Developmental tendencies in the Academic Field of Intellectual Property through the Identification of Invisible Colleges

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Abstract

The emergence of intellectual property as an academic issue opens a big gate to a cross-disciplinary field. Different disciplines start a dialogue in the framework of the international multilateral treaties in the early 90's. As global economy demands new knowledge on intellectual property, Science grows at its own pace. However, the degree of consolidation of cross-disciplinary academic communities is not clear. In order to know how closely related are these communities, this paper proposes a mixed methodology to find invisible colleges in the production about intellectual property. The articles examined in this paper were extracted from Web of Science. The analyzed period was from 1994 to 2016, taking into account the signature of the agreement on Trade-Related Aspects of Intellectual Property Rights in the early 90's. A total amount of 1580 papers were processed through co-citation network analysis. An especial technique, which combine algorithms of community detection and defining population of articles through thresholds of shared references, was applied. In order to contrast the invisible colleges that emerged with the existence of formal institutional relations, it was made a qualitative tracking of the authors with respect to their institutional affiliation, lines of research and meeting places. Both methods show that the subjects of interest can be grouped into 13 different issues related to intellectual property field. Even though most of them are related to Laws and Economics, there are weak linkages between disciplines which could indicate the construction of a cross-disciplinary field.

Keywords

Invisible colleges, Intellectual property, Network analysis, Co-citation, Modularity.

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Introduction

The study of intellectual property (IP) has become important since the signature of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) in 1994 (Laranjaa et al. 2008; Montobbio 2015). Since then, the number of publications has grown together with bibliometric studies addressing the number of produced articles, the number of authors, the number of citations received, the number of references, the number of co-authorships, the most cited magazines, the countries of origin of the authors, as well as the published sectors, showing that academic institutions are the major contributors (Swain and Panda 2012; Natarajan 2013; Garg and Anjana 2014; Velmurugan and Radhakrishnan 2016).

A general analysis of the state-of-the-art shows that it is a controversial subject, covering a great diversity of aspects making difficult to find suitable disciplinary indicators to determine its costs and benefits (Jackson 2003). This diversity of aspects in the intellectual property has also raised questions on the conformation of its knowledge structure, thus, Garg and Srivastava (2016) made a content analysis of published articles in the Journal of Intellectual Property Rights (JIPR) from 1996 to 2014, through the classification of titles in different subjects. The result allowed them to make inferences on the interests of researchers and to conclude that the field structure is highly fragmented and it is multidisciplinary (law, science, economics and management) (Garg and Srivastava 2016). Although the study of Garg and Srivastava (2016) exposes the fragmentation problem, its bibliometric data are restricted to the analysis of articles published in JIPR, which mainly contains literature from India (63,5%) and in a smaller proportion international literature (36,5%), being the United States the greater contributor.

On the other hand, literature faces important debates showing an alive field while there is diversity in the research results. Therefore, the scientific publications show that after the signature of TRIPS, countries face heterogeneous results (Lall 2003) and there is no agreement on the costs, benefits and impacts on innovation, economy and development. Also, the consequences of applying the IP is still a controversial subject among researchers, which may be due to the empirical evidence on its use which is scarce, ambiguous and scrambled (Jackson 2003; Rockett 2010). In general terms, the addressed aspects describe general dynamics of the field which allow to mention the existence or non-existence of certain dynamics of a communitarian structure. Nevertheless, the bibliometric and geographic layout indicators describe individual and non-communitarian data. The community is still a hypothesis to be proven while there are not evident bonds between the researchers and the common development of subjects.

To observe these communitarian structures that could lead to multiple interconnected or isolated research programs, Derek de Solla Price developed in 1963 the concept of Invisible Colleges (De Solla Price 1963). Although the term invisible colleges was used for the first time in 1645 by Boyle (Teixeira 2011), its sociology of scientific knowledge dates from the sixties, from the works of Price in 1963. His interest was to reveal the informal communication networks among academics of many institutions, geographically separated, to determine if they conformed significant social groups (Crane 1989). Due to the lack of information about informal communication, its study has been generally based on formal communication structures, identified through publications, and they have been defined as academic groups interacting in a formal and informal way, because they share common interests or scientific objectives, in a specific specialty subject. These subjects are nested in published documents, grouping authors in structured co-citation components according to the shared investigations of interest (Teixeira 2011).

