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What do you mean by "mobile"? Multi-applicant inventors in the European Bio-Technology Industry

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Abstract:
Many recent papers dealing with the issue of knowledge spillovers have relied on patent data to extract information on so-called mobile inventors that is inventors designated by patent applications filed by different companies. In this paper we follow in this tradition, but with the aim of setting straight a number of methodological issues. By making use of information on the identity and history of those applicants, we then propose a taxonomy of the phenomena behind multi-applicant inventorship, which distinguishes between job mobility, mobility as a result of M&As, a case which we suspect to be dominated by the markets for research and for technologies, and residuals cases. We then argue that different multi-applicant inventors' categories have to do with different patterns of knowledge diffusion, which include both spillovers and markets for technology.

Key words: Patents, mobile inventors, multi-applicant inventorship, knowledge diffusion
JEL Codes: O31, O32

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1. Introduction

Mobility of knowledge workers, such as R&D staff and other employees contributing to firms' innovation effort, is often pinpointed as a major factor contributing to knowledge diffusion. Starting with Arrow's (1962) classic reference, the issue of mobility has been most often linked to that of knowledge spillovers, that is of a particular kind of externality which is of direct relevance for a number of phenomena, such as the correct estimation of innovation production functions (Griliches, 2000), the existence of market failures (Geroski, 1995), and the agglomeration of industries and innovative activities (Feldman, 1999). Knowledge spillovers are often referred to as "pure externalities", as opposed to "pecuniary externalities", which also contribute to agglomeration, but have much less impact on economic theory and policy.

In most cases, mobility is intended as job mobility, such as "when researchers leave a firm and take a job at another firm" (Jaffe, 1996). This kind of mobility generates a pure externality to the extent that the mobile researchers bring with themselves information, contacts and ideas they generated or acquired while working in the company they have left. However, this is not the only mobility mechanism that can generate knowledge diffusion.

Employees of one company may end up working for another one as a consequence of mergers and acquisitions (M&A), in which case the absorbing company pays for the intellectual assets she acquires along with the absorbed company, including ideas embodied in individuals. In this case, "spillovers occur [only] when a researcher paid by one firm to generate new knowledge transfers to another firm […] without compensating his/her former employer for the full inventory of ideas that travels with him/her" (Geroski, 1995). That is, in the absence of data on the economic details of the M&A operations, we cannot presume the existence, nor quantify the relevance of the externality. Nevertheless M&As are so frequent in high-tech industries that any attempt to evaluate the importance of pure spillovers should compare the relative importance of different mobility mechanisms

It may also be the case that an inventor found to be responsible for, say, two patent applications held by as many different firms may in fact be working for a third one, whose business is performing contract research or consultancy; in which case we are at the opposite end of spillovers, and in the realm of markets for technologies (Arora et al., 2001). These can still generate externalities, but of a pecuniary kind. Recent work on academic inventors, that is university scientists responsible for patents owned by more than one business company, suggests that this may indeed be a relevant case (Balconi et al., 2003; Geuna and Nesta, 2003).

Following Almeida and Kogut (1996), many papers have tried to measure the extent of mobility of knowledge workers by relying on patent data, from which information is extracted on what we will call "multi-applicant" inventors, i.e. inventors designated by patent applications filed by different companies. In most cases, multi-applicant inventorship has been taken as an indicator of job mobility. We argue that, in the absence of information on M&A activities and the nature of patent applicants, it is often hard to tell whether this is the case.

In this paper we follow in the tradition of making use of patent data to track multi-applicant inventors, but with the aim of setting straight a number of methodological issues, and find out the relative weight of job mobility, M&A-induced mobility, and markets for technologies.

We rely on the EP-CESPRI database on patenting activity at the European Patent Office (EPO), 1978-2003, from which we have extracted data on all the inventors with more than one patent applications signed in biotechnology-related fields, and a European address. We focus on all inventors with two or more patent applications, and no less than two different applicants.

By making use of information on the identity and history of both the inventors and the applicants, we then propose a taxonomy of phenomena behind multi-applicant inventorship, among which job mobility turns out not to stand as the dominant one.

The paper is organized as follow. In section 2 we discuss the recent literature on inventors' mobility and propose a taxonomy of multi-applicant inventorship. In section 3 present the data and the methodology for the construction of the data set. In Section 4 we present our results on the weight of the different typologies of multi applicant inventorship, in terms of number of inventors. In the same section , by using social network analysis technique, we show some of the characteristics of the network among applicants, generated by the flows of inventors . Section 5 provides conclusions and directions for future research.

2. Multi-applicant inventorship: a review of patent-based studies and a taxonomy

Within the broad field of the economics of innovation, most of the attention devoted to knowledge workers' mobility has come from studies on geographical clusters and the spatial dimension of innovation diffusion.

