding to publication information and keyword occurrence respectively can be visualized, and thus, knowledge evolution can be mapped. Furthermore, network properties for keyword-based network development in this study can be calculated to obtain a quantitative analysis of knowledge evolution (Granovetter, 1973).

2. Research method

This research integrates social network analysis with keyword analysis in order to draw a picture of global open innovation research structure. The obtained structure can be called a "global open innovation research map," where each country, research institute, or researcher that contributed to global open innovation research can be positioned. The research process in this study is comprised of: (1) literature retrieval, (2) Keyword standardization, (3) Construction of Network Structure and Calculation of Network Centrality, and (4) Construction of Contour map.

2.1. Literature retrieval

Web of Science (SCI and SSCI) literature database is used for paper retrieval. Search strategy is: (open innovation) in both Topic or Title, a total of 130 papers have been obtained. The corpus comprises 91 article (research papers), 12 conference proceeding papers, 11 editorial materials, 7 book reviews, 6 review papers, and 3 new items. Table 1 shows the top 10 Journal for open innovation research papers. Database retrieval time is on January 5, 2010. Most papers (98.5%) are in English and only 62 papers contain author keywords.

2.2. Keyword: standardization

Owing to the fact that different words can be used to describe same or similar concept, it is necessary to standardize words that used to express similar concepts. For example, (1) intellectual property and intellectual property *right are standardized to* "intellectual property"; (2) business development and Business ecosystem are standardized to "business"; (3) external knowledge retention and external knowledge relation are standardized to "external knowledge"; and (4) "*Research and Development", "R and D" are standardized as "R and D"*, etc. A total of 206 keywords are obtained after standardization and Table 2 shows the top 20 most frequently occurring keywords.

2.3. Construction of network structure and calculation of network centrality

The networking of keywords is based on sufficient correlations among keywords. A correlation is presented as a "network tie." This study provides two methods of generating network ties. (1) The relationship between two different papers occurs because the two papers share at least one keyword. A network generated by this method is defined as an RFP network (research focus parallelship network). (2) The relationship among plural keywords occurs because these keywords are listed

Table 2
Top occurrence keywords.

Keyword	Occurrence
open innovation	32
innovation	16
intellectual property	8
knowledge	7
open source	6
technology transfer	6
licensing	5
external technology commercialization	4
R&D	4
absorptive capacity	3
entrepreneurship	3
open source software	3
organizational	3
social networks	3
strategic management	3
virtual communities	3

in the same paper. A network generated by this method is defined as a KCO network (keyword co-occurrence network). The detailed explanation of these two methods is as follows (Su & Lee, 2010):

(1) RFP network (Research focus parallelship network): The relationship between two different papers occurs because these two papers share at least one keyword. For example, a paper is used as a network actor (network node) and any two actors sharing the same keyword will be linked. This is based on an assumption made in this study that keywords represent the core research of a paper. If two papers share the same keyword, the implication is that these two researches overlap partially in areas that can be represented by that keyword. The two papers are thus regarded as a pair of parallel papers and the constructed network is defined as an RFP network. However, the network node is not necessarily the paper; it can be other actors that carry knowledge, e.g. the paper (first author), the research institute, or the country. The three types of RFP networks are:
- RFP-country network: Research focus parallelship network with the country as the network actor.
- RFP-institute network: Research focus parallelship network with the research institute as the network actor.
- RFP-paper network: Research focus parallelship network with the paper (first author) as the network actor (Su & Lee, 2010):

  In this study, RFP-country network, RFP-institute network, RFP-paper network are investigated in order to understand parallelship of knowledge structure of global open innovation research at micro, meso, and macro levels, respectively.

(2) KCO network (Keyword co-occurrence network): The relationships of author keywords are formed because the author keywords specified by authors are listed in the same paper. Author keywords listed in the same papers are linked together because all these keywords can be used to represent the core ideas of a research paper and have a strong relation to each other. Keywords in the same paper share equal importance for the paper.
- KCO network: Keyword co-occurrence network.

In this study, KCO network is investigated in order to understand co-occurrence of keywords in global open innovation researches at micro level.

Computer software, Netdraw (Analytic Technologies, 2011), is used to visualize RFP network and KCO network and then network properties are subsequently calculated. In social network theory, centrality is used to estimate influence of actors. Centrality as an indicator can be used to understand in what degree an actor is able to obtain or control resources. Brass and Burkhardt (1992) indicated network centrality is one source of influence from the viewpoint of organizational behavior, a person with higher centrality in an organization is always the one with higher influence (Brass & Burkhardt, 1992). Freeman (1979) suggested three methods of centrality measurement for a network: (1) degree centrality, (2) betweenness centrality, and (3) closeness centrality (Freeman, 1979). Network properties are calculated by the above three methods in order to understand the power of influence of paper (first author), research organization, and country in the field of open innovation research. A social network can be either a directed network or an undirected network. But networks constructed in this research are undirected networks because no in-and-out concept, e.g. causal relation, position difference, flow, or diffusion, existed behind any linked keywords.

2.3.1. Degree centrality

Network nodes (actor) which directly linked to a specific node are neighborhood of that specific node. The number of neighbors is defined as nodal degree, or degree of connection. Granovetter (1973) suggested nodal degree is proportional to probability of obtaining resource. Nodal degree represents to what degree a node (actor) participates the network; this is a basic concept for measuring centrality.

Degree Centrality: the number of direct linkage between actor i and other actor.

$$d(i) = \sum_{j} mji$$

where $m_{ij} = 1$ if actor i and actor j are linked.

