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Commonalities and differences between scholarly and technical collaboration

An exploration of co-invention and co-authorship analyses

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Co-authorship analysis is a well-established tool in bibliometric analysis. It can be used at various levels to trace collaborative links between individuals, organisations, or countries. Increasingly, informetric methods are applied to patent data. It has been shown for another method that bibliometric tools cannot be applied without difficulty. This is due to the different process in which a patent is filed, examined, and granted and a scientific paper is submitted, refereed and published. However, in spite of the differences, there are also parallels between scholarly papers and patents. For instance, both papers and patents are the result of an intellectual effort, both disclose relevant information, and both are subject to a process of examination. Given the similarities, we shall raise the question as to which extent one can transfer co-authorship analysis to patent data.

Introduction

Science is a social activity in both a cognitive as well as an 'operational' sense. Collaboration is one of the characteristic features of science. It can take varieties of forms, one of the results being the co-authorship of research papers. Co-authorship is one of the most frequently applied indicators in bibliometrics. It is used to track cross-national and cross-sectoral research collaboration (e.g., NARIN et al., 1991; GLÄNZEL, 2001; CARAYANNIS & LAGET, 2004), the level of scientific cooperation among sub-national regions (DANELL & PERSSON, 2003) or behavioral patterns in invisible colleges (KRETSCHMER, 1997). There are also many other purposes (see IDEA reports). The frequent use of co-authorship analysis has also given rise to a debate about its meaning and interpretation (e.g., LAUDEL, 2001; KATZ & MARTIN, 1997; MELIN & PERSSON, 1996). Contrary to the bibliometric analysis of research collaboration, co-inventive activity is a much less studied field that may gain more importance in the future.

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The methods of informetric analysis are increasingly applied to patent data. There are parallels between scholarly papers and patents which justify the transfer of bibliometric approaches. For instance, both are output indicators of R&D activity and have to go through an external review process before being accepted as a tangible output. Novelty is one of the essential criteria for both these outputs. In this sense, bibliometrics can be a source of inspiration for patent analysis. But there are caveats in analyzing patent data in a manner similar to scholarly publications. One of us (MEYER, 2000a) has shown for another method that bibliometric tools cannot be applied without difficulty in patent analysis. This is due to the essentially different process in which a patent is filed, examined, and granted and a scientific paper is submitted, refereed and published. Following this notion, we ask to what extent one can transfer co-authorship analysis to patent data. Co-invention is the analogous concept to co-authorship in terms of patents.

First, we shall discuss the differences between the processes that lead up to a scholarly publication and a patent, respectively. Then a discussion follows as to how the differences may affect co-authorship/inventing patterns, the structure of these two networks, in a given field. A case study of co-authorships and co-inventing will illustrate different patterns. In conclusion, tracing co-authors and co-inventors can exhibit the different intellectual and cognitive structures in a field of science and technology. Comparing co-authorship and co-inventing patterns may contribute to a better understanding of why knowledge transfer between science and technology is not a straightforward but highly complex process.

Motivation

The aim of this section is to demonstrate that comparing the concepts of co-authorship to co-invention is not totally unintelligible. As one of us pointed out before, drawing analogies between publication and patent metrics is a source of inspiration but also an effort that must be undertaken with great care (MEYER, 2000a). A blind transfer of methods and interpretations would not serve any purpose. Therefore, we will critically outline possible commonalities and differences in this section. This will then be completed by an exploratory analysis of data on thin-films science and technology.

Similarities between publication and patent

Only few authors have compared patent documents to scientific publications. Yet when done, interesting parallels can be uncovered. Patents, or at least certain parts of patents, are composed much like a journal article. WALKER (1995) draws a comparison between specifications and journal articles saying that a patent specification corresponds to a journal article in certain ways. He subdivides the specifications into a number of components, such as the subject that is discussed, object of the invention or discovery, and discussion of earlier work. Then a solution, including specific examples, is offered. In the final section of the specifications, the unique advantages and applications of the invention are restated.