At the time in which De Solla Price developed the concept of Invisible College, it was methodologically impossible the accuracy that can be obtained today with the relatively recent development of algorithms and applications to detect communities through data already systematized in databases like Web of Science (WoS) or Scopus which did not exist at that time. Subsequent to De Solla Price, the communitarian hypothesis raised in his texts and demonstrated solely from the aggregation of data, can be observed in an empirical way through tools such as the Main Path Analysis (Hummon and Doreian 1989) or the Algorithmic historiography of Garfield (Garfield et al. 2003), more recently the developments to detect communities through modularity algorithms and complex networks (Newman 2006).

Therefore, we observe these communication structures as information systems, which can be described in terms of complex networks, whose topology combines self-organization and randomness elements. To detect the natural organization of the network in groups demands comprehensive methods on the structure of information, for which a decomposition of it in sub-units must be done to discover functional modules (Blondel et al. 2008), which, in this case, serve as invisible colleges with an interest subject in common: intellectual property. The subjects of scientific interest can be represented by data connection networks, which are naturally divided in communities or modules conforming a structure, susceptible to be detected and characterized. The detection of communities requires the partition of the network in communities of densely connected nodes. One of the detection methods of possible divisions of the network structure in communities is modularity, which makes possible to find the best division, without super-positions and determining the number and size of groups (Newman 2006).

The proper modularity or division of the network topology is that which organizes the communities in a way so the number of relations among the groups is smaller than the number of relations within the groups. Since the modularity is a network property and a measure of how good a specific division of that network vertices in communities is, to the effect that there are many edges within the communities and few among them, this one increases as it has a better division of the network. The magnitude of elements is measured through the determination of how strong is the belonging of an edge to a community or to another one. The high values of modularity correspond to a good division of the network in communities, which are found by optimization techniques or approaching algorithms to find the maximum possible global modularity in big networks (Clauset et al. 2004). If we observe the overall definitions laid out above on invisible colleges, it is possible to relate these modules with invisible colleges.

Since a specialty subject is not an invisible college by itself, but they emerge from the density of bonds among those communities formed around a subject (Teixeira 2011), it is necessary to determine if an invisible college has been formed with regard to intellectual property. To detect the existence of them, identifying significant groups in the network, is possible through thickening of combined groups with the refinement of multilevel algorithms, that perform a local search through an individual iterative movement of the edges in different groups until the modularity increases, which produces better results than the single level ones (Noack and Rotta 2008). The partition quality, measured by the modularity, is a scale value between 0 and 1, which measures the density of bonds within the communities compared with the bonds among communities (Blondel et al. 2008).

In this context, the current study has the objective of determining the distribution of historical communities around the IP subject from scientific communications, through the identification and characterization of invisible colleges by the method of bibliographic coupling and detection of clusters through modularity algorithms. The resulting clusters are considered semantic communities, i.e. texts, which independent from the impact of an author and his citations on its neighbors, have a common referencing pattern that allows to observe sense linking, that is to say, texts that may share common subjects because they are reading more or less the same literature. We have called these linking Networks of Meaning (Vélez-Cuartas 2013). Thereby, when identifying thematic groups, it is possible to find the diversity of problems of a knowledge field. The basic problem to identify significant groups by number of shared references becomes problematic while it is difficult to establish a significance threshold by number of references to be considered to identify clusters. A proposal that allows to solve this problem is made in this article.