2.3.2. Betweenness centrality

The concept of betweenness is a measure of how often an actor is located on the shortest path (geodesic) between other actors in the network. Those actors located on the shortest path between other actors are playing roles of intermediary that help any two actors without direct contact. Actors with higher betweenness centrality are those located at the core of the network.

$$b(i) = \sum_{j,k \neq 1} \frac{gjik}{gjk}$$

where g_{jk} is the shortest path between actor j and actor k; g_{jik} is the shortest path between actor j and actor k that contains actor i.

2.3.3. Closeness centrality

The closeness centrality of an actor is defined by the inverse of the average length of the shortest paths to/from all the other actors in the network. Higher closeness centrality indicates higher influence on other actors.

$$c(i) = \sum_{j=1}^{N} \frac{1}{dji}$$

where d_{ji} is the shortest path between actor j and actor i.

2.4. Construction of contour map

In this study, contour maps are also obtained by calculating relative positions and density of network actors in a contour map on the basis of network constructed previously. The obtained contour maps are named as "knowledge maps" since they directly reflect the fundamental structure of knowledge. The algorithm used in this study is proposed by Van Eck and Waltman (2007).

(1) *Actor position*: The positions of network actors in the map are based on visualization of similarities. If there are totally n actors, a two-dimensional map where the actor 1–n are positioned in a way that the distance between any pair of actor i and j reflects their association strengths a_{ij} as accurately as possible, i.e. distance between i and j is proportional to a_{ij}, Van Eck and Waltman's algorithm is used to minimize a weighted sum of the squared Euclidean distance between all pairs of actors, the objective function to be minimized is given as below:

$$E(x_1, \ldots., x_n) = \sum_{i<j} a_{ij} ||x_i - x_j||^2$$

where the vector $x_i = (x_{i1}, x_{i2})$ denotes the location of actor i in a two dimensional space and $||\bullet||$ denotes the Euclidean norm.

(2) *Actor density*: actor density at a specific location in a map has to be calculated. The actor density is calculated by first placing a kernel function at each actor location and taking a weighted average of the kernel function.

The actor density at location $x = (x_1, x_2)$ is given by:

$$D(x) = \frac{1}{h^2 \sum_{i=1}^{n} c_{ii}} \sum_{i=1} c_{ii} K \left(\frac{x_1 - x_{i1}}{h}, \frac{x_2 - x_{i2}}{h} \right)$$

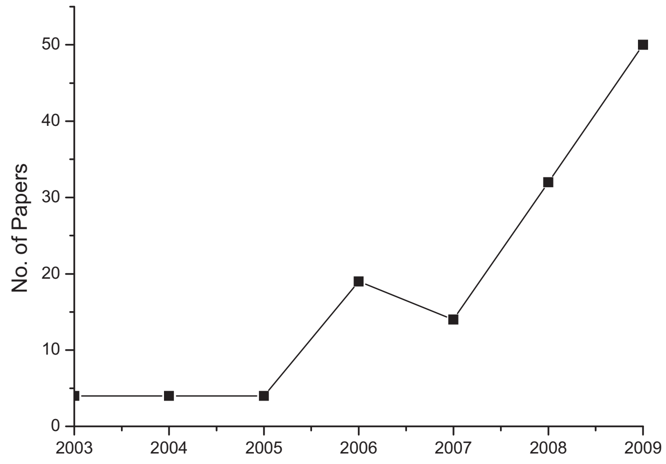

Fig. 1. Number of paper along time horizon.

where K denotes a kernel function and h denotes a smoothing parameter. c_{ii} denotes the number of occurrence of actor i and $x = (x_1, x_2)$ denotes the location of actor i in the map. The kernel function K is a non-increasing Gaussian kernel function given by

$$K(t_1, t_{2n}) = \frac{1}{2\pi} \exp\left(-\frac{t_1^2 + t_2^2}{2}\right)$$

3. Results and discussion

3.1. Initial statistics

The obtained 130 papers are plotted along time horizon (Fig. 1). Despite its ZigZag behavior, a gradual increase after 2005 can be observed, this suggests there are still rooms for open innovation research papers in this field. Among all the papers obtained, a total of 23 countries have contribution to these papers. US has the most papers (34 papers), then Germany (30), England (13), Netherlands (9), Switzerland (8).

3.2. Network overview

For RFP-country network, RFP-institute network, RFP-paper network (Figs. 2–4), and KCO network (Fig. 5), are constructed on the basis of keyword co-occurrence. Due to the limitation that only 62 out of the 130 initial papers have keywords assigned in the papers, the 62 papers are used for constructing the four types of networks.

3.3. RFP-country network

Papers are grouped together by countries, any two countries that have same keywords are linked together. A total of 21 networks and 47 network ties are obtained (Fig. 2).

3.3.1. RFP-institute network

Papers are grouped together by institutes, any two countries that have same keywords are linked together. A total of 46 network actors and 76 network ties are obtained (Fig. 3).

3.3.2. RFP-paper network

Any two papers that have the same keywords are linked together. A total of 48 network actors and 78 network ties are obtained (Fig. 4).

3.3.3. KCO network

Each keyword is a network actor, a total of 206 network actors and 250 network ties are obtained (Fig. 5).