Table 1 gives an overview. Walker concludes that each of the components he described has its corresponding component in a journal article. If a paper is subsequently published in a journal, the descriptive parts of the article may be nearly identical to those found in the previously written patent specification. For instance, a patent attorney reported that sometimes some of his researcher clients call him up and tell him to file a patent application the day before they are due to give a paper on a conference.

Table 1. Structure of a US specification

Sections of a specification	Contents
The field of the invention	A statement of the subject
Background of the invention	Indicates the problem to be solved by the invention, including the prior art (previous inventions in the field and their limitations as solutions to the problem.)
Objects of the invention	A list of the benefits to be accrued from the invention
Summary of the invention	Definition of the invention and the solution to the problem it provides.
Detailed descriptions of the invention	Includes drawings with appropriate text. Experimental data, where applicable, are given and detailed descriptions of the method and apparatus or instruments used in the method and process are included here. This section is roughly the same as the one found in a journal article; it may contain greater details to permit the replication by a skilled artisan. The structure of certain inventions and their operation are described. The usefulness of the invention is discussed and examples are sometimes given.

Source: Meyer, 2000a.

Document-related differences

In spite of these similarities, there are also considerable differences between a patent specification and a journal article. For instance, the citation process is different. While in scholarly articles, the author cites those authors that have contributed to the subject matter the article covers (WALKER, 1995), patent examiners play a far more proactive role in selecting and excluding citations than a referee possibly can in a scientific publication (MEYER, 2000b).

As WALKER (1995) points out, the assumptions of authors and inventors are different. In scientific publications, authors assume that their readers are familiar with the subject matter of the article. Patent documents need to be written in a way that someone skilled in the art can understand the specific application for which patent protection is sought. Another difference is that a patent document contains both a solution to a problem and an elaboration of applications and opportunities for applications, some of which can be quite speculative. Also, there is an emphasis on the deficiencies in earlier undertakings to an extent one does not typically find in the journal article neither in frequency nor intensity. Table 2 summarizes the basic difference between patents and research papers.

Table 2. Differences between patents and scientific papers

Substantive requirement	Applicable to	For patents	For journals
Subject matter	Patents as well as research papers	An invention must fall into one of the categories that the patent law divides patentable subject matter into.	Should fall within the scope of a journal. But is not a very stringent criteria like patents.
Utility	Patents	An invention must fulfill the requirement of 'utility'. The utility doctrine requires only a minimum level of applicability: An invention must perform a designed function or achieve some minimum human purpose.	Not applicable to research papers.
Novelty	Patents as well as research papers	An invention has to be novel, depending on the circumstances, prior art constitutes of anything previously published, patented, known, used, or sold by an inventor or anyone else that is relevant to an invention.	A research paper has to be novel and should indicate novelty, for example in the selection of the problem, or methodology or in analysis of the data.
Non-obviousness	Patents as well as research papers	The knowledge in the technological skill should not be obvious to one of ordinary skill in that area. A patent application will be rejected if the examiner can show that a researcher with ordinary skill in the technological field in question would see the invention as an obvious next step.	True for a research paper also. The problem/findings or other analytical steps should not be obvious.
Definiteness	Patents	A skilled artisan must understand the limits of the invention based on the claim language. If the claim language is not definite or clear, the patent can be rejected. This type of rejection also applies to specifications.	Not applicable to research papers.

Different underlying processes

Patents and publications are associated with two widely autonomous yet increasingly intertwined processes – science and technology. Interaction might take place in a mediated manner – through 'instrumentalities' and human resource transfer (PRICE, 1984; MEYER, 2001). PAVITT (1998) denotes basic research as an activity "to increase generalisable and replicable knowledge of nature, usually performed in, or near, universities". The results of this activity are reproduced in refereed journals. Technological development is depicted as an activity "to increase knowledge of artifacts (products, processes, services) usually performed in business firms". The results of these activities are "embodied in the artifacts themselves, and partly published in patent literature". Table 3 compares the main features of science ('basic research') and technological development, drawing on PAVITT (1998).