Methodology

In order to determine the invisible colleges concerning intellectual property and to analyze the existence as well as the characterization of invisible colleges, a search by subject was made in the main database of Web of Science through the equation "(innovation OR knowledge) AND (legislation OR law OR rights) OR (intellectual property)." The search was limited to published scientific articles between 1994 and 2016 in research areas where the greater amount of publications is focused: business economics, public management and government laws. The result was 1580 articles, a total of 94,743 references were extracted from them. The characterization of data is shown in the table 1.

Table 1. Data of scientific articles on the subject of intellectual property.

	Articles	Number of References	Number of Authors	Authors Affiliations	Citations	Number of Countries
Total	1580	94,743	2,269	2,409	27,924	59
Average		59.96	1.43	1.52	17.67	

Source: Compiled by authors with Web of Science data (1994-2016).

Table 2 shows the ranking of countries with greater production volume in the subject, it was obtained from the location of those institutions which the authors are affiliated. Countries appearing on the table match the geographic location of the 10 more influential authors (USA) and with the physical space meeting of researchers in the subject (USA, England, China and Spain).

Table 2. Ranking of countries with greater production of articles in the subject of intellectual property.

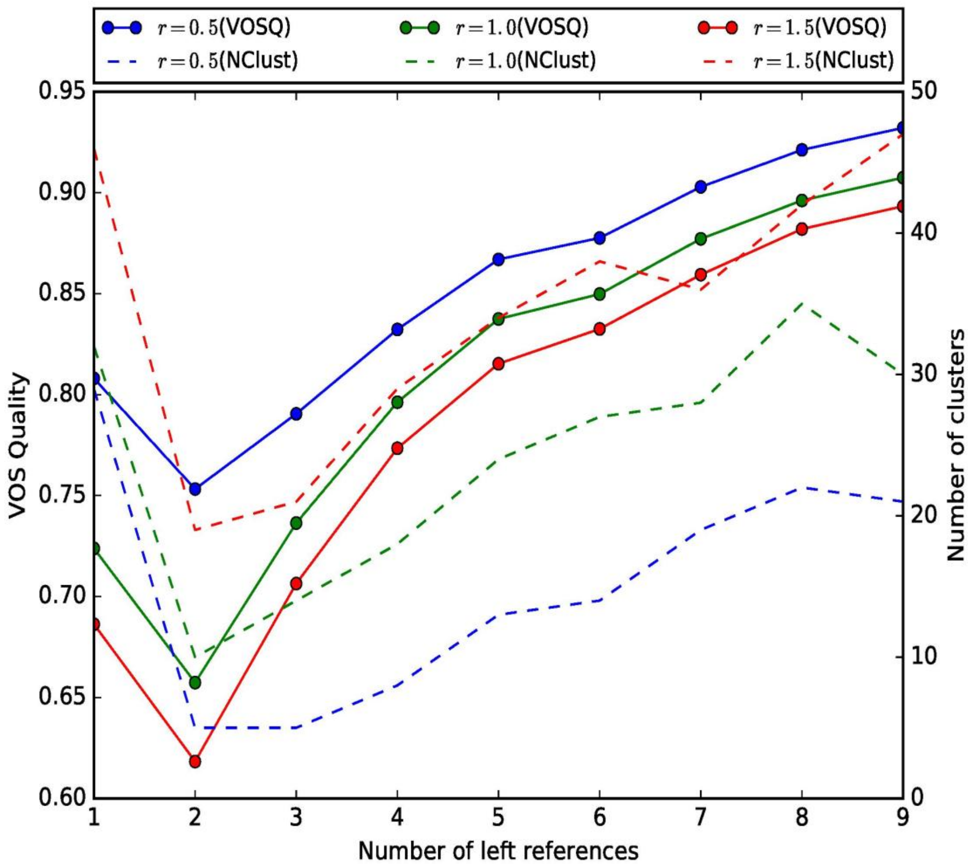
Rank	Country	Freq
1	USA	998
2	Italy	227
3	England	225
4	Germany	210
5	China	140
6	France	139
7	Taiwan	124
8	Netherlands	122
9	Japan	107
10	Spain	96

Source: Compiled by authors with Web of Science data (1994-2016).