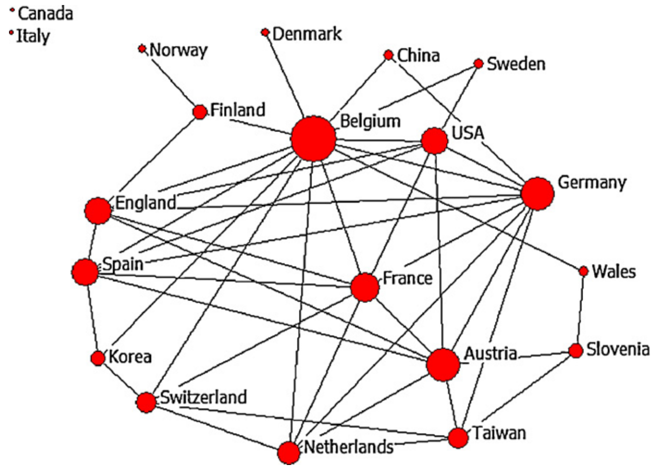

Fig. 2. RFP-country network.

3.3.4. *Network centralities calculation*

Betweenness centrality, degree centrality and closeness centrality are calculated for each network actor to understand its network centrality quantitatively.

For RFP-Country network (Fig. 2), top 15 centralities countries are listed in Table 3. Belgium is the country with the highest centralities, then Austria, Germany, France, Spain and USA, etc. Most of the countries are European countries except USA, Taiwan, Korea and China, this indicates important role of Europe in open innovation. Due to the fact that each country published different number of papers, countries with more populations easily have higher centralities because they have more publications and thus more keywords to be linked to other countries. It is anticipated that big countries such as USA and China to be in the top 15 countries list. Both Taiwan and Korea are not big countries in terms of populations but still show very high centralities, this indicates both countries act as important players in global open innovation researches.

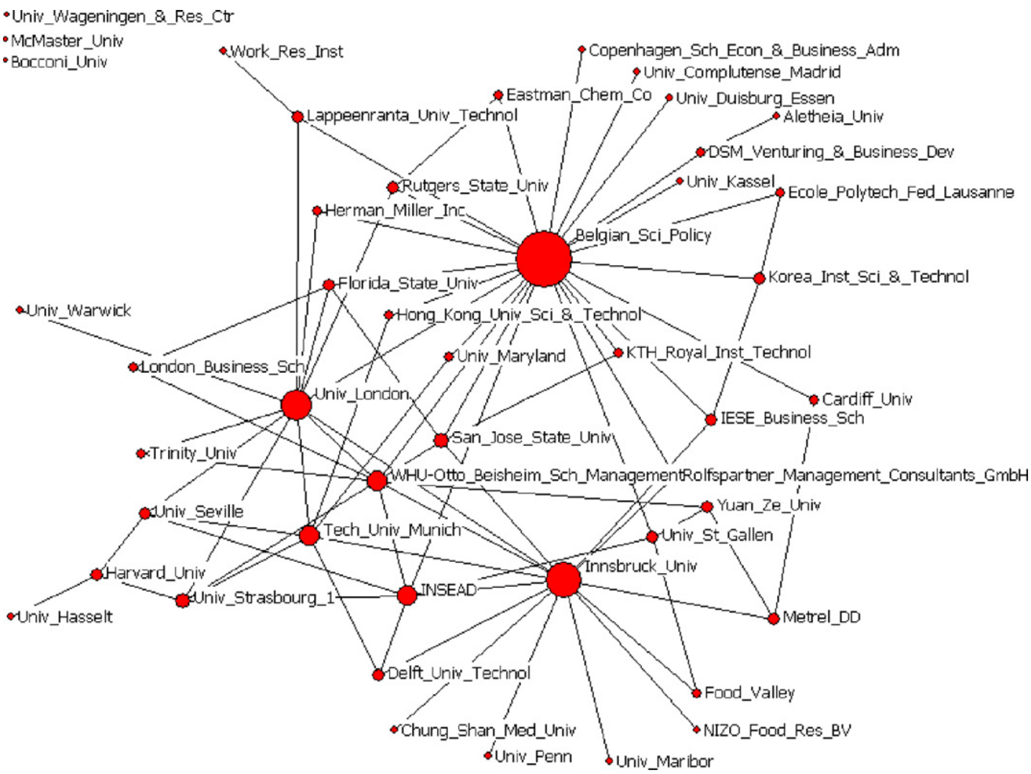

Fig. 3. RFP-institute network.

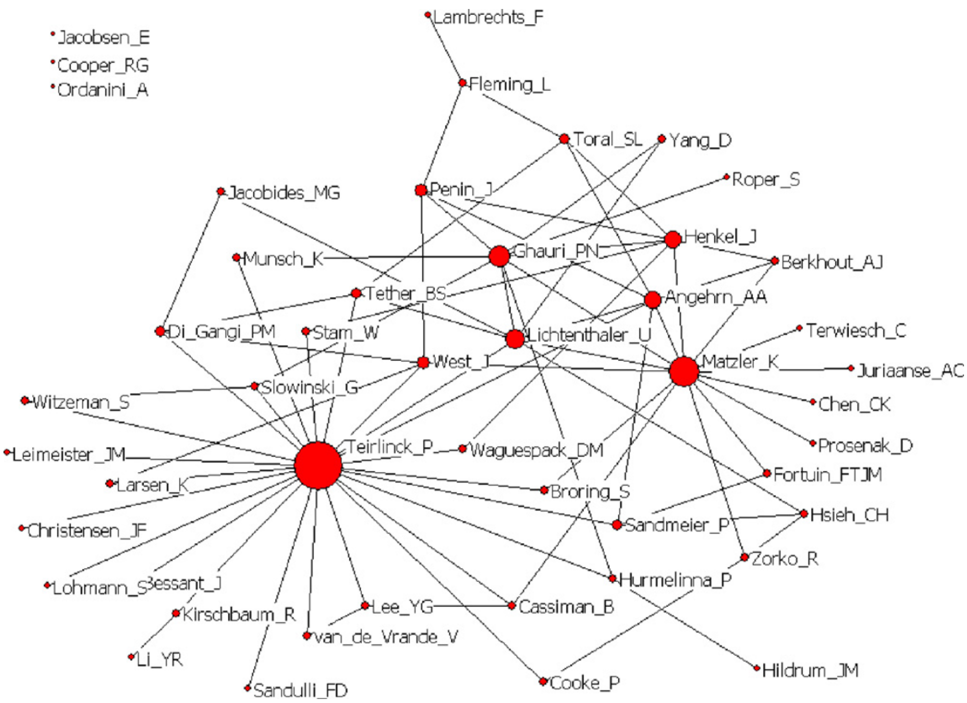

Fig. 4. RFP-paper network.