Table 3. Differences between basic research and technological development (after PAVITT, 1998)

Type of activity	Purpose of experiments	Essential (tacit) skills	Disciplinary base (tendency)	Main output (secondary outputs)	Location
Basic research ('Science')	To develop and test generalizable theories	To simplify to the essential to allow prediction	Single or few	– Papers – (Skills) – (Techniques) – (Networks)	– Universities
Technological development	To develop and test specific artifacts	To integrate the essential to ensure target performance	Several (engineers as integrators)	– Artifacts – (Skills) – (Patents) – (Papers) – (Operating instructions) – (Techniques)	– Business firms – Hospitals

While science is viewed as a process directed at understanding phenomena, technology is seen as an activity with an aim to create artifacts. While publication of research results is perceived as a representation of scientific work, technological activity materializes in the artifact itself. Due to the examination of a patent from legal aspects, a patent is organized in a different way than scientific papers. PRICE (1965) distinguished between 'papyrophile' scientists and 'papyrophobe' engineers. While the former aim to contribute to the eternal archive of science by publishing, the latter were characterized by absorbing published science and developing artifacts, some of which are protected by patents.

These differences are the result of two predominant, fundamentally different knowledge regimes in science and technology. Scientific research at least used to be based on an 'open science' regime in which science can be viewed as a public good. Research results were freely disseminated. 'Open science' is typically contrasted with the 'proprietary technology' regime in which knowledge has private good character and its dissemination is restricted through a number of mechanisms, one of which is patenting. About 80% of patenting is firm-based, often by large corporations. Assuming the predominance of the proprietary technology regime in industry, one would expect a far more restricted pattern of collaboration with a preference for intramural rather than extramural co-invention.*

In light of changes in the academic research system, which some observers call the second academic revolution (ETZKOWITZ et al., 2000), one might raise the question to what extent these regimes remain dominant especially in areas of close science-technology interaction. If research groups begin to act as 'quasi firms' (ETZKOWITZ, 2003) and science is increasingly delivered in an application context (GIBBONS et al., 1994), could these changes also go some way to bring academic patterns of collaboration to technology? This is an especially relevant question as one can link a considerable share of patents also to inventors who are academics (e.g., MEYER, 2003; MEYER et al., 2003).

Case selection and data

The area of thin films was chosen not only for practical considerations but also because it is a field in which technology is close to science and vice versa. There is a relatively high level of science-technology interaction (BATTACHARYA et al., 2003). If co-inventing activity emulates co-authorship then one should expect it to happen in an area, such as thin films.

For our analysis in this paper we can draw on data sets derived from previous research (Bhattacharya & KAHN, 2001). More specific information on the data retrieval and the databases is provided in the aforementioned reference as well as in BHATTACHARYA et al., 2003). In our analysis, we focus on 399 patents and 2963 scientific articles.

More specifically, we analyse first the size of the collaborating teams in thin-film science and technology, then explore for patents and publications the level of cross-national and institutional collaboration, before we look at different level of collaborative intensity of prolific and less prolific authors. In another step, we explore the network nature of collaboration processes in thin-film science and technology by mapping co-authorship and co-invention at the level of individual knowledge producers. Finally we use exemplary co-activity data to raise the question as to whether co-activity analysis (and thus the combined analysis of publication and patent data) may be a fruitful extension to transferring bibliometric approaches of analysis to patent data.

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* Following the debate on co-authorship as an indicator of collaboration, this is not a trivial point. While critics point to co-authorships not accounting appropriately for contributions made by (internal) members of research groups (LAUDEL, 2001), other analysts make the case for co-authorship as a 'fair' indicator of particularly extramural collaboration (GLÄNZEL & SCHUBERT, 2004).