A relational matrix of correspondence between articles and references was constructed using the isi.exe software available at http://www.leydesdorff.net. This software allows to distribute and generate a list of articles associated to the total of their references, raw material to construct a two mode network. Using Pajek (Batagelj and Mrvar 1998) it is possible to construct to a co-citation network defined as shared references network among a set of articles (Garfield et al. 2003; Leydesdorff 1998). When considering the number of shared references among articles it is possible to observe significant relations, a significant relation is understood as a threshold number of shared references.

Today, it is not possible to mathematically establish a unique significant threshold to observe the similarity between two articles by shared references, because the significance varies among disciplines and subjects. Nevertheless, exploring and testing different thresholds and observing the conformed groups of emergent articles, it is possible to determine the significance in an exploratory way when observing the results. Figure 1 shows the behavior, as the shared relations are eliminated, of values obtained for VOS quality and the number of clusters using the algorithm of VOS clustering (Waltman et al. 2010) available in Pajek. We can see that no matter the resolution parameter (0.5, 1.0 or 1.5), from two shared relations the value of VOS Quality increases as the low values of shared relations are removed. Similarly, for the number of clusters a growth is observed, which in spite of having fluctuations, there is in general an increase of the number of clusters as a greater number of shared references is eliminated.

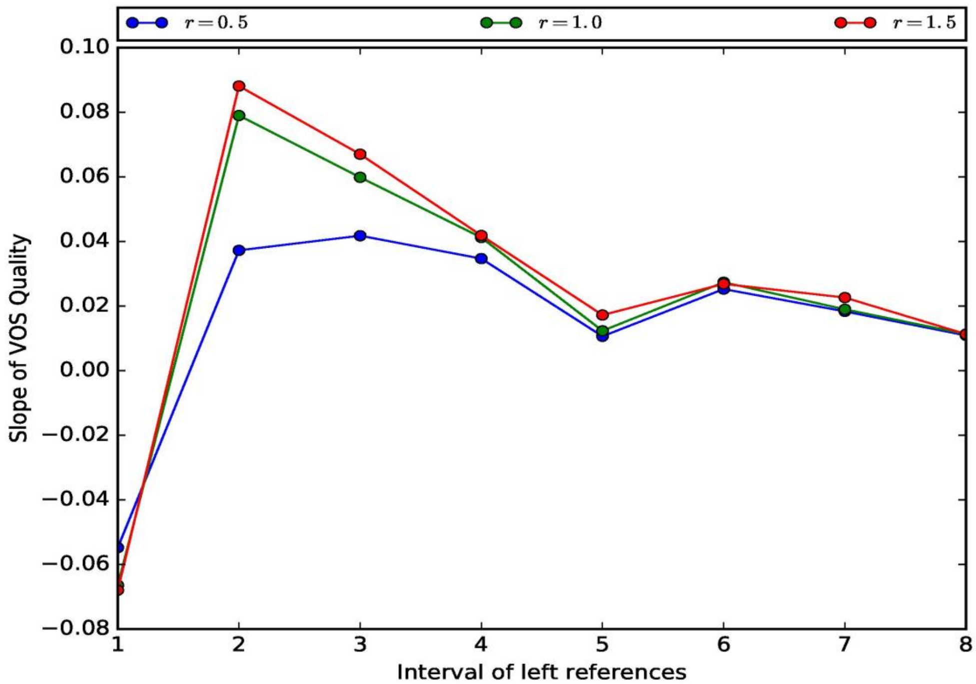
Figure 1. Detection of communities through shared references.



In order to select the best threshold of shared references to be eliminated, it was taken into account the consideration that VOS quality must be maximum to assure a good clustering process, the minimum number of clusters to obtain an easy classification of articles within them and finally, to minimally affect the network, the smaller possible number of links must be eliminated, i.e. this threshold must be the lowest possible value.