For RFP-institute network (Fig. 3), top 15 centralities institutes are listed in Table 4. The top institutes with the highest centralities are Belgian Science Policy Office (Belgium), University of Innsbruck (Austria), University of London (UK), INSEAD (France), WHU-Otto Beisheim School of Management (Germany), etc. There are seven institutes located outside of Europe, i.e. San Jose State University (USA), Harvard University (USA), Florida State University (USA), Rutgers State University (USA), Herman Miller Inc (USA), Hong Kong Univ. Science and Technology (China), Yuan Ze University (Taiwan).

For RFP-paper network (Fig. 4), the top 15 papers (presented as first author) are listed in Table 5 and are mostly European authors. The authors with highest centralities are Teirlinck P. from Belgian Science Policy Office (Belgium), and then Matzler_K (Austria), Ghauri_PN (England), Lichtenthaler_U (Germany), Angehrn_AA (France).

For KCO network (Fig. 5), top 15 centralities keywords are listed in Table 6. Top centralities keywords such as innovation, open innovation are due to the selection of open innovation research as investigated topic. The other high centrality keywords such as Connection dynamics, Intellectual property, Open source, Open source software, Measurement, Virtual communities, Activation, External technology commercialization, provides important implications to open innovation. By examining Fig. 5 and Table 6, it is very straightforward to understand what elements are important in the field of open innovation.

Table 3
Top 15 centralities countries.

Degree centrality	Betweenness centrality	Closeness centrality
Belgium	Belgium	Belgium
Austria	Austria	Germany
Germany	Finland	Austria
France	Germany	England
Spain	England	France
USA	USA	Spain
England	Spain	USA
Netherlands	Wales	Netherlands
Switzerland	Switzerland	Switzerland
Taiwan	France	Taiwan
Slovenia	Taiwan	Wales
Korea	Netherlands	Korea
Finland	Slovenia	Finland
Sweden	Korea	China
Wales	Sweden	Sweden