Findings

The conceptual understanding from the discussions above provides us to interpret the findings in proper context. Our findings indicate that

- While both patents and papers are generated by teams rather than individuals, patents result to a larger extent from efforts of individuals and small teams rather than larger groups.
- Co-inventions appear to occur less frequently as cross-institutional collaborations than scientific publications.
- While one can trace co-authorship networks, co-invention networks occur at best in a rudimentary form.
- While in papers varied rates of connectivity occur with different rates of publication, one can distinguish two classes of connectivity among co-inventions – high and low but not medium – which concur with different levels of relative patent frequency.

The following section will present these findings in more detail.

Single vs multiple person collaboration

There are 399 patents, and 2963 scientific articles in “thin films” in 1997. Segregating the patents and scientific articles in terms of inventors/authors per patent/scientific article shows a large number of multi-authorship in both cases. However, as illustrated in Figure 1, the share of individual inventors is seven times the share of individual authors. The share of ‘small collaborations’ is one third larger in patents than it is among publications. It can be observed that the number of papers having very high degree of multi-authorship is a very significant feature in scientific output. Scientific articles with a single author are a rarity. The maximum for papers is observed with four or more authors per paper. In case of patents, the distribution is more uniform in terms of segregation. However, patents with two-three inventors occur most frequently.

A high degree of cooperative linkage is observed in both cases. Among scientific articles, 96% of the papers result from collaboration whereas about 72% of the patents result from cooperative inventive efforts. The next two sections will explore collaborative activity further with respect to authors/inventors’ output and connectivity as well as the overall network structure.

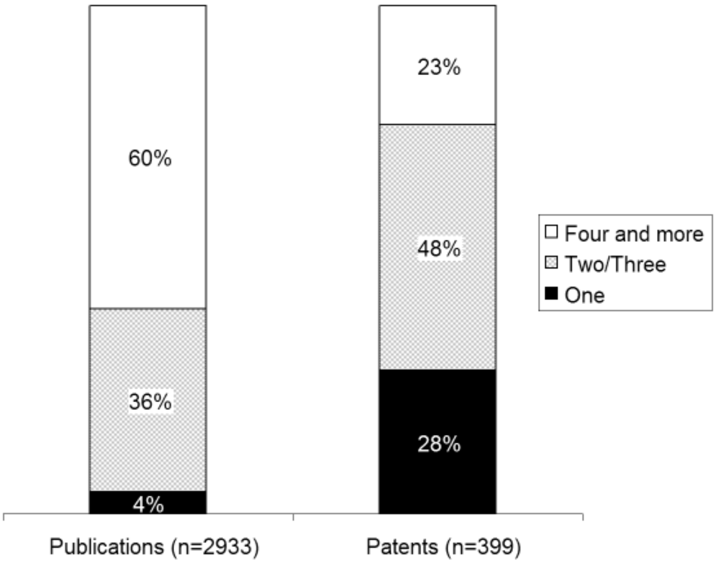

Figure 1. Number of collaborators per paper and patent

Intensity of collaboration among productive authors/inventors

Authors and their connectivity. Sixty-five authors were selected in terms of their frequency of occurrence, i.e. number of papers authored by them (individually/in collaboration). Their productivity ranged from seven papers to the maximum twelve papers. Thirty-three inventors were similarly selected having at least minimum of three patents per inventor. The most productive inventor had eleven patents.

The cooperative links were calculated within these two sets. The author centralization (network centralization) was only 15%. This indicates low level of connections among the group of frequently occurring authors. Similar to the co-authorship linkage, the network centralisation among co-inventors was only 11%. However, in spite of similarity of network centralisation, differences were seen among pattern of connectivity within the two sets. Most of the central authors were those having seven or eight papers. The most frequently occurring authors (i.e. having papers 12 to 9) exhibit less central profile. However, unlike the case of scientific output, the inventors who were very prolific were also observed well connected. Table 4 highlights the differences in the pattern of connections.