On Figure 1 it is not trivial to identify which value this threshold must have, because the behavior of the curves is not smooth nor monotone. In order to find a solution in that direction, it was considered the analysis of the value of slopes of each section on the obtained curve for VOS quality and the results are shown on Figure 2. It is clear that for section number 5 a local minimum appears in the value of slopes of VOS Quality. Now, if this minimum is interpreted as a value from which the remotion of the next set of shared relations does not generate a significant gain in the VOS quality value and it also satisfies the conditions for keeping low the number of clusters and links removed, we can affirm that the most significant threshold by the clarity in definition of sub-groups when sharing common subjects was of five shared relations.

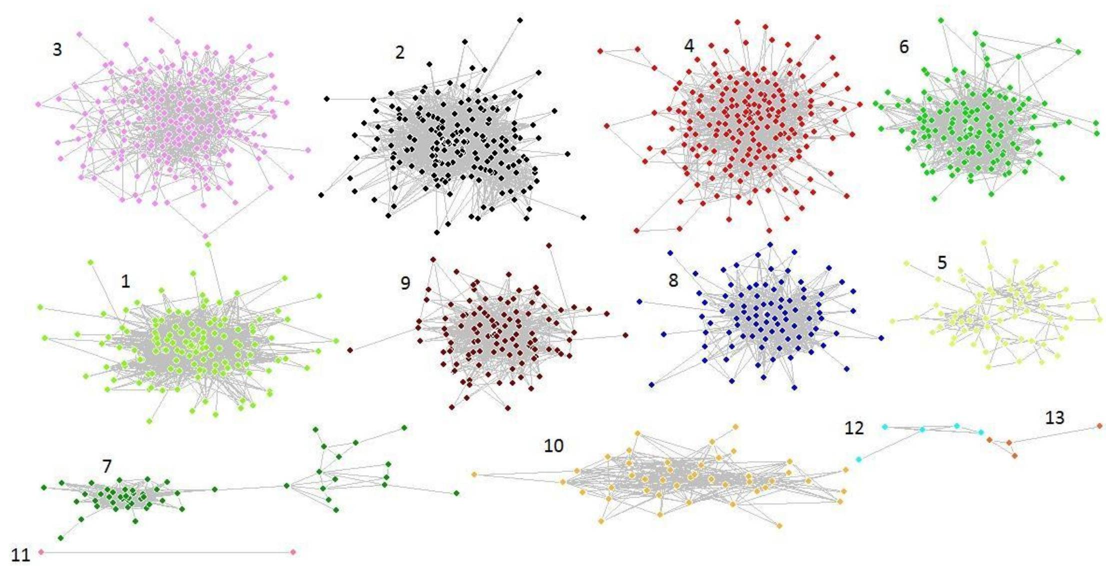
Figure 2. Identification of optimal modularity to detect communities



Results and discussion

The communities were constructed from identifying those articles sharing at least five joint references and removing the relations with a lower threshold. The greater component was extracted, it was made up of a total of 1267 articles. The remaining 313 articles were rejected in the analysis due to not having significant relations because they did not share five or more common references. VOS clustering algorithm was applied to them, whose modularity method is based on the optimization of the quality function. The 0,5 refinement was done through Multi-Level Coarsening + single Refinement available in Pajek on the partition obtained in the last level. A total of 13 communities was obtained with it (Fig. 3) with VOS Quality= 0,866974, a value close to one, which indicates that the refinement gathered the edges in groups in such a way that there is a greater amount of edges within the groups than among the groups (Clauset et al. 2004).

Figure 3. Thematic modules identified by the modularity.



Once the 13 communities were obtained, through a semantic association of the titles of articles contained in each one of them, each community was labeled with a general subject title integrating the research interests thus to obtain thematic modules (Refer to Table 3). The result allows to make inferences on the interests of researchers and to see that they aim towards specific programs of research within the knowledge-based economy conforming invisible colleges. The analysis made by Garg and Srivastava (2016) on the structure of knowledge showed the economy as one of several disciplines studying the intellectual property , but not like the governing axis of research subjects, thus the study concludes that there is fragmentation on the subject (Garg and Srivastava 2016). The evidence of this study demonstrates that the economy constitutes a cross-sectional subject for the global scientific production in IP in contrast to what was found by these researchers.