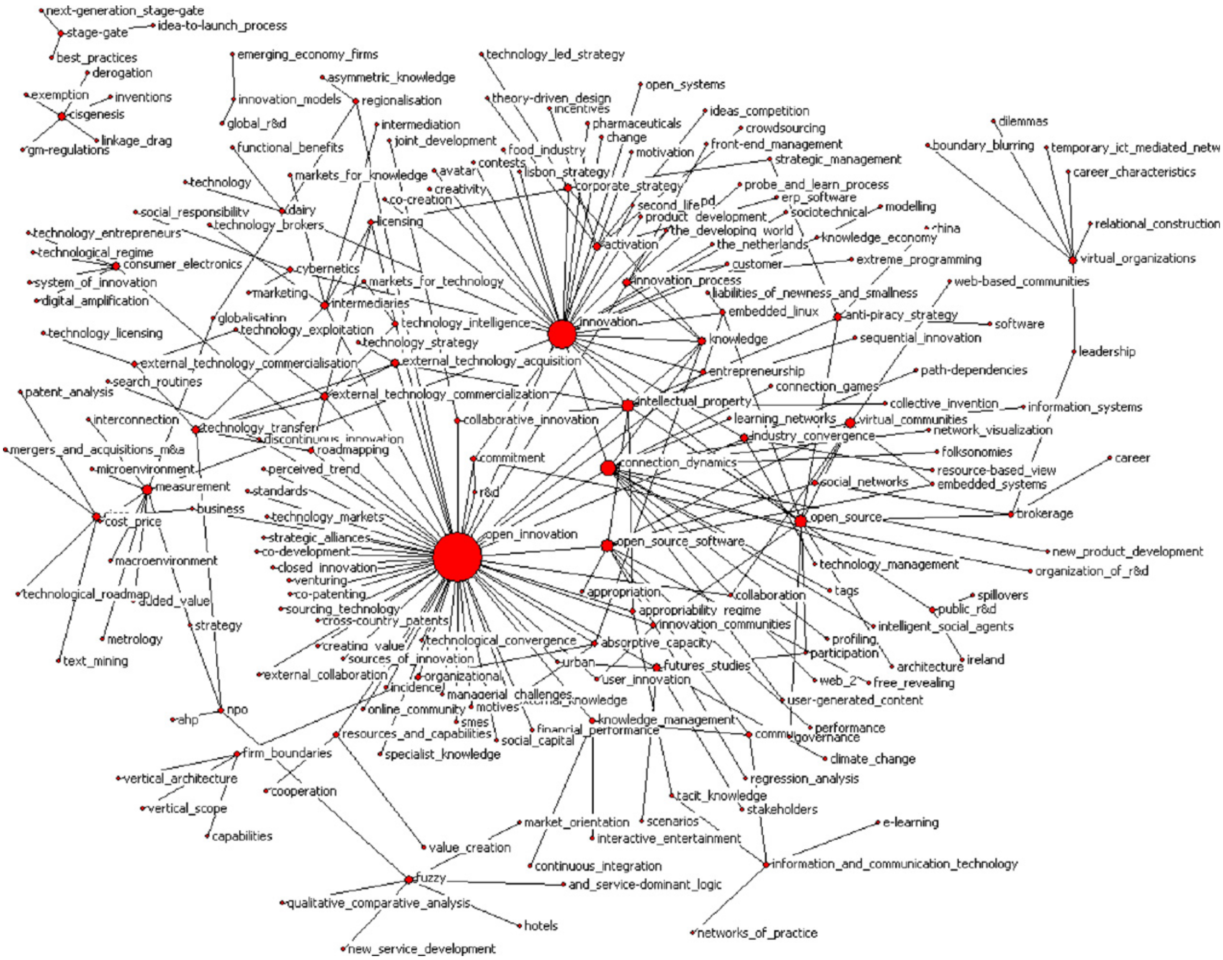

Fig. 5. KCO network.

Table 4
Top 15 centralities institutes.

Degree centrality	Betweenness centrality	Closeness centrality
Belgian Sci Policy (Belgium)	Belgian Sci Policy (Belgium)	Belgian Sci Policy (Belgium)
Innsbruck Univ (Austria)	Innsbruck Univ (Austria)	Univ London (England)
Univ London (England)	Univ London (England)	INSEAD (France)
INSEAD (France)	WHU-Otto Beisheim Sch Management (Germany)	WHU-Otto Beisheim Sch Management (Germany)
Tech Univ Munich (Germany)	INSEAD (France)	Innsbruck Univ (Austria)
WHU-Otto Beisheim Sch Management (Germany)	Univ Strasbourg 1 (France)	San Jose State Univ (USA)
San Jose State Univ (USA)	Harvard Univ (USA)	Univ St Gallen (Switzerland)
Univ Strasbourg 1 (France)	Lappeenranta Univ Technol (Finland)	Florida State Univ (USA)
Univ Seville (Spain)	DSM Venturing & Business Dev (Netherlands)	Lappeenranta Univ Technol (Finland)
Univ St Gallen (Switzerland)	Tech Univ Munich (Germany)	Tech Univ Munich (Germany)
Florida State Univ (USA)	San Jose State Univ (USA)	IESE Business Sch (Spain)
Delft Univ Technol (Netherlands)	Univ Seville (Spain)	Rolfspartner Management Consultants GmbH (Germany)
Metrel DD (Slovenia)	Univ St Gallen (Switzerland)	Rutgers State Univ (USA)
IESE Business Sch (Spain)	Florida State Univ (USA)	Herman Miller Inc (USA)
Yuan Ze Univ (Taiwan)	IESE Business Sch (Spain)	Hong Kong Univ Sci & Technol (China)

Table 5
Top 15 centralities paper (first author as actor).

Degree centrality	Betweenness centrality	Closeness centrality
Teirlinck_P (Belgium)	Teirlinck_P (Belgium)	Teirlinck_P (Belgium)
Matzler_K (Austria)	Matzler_K (Austria)	Lichtenthaler_U (Germany)
Ghauri_PN (England)	Ghauri_PN (England)	Angehrn_AA (France)
Lichtenthaler_U (Germany)	Lichtenthaler_U (Germany)	Matzler_K (Austria)
Angehrn_AA (France)	Angehrn_AA (France)	West_J (USA)
Henkel_J (Germany)	Penin_J (France)	Ghauri_PN (England)
West_J (USA)	Hurmelinna_P (Finland)	Tether_BS (England)
Penin_J (France)	West_J (USA)	Cassiman_B (Spain)
Toral_SL (Spain)	Henkel_J (Germany)	Hurmelinna_P (Finland)
Sandmeier_P (Switzerland)	Fleming_L (USA)	Sandmeier_P (Switzerland)
Di_Gangi_PM (USA)	Kirschbaum_R (Netherlands)	Broring_S (Germany)
Tether_BS (England)	Toral_SL (Spain)	Henkel_J (Germany)
Berkhout_AJ (Netherlands)	Sandmeier_P (Switzerland)	Slowinski_G (USA)
Zorko_R (Slovenia)	Tether_BS (England)	Munsch_K (USA)
Cassiman_B (Spain)	Cassiman_B (Spain)	Stam_W (China)

Table 6
Top 15 centralities keywords.

Degree centrality	Betweenness centrality	Closeness centrality
open_innovation	open_innovation	open_innovation
innovation	Innovation	intellectual_property
connection_dynamics	intellectual_property	connection_dynamics
intellectual_property	connection_dynamics	innovation
open_source	open_source	open_source_software
open_source_software	open_source_software	industry_convergence
measurement	Measurement	commitment
virtual_communities	Brokerage	entrepreneurship
activation	technology_transfer	external_technology_acquisition
external_technology_commercialization	Npo	innovation_communities
innovation_process	Activation	appropriability_regime
intermediaries	Leadership	collaborative_innovation
futures_studies	Intermediaries	open_source
fuzzy	industry_convergence	innovation_process
knowledge	fuzzy	knowledge

4. Analysis of contour map

Figs. 6–8 are global open innovation research maps with country, research institute, and paper author as actors. Each of the three maps shows a big continent and a small island, visually presents the major research trend on the left and the smaller research group on the right, respectively. The colors of the contour plot (Figs. 6–8), indicate the degree of research concentration. Red color indicates high research concentration area where a lot of actors are doing similar researches that can be correlated to each other by their shared keywords. On the contrary, green color area is the area where low research concentration is found.