Table 4. Prolific authors

Authors with low connectivity (within the set)

Author-name	No. of papers	Connectivity
Bernede-JC	12	0
Laskela-M	10	0
Desu-SB	10	2
Adrian-H	9	1
Eom-CB	9	2
Habermeier-HU	9	2
Hahn-J	9	2
Judy-JH	9	2
Lee-JS	9	2
Tanaka-K	9	2

Authors with high connectivity

Author-name	No. of papers	Connectivity
Wang-H	7	12
Liu-HB	7	8
Zhou-YL	11	7
Zhou-JS	7	6
Ming-NB	7	6
Li-KB	8	6
Chen-ZH	10	6

Inventors and their connectivity

The situation among inventors is somewhat different. The overall level of connectivity seems somewhat lower than we observed for authors. Also, we had inventors in our set of patents with zero-connectivity but none of these had a very high level of inventive activity. This was somewhat different in the case of scholarly papers. Table 5 presents an overview of inventors with a relatively high and low degree of connectivity.

Co-authorship/co-invention analysis indicates the pattern of connectivity in science/technology. There is a general trend in both the cases of increase in collaboration activity. However single author papers are only a small fraction of the total scientific output, which is not the case in patents. Authors who are prolific have much higher level of activity, but tend to collaborate less frequently (at least among other productive authors).

A comparison of output and connectivity measures. This section compares output and connectivity of authors and inventors directly to explore to what extent certain levels of output are related to certain levels of connectivity. The level of activity is determined in relation to the most prolific author/inventor whose output is set 100%.

Table 5. Profilic inventors

Inventors with high connectivity

Inventor-name	No. of patents	Connectivity
Takimura-Y	11	5
Zhang-H	8	5
Takayama-T	6	4
Yamamoto-M	3	4

Inventors with low connectivity

Inventor-name	No. of patents	Connectivity
Manning-M	9	1
Cohen-U	6	1
Min-Y	6	1
Batra-S	5	1
Lee-J	5	0
Lee-W	5	0
Arai-M	3	0
Cabral-JRC	3	0

In the same way, we relate different individuals' connectivity to the scientist/inventor with the most connections. Figure 2 presents a map of these relative measures.

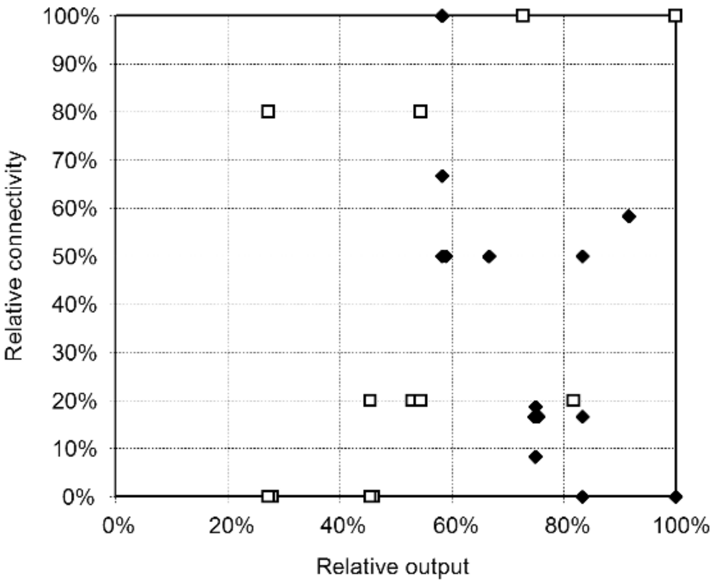

Figure 2. Relative output to relative connectivity
Note: White squares indicate inventors, black squares authors.

The map indicates that scientists tend not to go below a certain threshold of activity (here 50% of the output of the most prolific authors) whereas all levels of connectivity occur. In the case of technical collaboration, the picture is a different one. Here we find a level of comparatively high connectivity and a level with very low or no connectivity at all. Medium-level connectivity cannot be traced in our dataset. In terms of output inventors do not have a similar threshold as authors. There are a considerable number of one-time inventors to be found as well.