Table 3. Thematic modules.

Community	**General subject**	**Number of articles**	**% of 1267**
3	Schumpeter legacy, innovation capabilities, knowledge flows, R&D spillovers and spatial proximity.	204	16,1
2	The impact of IPR on foreign direct investment in developing countries and economic growth.	200	15,8
4	Patent information for quantitative estimation of technological impact.	199	15,7
6	Appropriability strategies, Open Source, markets for technology and Intellectual Property.	143	11,3
1	Pirates, innovation by imitation, patent trolls and rethinking IP and the commons.	136	10,7
9	Biotechnology industry, university-industry collaborations, academic and industry patents.	119	9,4

8	Infringement and litigation of patents, patent thicket, patent pooling, benefits and costs of strong patent protection.	92	7,3
5	Corporate innovation and venture capital.	66	5,2
7	Patent licensing, knowledge flows and spillovers.	54	4,3
10	Models of technological change, R&D, regulations, policy, and transfer of climate change mitigation technologies or eco innovations.	43	3,4
12	Pharmaceutical innovation and drug patenting	5	0,4
13	Technological convergence and patent indicators	4	0.3
11	Innovation in China	2	0,2

Source: Compiled by authors with Web of Science data (1994-2016).

The 13 communities detected by the modularity algorithm, once being classified in general interest subjects, show that the 47,6% of the edges are concentrated in economics subjects derived from schumpeterian theories, which can be observed with the merging of communities 3, 2 and 4. On the other hand, communities 6, 1, 9 and 8, which constitute 38,7% are focused in the costs and benefits of intellectual property mixing the economics and law in their studies. Small communities 5, 7 and 10 show that 12,9% remain within the scope of the economics, but they add subjects related to business, eco innovations and public policies. The small satellites 12, 13 and 11 conforming 0,9%, although focus in case studies, are also related to economics subjects, therefore are connected to the biggest communities through the cites of the most influential authors.

The fact that all the modules display a relation with economics matches the fact that most influential authors are affiliated to economics departments (Refer to Table 4). Also, when crossing the semantic sense and the co-citation it can be observed that, although there is diversity of subjects, there is a main current of authors who conform invisible colleges, whose common interest is the knowledge-based economy. Although this interest is not explicit, the revision of the semantic content of the modules shows predominance of a concern of the relation between variables of economy with intellectual property and knowledge.

The economics appears as the main discipline because the theoretical-methodological framework studying the knowledge-based economy are embedded in the neoclassical economy and schumpeterian models, which equip Intellectual Property Rights (IPRs) with a crucial role to provide incentives for the private creation of knowledge. This is due to the approach of innovation systems which emphasizes the importance of institutions to mediate main activities of the knowledge-based economy, which are directly based on production, distribution and use of knowledge to create value. The IPRs became important because the innovation has globalized and the demand for a global knowledge governance has grown. Through the TRIPS a framework of meta-regulation of knowledge is offered and this is why the studies dedicated to contribute empirical evidence about their efficiency have proliferated (OCDE 1996; Harris 2001; Laranjaa et al. 2008; Montobbio 2015).

Titles of articles show that the authors have as common interest to obtain empirical evidence on the effectiveness of the patents system in the creation of incentives for innovation, i.e. study the relation of IPRs with the production of knowledge in the private and academic sector. They also analyze costs and benefits of strengthening the IPRs and their relation with increases in economic variables such as economic growth, investment in R&D, knowledge spillovers, dissemination of knowledge, innovation rates in different technological sectors, supplies or products of R&D, effects of geographically located knowledge, endogenous growth, direct foreign investment, technological balance of payments or royalties, technological markets and technological change. Since citations are the main indicator of the influence of a scientist in their specialty (Teixeira 2011), it was made a count of citations to elaborate a list of the most influential authors in the subject, and the following ranking was elaborated with them (Refer to Table 4).