Fig. 6 shows Belgium, Germany, France, Netherlands, Austria are located at the core (red color area) of the big continent. Germany has relatively large number of publications providing more opportunity to be link to other papers so it is easily to be located at the core of the map. However, for countries with smaller number of paper but still can be positioned in core area, such as Belgium (2 paper), France (2 papers), Australia (1 paper), is because keywords they used are also highly co-occurred in other papers and thus more connections to other papers can be expected. Both Finland (Hurmelinna, Kyläheiko, & Jauhiainen, 2007) and Norway (Hildrum, 2009) form an isolated island on right hand sides of the map, the island is formed

Table 7
Papers which form an isolated island in Fig. 6.

Paper title	Journal	Keywords	Year	Ref.
The Janus face of the appropriability regime in the protection of innovations	Technovation	appropriability regime, tacit knowledge, intellectual property, open innovation	2007	Hurmelinna et al. (2007)
Sharing Tacit Knowledge Online: A Case Study of e-Learning in Cisco's Network of System Integrator Partner Firms	Industry & Innovation	Information and communication technology, e-learning, tacit knowledge, community, networks of practice	2009	Hildrum (2009)

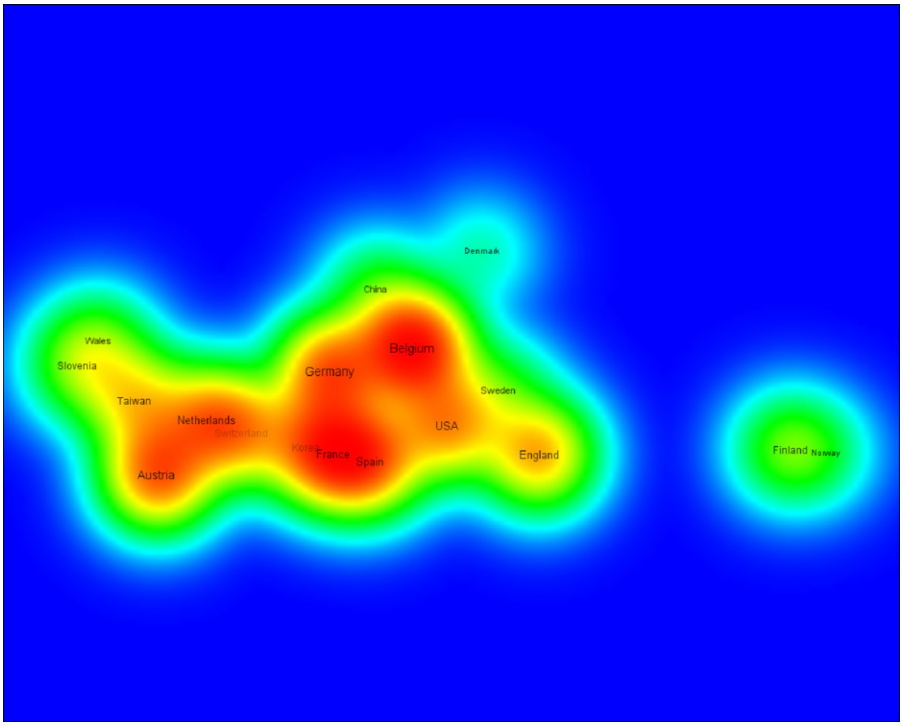

Fig. 6. Global open innovation research map-country as actor.

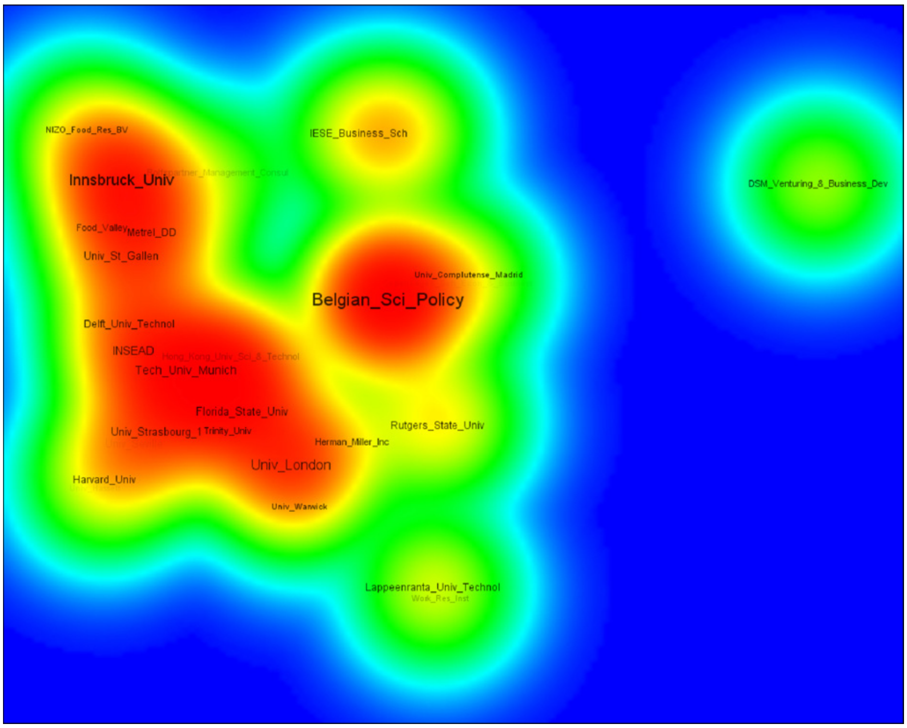

Fig. 7. Global open innovation research map-institute as actor.