Networks of inventors and co-authorship maps

Mapping the links between co-authors and co-inventors illustrates the different types of collaboration. The co-authorship map, depicted in Figure 3a, resembles a network of authors as we are familiar with. Most of the authors in the field are interrelated with other contributors to the area. Some authors have more links than others. One can distinguish central actors (see e.g. #59) but also most others are interconnected.

This is different for inventors. Their activities can be found in Figure 3b. Here, one can at best identify rudimentary networks of inventors which are rather limited in scope and reach. The field is in no way interconnected, some of its actors are. A considerable number of inventors are not connected with each other at all. Dyadic relationships are particularly strong. Here one can see the different approaches between science and technology. Co-invention networks are limited, often to networks of individuals working in the same laboratory or firm.

Connecting collaboration in science and technology

Apart from looking at co-inventor and co-author networks separately, one can also explore to what extent there are individuals bridging the spheres of science and technology. Furthermore, it would be interesting to explore where in the networks co-active knowledge producers are situated. While a full analysis of this issue goes beyond the scope of this paper, we checked for prolific inventors to what extent they were also publishing scientific papers. For instance, Y. Takimura who is the most prolific inventor with 11 patents has also published a research article in the same year. This author happens to be at the center of the only network structure we observed for inventions (see #1 in Figure 3b). Other authors are less prolific or central but also co-active, as for instance:

Yonezawa, T:	4 patents – 1 publication
Hario, T:	3 patents – 2 publications
Cabral, C:	1 patent – 1 publication

The examples indicate that there is indeed some overlap between scientific and technological activity. Studying the position of co-active knowledge producers in the respective networks may therefore be an interesting aspect to be taken up in future research.