Table 4. Most influential authors.

Rank	Most influential authors	Number of citations
1	Griliches Z, 1990, J ECON LIT, V28, P1661	254
2	Hall VH, 2001, RAND J ECON, V32, P101	189
3	Levin R.C., 1987, BROOKINGS PAPERS EC, V1987, P783	188
4	Heller MA, 1998, SCIENCE, V280, P698	161
5	Cohen WM, 1990, ADMIN SCI QUART, V35, P128	150
6	Teece DJ, 1986, RES POLICY, V15, P285	146
7	Hall VH, 2005, RAND J ECON, V36, P16	144
8	Jaffe AB, 1993, Q J ECON, V108, P577	139
9	Trajtenberg M, 1990, RAND J ECON, V21, P172	130
10	Merges RP, 1990, COLUMBIA LAW REV, V90, P839	127

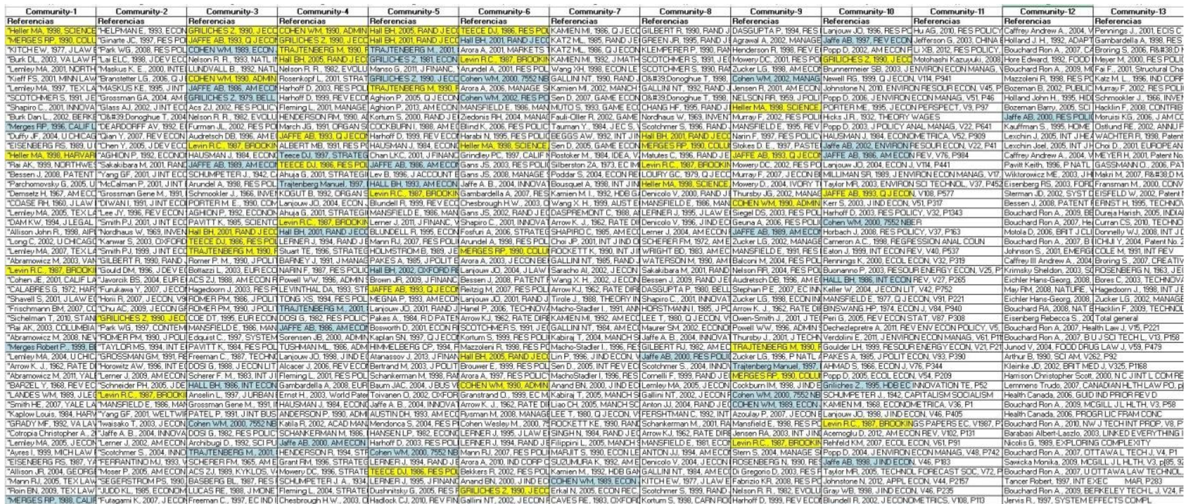
Source: Compiled by authors with Web of Science data (1994-2016).

Detection of the most influential authors, their institutional affiliations and their research field corroborate that the main interest of communities is within the economics (80%) and, in a smaller proportion, in law (20%). The majority of the most influential authors are affiliated to North American universities: Griliches (Harvard University), Hall (University of California, Berkeley), Levin (Yale University), Cohen (Duke University), Teece (University of California, Berkeley), Jaffe (Brandeis University), Heller (Columbia Law School) and Merges (University of California, Berkeley), with the exception of Trajtenberg (Tel Aviv University).

A concern of several aspects of the knowledge-based economy can be seen on their research fields and law is addressed to look into the edges of intellectual property, which is considered a fundamental institution for the global governance of knowledge. The main research fields of these authors are the economy of technological change, empirical studies of dissemination of innovations, R&D role, patents and econometrics, science and technology policy, law theory, determinants of innovating activity, benefits of technological innovation, dynamic capacities and strategic management, defense of competition, law of patents and intellectual property in the new technological era.