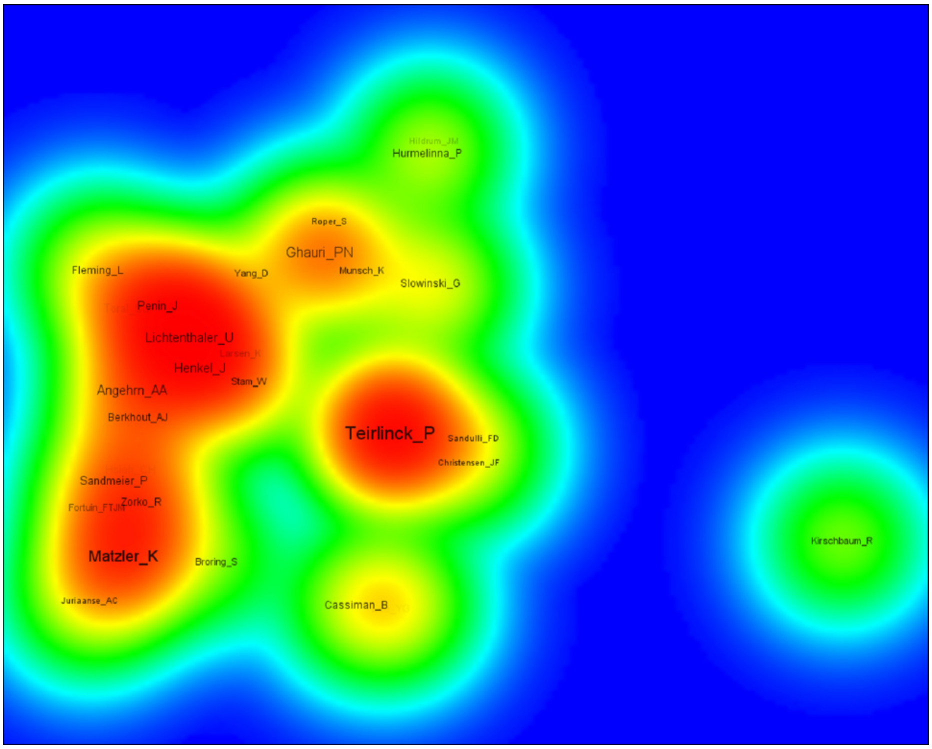

Fig. 8. Global open innovation research map-paper (first author) as actor.

by two papers listed in Table 7. This suggests that Finland and Norway were doing researches similar to each other's but differed greatly from the global trend, and that Vietnam was a new entrant in this field.

Fig. 7 is global open innovation research map- institute as actor. Similar to Fig. 6, an irregular continent and an isolated island are shown in the map. In the continent, *Belgian Science Policy* Office is the most outstanding one, together with Innsbruck University, University of London, WHU-Otto Beisheim School of Management and Innsbruck University, etc., are dominating the big continent. The isolated island on the right side is formed by Netherlands' "DSM Venturing & Business Development" (Kirschbaum, 2005) and Taiwan's "Aletheia University" (Li, 2009) (Alethia University is located very close to DSM Venturing & Business Development, not shown in Fig. 7 but can be observed once after locally amplifying the isolated island). The detailed paper information are listed in Table 8.

Fig. 8 is global open innovation research map-paper (first author) as actor. Fig. 8 also shows a big continent dominated by Belgium *Science Policy* Office's Teirlinck, Innsbruck University's Matzler, and some other authors positioned on the red color area on the big continent. The isolated small island is formed by Kirschbaum (2005) and Li (2009) who are also the contributors of the small island in Fig. 7. The detailed information for the small island are the same as what listed in Table 8. Ideally, more researches would be desirable in order to build more connections among actors; in this way the knowledge structure of this field could be further enhanced and thus the research gap could be reduced. When it comes to research collaboration or competition, it should be noted that neighboring authors in Fig. 8 signify potential collaborators or competitors because these authors are doing similar research.

Fig. 9 is global open innovation research map-keyword as actor. Fig. 9 shows five islands with a bigger one in the middle. Each of the islands is labeled by the most outstanding keyword, i.e. Future Study, Activation, Open Innovation, Connection Dynamics, Virtual Communities (from left to right). These keywords comprised in the five islands are:

Table 8
Papers which form an isolated island in Fig. 7.

Paper title	Journal	Keywords	Year	Ref.
Open innovation in practice	Research-Technology Management	open innovation, creating value, venturing, business	2005	Kirschbaum (2005)
The technological roadmap of Cisco's business ecosystem	Technovation	Cisco, business, Mergers and acquisitions (M&A), patent analysis, text mining, technological roadmap	2009	Li (2009)