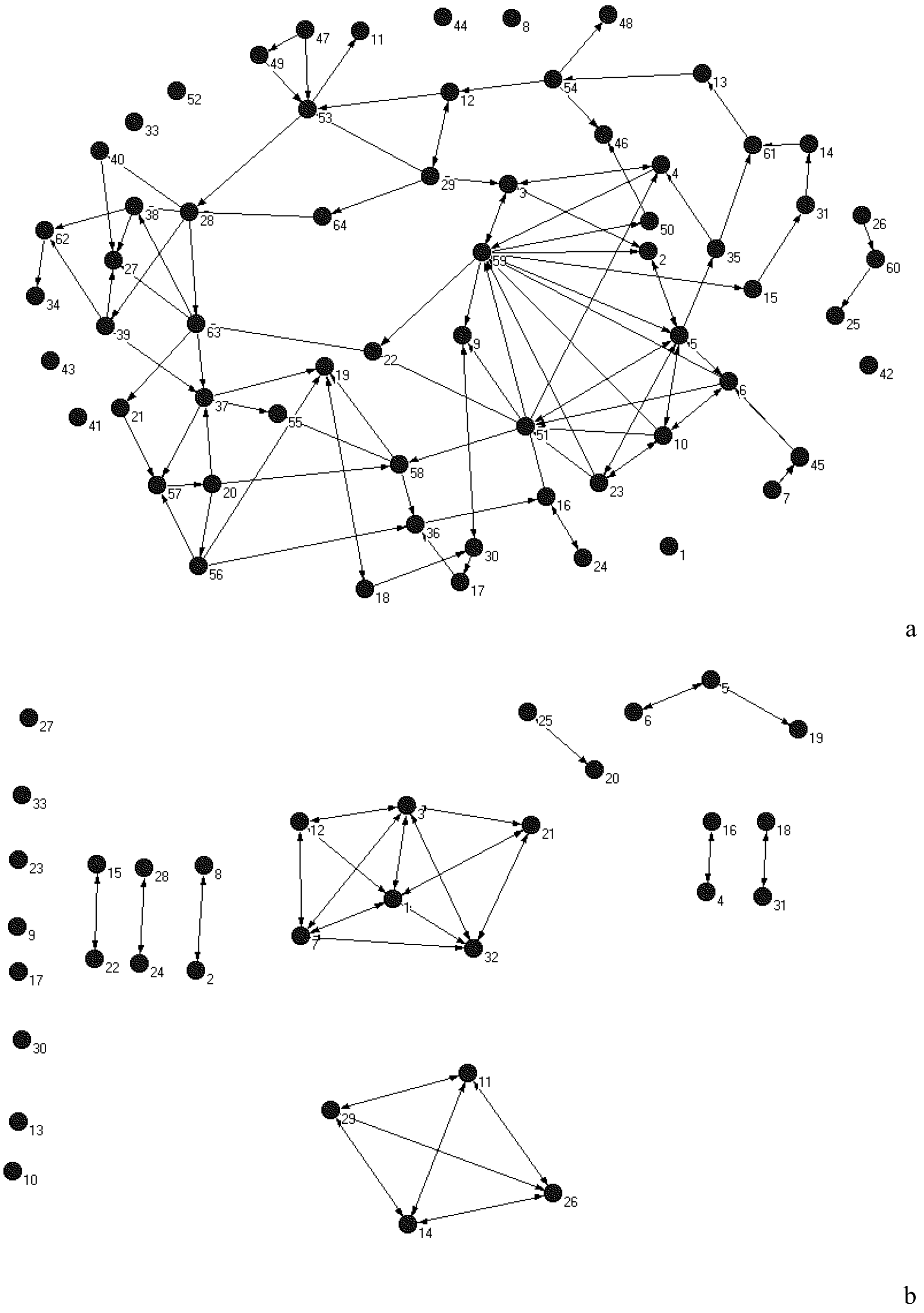

Figure 3. Collaboration links (a) among authors, (b) among inventors

Discussion and conclusions

Co-invention analysis may share the basic concept with co-authorship analysis but co-invention data exhibits different characteristics. The level of collaboration in technology has not reached the level of science. Also, co-invention networks do not resemble co-authorship networks. They are more dyadic in nature and thereby characterized by few connections only. This is partly because co-invention is more of an intramural and less of an extramural phenomenon than co-authorship. This why applying interpretative frameworks of (predominantly extramural) co-authorship analysis to (principally intramural) technological collaboration remains problematic.

Given the nature of technology this is not surprising and confirmed expectations widely. Technology is generated in industry still predominantly where the proprietary knowledge regime rules. Collaboration is to be expected within firms or at best in strategic alliances. This can include also and, perhaps increasingly, academic actors.

An interesting observation in this context is related to scientific and technological co-activity. We could identify inventors in thin films who are also active on the science side in the same year in which patents were filed. One of the key inventors we could trace also was involved in scientific research. One interesting question to pursue in future research would be where co-active knowledge producers appear on scientific and technological network maps and with which type of institution they are affiliated with (firm or academic): Are prolific and connected inventors in science-based technologies also engaged in science? Where are they based? What position do they have in co-authorship networks? Conversely, are prolific authors also involved in patenting?

Comparing co-authorship and co-inventing may contribute to a better understanding of why knowledge transfer between science and technology is not a straightforward but highly complex process. For this purpose, it would be useful to trace prolific inventors in co-authorship networks. The extent to which prolific authors engage in co-authorship and inventive activity may also give interesting clues. A policy-relevance analysis would be to trace co-inventive activity by a country. This would allow the policy analyst to obtain some information about the extent to which the generation of technological knowledge goes across borders.

Apart from these points, one must bear in mind some limitations of this research that can be addressed in future work. The data base of this exploration was weak and could be improved significantly. In particular, a longitudinal analysis would be needed rather than a snapshot of activities alone. Other fields should be studied to generate a more general knowledge base about how co-invention is a domain-dependent phenomenon.

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