The structure of observed invisible colleges in the communities is evident, in a way in which theoretically De Solla Price (1963) could identify them. He has proposed a structure where there are prestigious authors and around them, some researchers who are mentioned by the text set corresponding to the colleges. It is also how the IP is constituted as a science topic while these influential authors appear in different colleges where different subjects are being questioned around this central axis as it can be observed in Figure 4.

Figure 4. Distribution of the most prestigious references in thematic modules.



Each column in Figure 4 represents a listing in frequency order of those references used more by the text set of each community or invisible college. The highlighted cells correspond to the ten most productive authors displayed in Table 4. They appear in several communities and allow not only to speak about isolated subjects, but about the establishing of several thematic concerns which are conforming a complex study field. Nevertheless, there are some columns that correspond to communities 2, 7, 11, 12 y 13 in which these authors do not appear, nevertheless, they share the semantic presence of terms related to intellectual property. This allows to speak about interrelated emergent fields with the main current of concerns, but with weak bonds due to not sharing 'mainstream ' referenced literature. This can be interpreted as other directions of IP discussions and grants an emergent character to these subjects within the semantic field of this object of study.

Conclusions

This investigation has used a new procedure to establish invisible colleges from the semantic structure emerging from the text sets sharing a specific threshold of references. This methodology has turned out useful to identify the conformation of invisible colleges from specific subjects within a general thematic field as it can be the IP. The methodology has also allowed the identification of the interconnection among these isolated invisible colleges, conforming denser and more complex groups of subjects associated to a general knowledge field, this would allow to establish the direction of a specific subject of science while it is possible to identify interrelated subjects through visible authors who lay out the field according to the definition of invisible colleges of De Solla Price. Nevertheless, the methodology also allowed to identify emergent subjects which are not interrelated by the most prestigious authors in the field, but they have some type of continuity and display subjects related to the main thematic field through common concepts shared from different points of view.

The crossing between the 13 communities obtained through the modularity algorithm and its corresponding semantic association with general interest subjects made visible the existence of invisible colleges, whose specific research programs are aimed towards the knowledge-based economy. This is inferred from a revision of the semantic sense of the modules, which show as a main concern the relation between variables of the economy with intellectual property and knowledge. The economy appears as the main discipline because the theoretical-methodological framework studying the knowledge-based economy are embedded in the neoclassical economy and schumpeterian models, which equip Intellectual Property Rights (IPRs) with a crucial role to provide incentives for the private creation of knowledge.

This finding allows to conclude that researches on intellectual property are not highly fragmented, as it was shown by the study made by Garg and Srivastava (2016) on the structure of knowledge, but rather the knowledge-based economy serves as a governing axis. Also, although it is true that there are multidisciplinary contributions in the subject, it is possible to observe a clear predominance of the economics. Likewise the content analysis and classification method used by Garg and Srivastava (2016) allows to see the diversity of aspects including the intellectual property, it is evident that it is not enough to reveal the general interest causing the conformation of invisible colleges. For that reason it is necessary to apply methodologies like the ones exposed in this document.

From the methodological point of view, the modularity method allowed to identify the existence of invisible colleges, seen from references in formal scientific communications. Unlike other methodologies (Hummon and Doreian 1989; Garg and Srivastava 2016; Garfield et al. 2003), the identification of colleges from the analysis of co-references (bibliographic coupling) and the establishment of thresholds for shared references to identify communities, allows to observe not only the constitution of a 'main stream' in which there are several thematic communities related, but also emergent subjects within a knowledge field, in this case, the IP.

Finally, the result allows a global approach to group knowledge, and the obtained communities made possible to classify subgroups in a way so that they represented indicative subjects of concerns or interests of researchers. Also, this study evidences the necessity to research the characterization of communities in a deeper way, for which it will be necessary to determine in later studies the cohesion degree of the groups, the diversification degree in the subject, the centrality of authors and to specify if the intellectual property is being conformed as an independent research field of the economics, public management and law or if it is still a fragmented subject of specialty. It will be also necessary to find out if the fragmentation displayed by the subject indicates the emergence of subjects within the specialty.

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