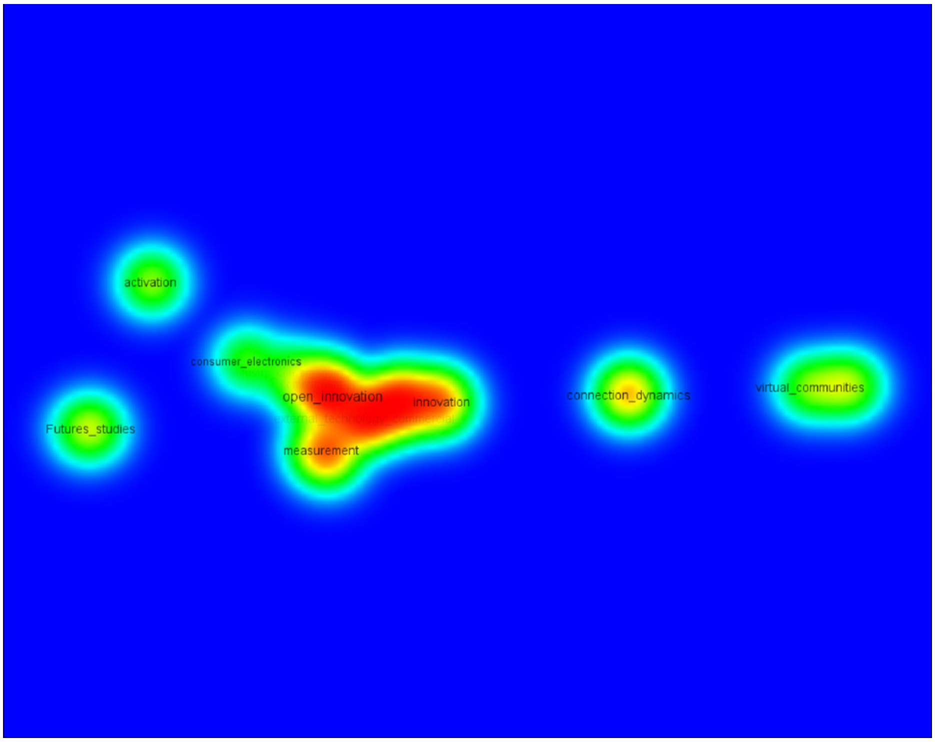

Fig. 9. Global open innovation research map-keyword as actor.

1. *Future Study*: future study, open source, participation, climate change, etc.
2. *Activation*: activation, crowdsourcing, ideas competition, ERP software, motivation, etc.
3. *Open Innovation*: open innovation, innovation, consumer electronics, external technology commercial, measurement, intellectual property, technology transfer, etc.
4. *Connection Dynamics*: connection dynamics, SLATES, folksonomies, Web 2, intelligent social agents, learning networks, connection games, user-generated content, network visualization, etc.
5. *Virtual Communities*: virtual communities, social network, brokerage, leadership, virtual organization, etc.

Fig. 9 provides a basis for interpreting global implications of open innovation study. By analyzing keywords in the five islands, a scenario for global open innovation could be obtained that open innovation has a lot to do with idea, software and require consideration of technology transfer, IP, commercialization, in order to generate connection and networking which contribute to formation of virtual community and lead to better future environment. However, a more detailed analysis is necessary if a more specific question is to be answered.

5. Conclusion

“Open innovation” has gradually become an important research field which requires a systematic analysis on its knowledge structure that has been pending to be investigated. This study integrates social network analysis and keyword co-occurrence analysis to investigate knowledge structure of “Open innovation” for the purpose of systematically examining fundamental components underlying this research field investigated differently in different regions of the world.

In summary, this study proposes four types of networks based on co-occurrence of keywords for full spectrum analysis on research papers, i.e. RFP-country network, RFP-institute network, RFP-paper network and KCO network (Figs. 2–5) and contour maps (Figs. 6–9), to reflect knowledge structures on macro, meso, and micro levels, respectively. A total of 206 standardized keywords contained in 62 open innovation papers have been analyzed in this study, networks and contour maps are quantitatively and visually created to understand research structure of global open innovation community.

Tables 3–6 and Figs. 6–9 show quantitative results of networks and contour maps. Different actors, i.e. country, institute, paper network, keyword with higher centrality are those act as hubs in research structure and are therefore more important in terms of formation of a research community. The most highly centralized papers are published by Belgium Science Policy Office, Innsbruck University and University of London, which lead their countries to be highly centralized. Top 10 actors in Tables 3–5 are all from Europe and USA. The three countries outside of Europe and USA in the research community are Korea, Taiwan and China, this might be due to their fast-paced development contexts. The US has the most papers in the field of open innovation but is only ranked Nos. 6–7 in network centralities. This is not very common because the US is easily ranked as the top one country in terms of research performance evaluated by different bibliometric analysis, due to its large number of researchers and research activities in many fields. Europe seems to be the leader of global open innovation research. Taiwan, Korea and China are three Asian countries ranked Nos. 10–14 in different network centralities, this has to do with their face-paced research induced by economic growth.

It can be found that Europe is the leading area in open innovation research. Belgium, Australia, Germany are the top three countries with the highest centralities in this field. Belgian Science Policy Office, Innsbruck university, University of London, WHU-Otto Beisheim School of Management and Innsbruck University, etc., are dominating this field.

As shown in Fig. 9, (1) Future Study, (2) Activation, (3) Open Innovation, (4) Connection Dynamics, (5) Virtual Communities are the five most significant keywords dominating the five groups of keywords in open innovation research, respectively. Keywords which provide the important implications to open innovation comprise Connection dynamics, Intellectual property, Open source, Open source software, Measurement, Virtual communities, Activation, External technology commercialization. According to these obtained keywords, it can be derived that open innovation has a lot to do with idea, software and require consideration of technology transfer, intellectual property, commercialization. Connection and networking, e.g. interdisciplinary linkage or collaboration which contribute to formation of new idea, and new basis for further development is of critical in the core of open innovation.

It is to be noted that this study seeks to (1) visualize overview of global open innovation research, (2) demonstrate how to retrieve useful implication from networks (Figs. 2–5) or contour maps (Figs. 6–9), and does not intend to analyze specific detailed insight of global open innovation researches. Readers of this paper should be able to create their own maps for their particular fields and understand how to position their researches on the research structure and retrieve useful information and implication to meet their different needs, for example, (1) R&D resource allocation, (2) research performance evaluation, (3) understanding of future research opportunity, and (4) potential collaborator or competitor identification.

Some issues that are not considered in this study can be further investigated to refine this research in the future, e.g. (1) compare results obtained from different databases, (2) revision of search strategy to cover more precisely in the selected topic, and (3) text-mining can be used to sort out the problem of lack of author keyword.

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