In a pioneering contribution, Jaffe, Trajtenberg and Henderson (1994; from now on JTH) shows that knowledge spillovers, which they measure with citation data, tend to be highly localized in space, even more than one could guess from merely looking at industrial agglomeration patterns. Many authors who have built upon JTH's results have invoked both job mobility and social networks as explanations for JTH's results (for a survey: Breschi and Lissoni, 2001). Only a few studies, however, have tried measuring inventors' mobility in a straightforward way.

Agrawal et al. (2003) explore the consequence for knowledge diffusion of inventors' mobility in space. They find that mobile inventors' patents tend to be cited by former research partners, which may be proof of the existence of social ties which both convey technological knowledge and resist to locational change.

These results are consistent with those achieved by Rosenkopf and Almeida (2003), who find that job mobility contributed, along with alliances, to knowledge diffusion in the US semiconductor industry.

In the same vein Song, Almeida, and Wo (2001) focus on the patenting activities of engineers who moved from US to non-US firms, and investigate the extent to which mobility helps hiring firms to reach beyond their current technological and geographical boundaries. They find some evidence that learning-by-hiring is most useful when hired engineers are used for exploring new or distant knowledge rather than reinforcing existing expertise[1].

Singh (2004) builds a social proximity graph of inventing teams for all US Patent Office patents from 1975-1995[2]. He finds out that knowledge flows are more likely to occur if mediated by social proximity among inventors' teams, and that such social proximity explain geographic localization of knowledge spillovers. Teams are connected by inventors who move across teams. Similar methodology and results can be found in the work by Breschi and Lissoni (2003), based upon European Patent Office data.

None of these studies, however, investigates the different reasons why inventors move across firms or in space, and link up to new research teams.

The only exception is Stolpe (2002), who analyzes the nature of R&D spillovers in the field of liquid crystal display technology: «research workers may move among different laboratories owned by one and same firm, or they may become an employee of a new firm when their old employer is the target of a take-over. In a similar vein , inventors may meet and collaborate in temporary research joint ventures» (Stolpe, 2002; pp. 1187).

However, Stolpe ends up encompassing all those forms of mobility in what he calls "changes of professional affiliation". In particular, he identifies such changes by simply counting the number of inventors affiliations as emerged from the patent document. In a similar vein, Almeida and Kogut (1999) define moves [of inventors] as "the number of times that a major patent holder changes firms, as revealed in an analysis of all semiconductor patents".

Trajtenberg (2005) follows the same methodology. He analyses the patents of 1,565,780 inventors listed on U.S. patent documents. In what it promises to be the largest-scale attempt to measure inventors' mobility, he equates each multi-applicant inventor to a mobile one and finds that 216,581 (about 33%) out of the total inventors have moved at least once.

However, counting any inventor's change of applicant as a "job move" across companies may be a highly misleading exercise.

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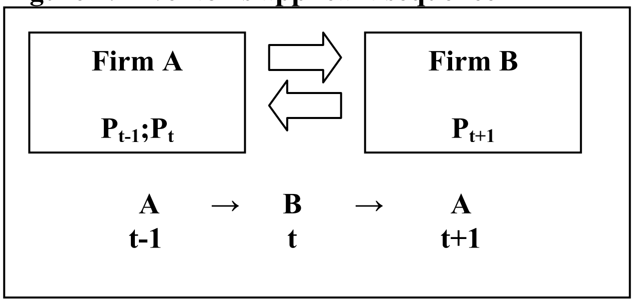
[1] This result is consistent with other works dealing with the linkage between technological benefit from alliances and mobility and technological distance between firms: going far beyond geographical boundaries could avoid technological path dependence and increase technological diversity.

[2] The graph is defined to have an edge between any two teams with common inventor. Teams with socially linked inventors have nodes belonging to the same connected component of this graph. The strength of their social link, or the social distance between the teams is given by the number of intermediate nodes on the minimum path between the two.

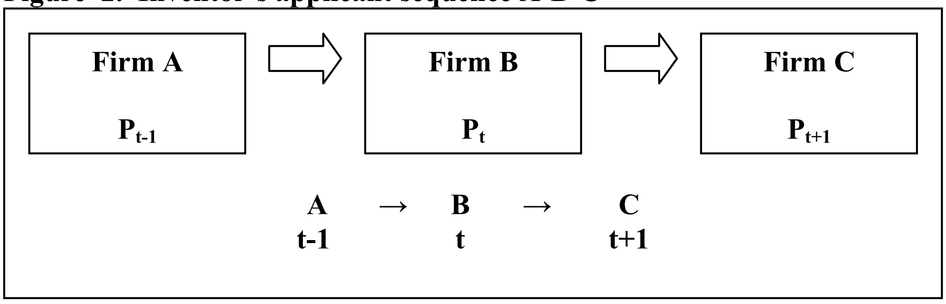
Consider the case of an inventor, whose name appears on 3 patents filed at times t-1, t, and t+1, respectively by companies A, B, and (again) A (figure 1). As we will show below, this is a frequent case: shall we interpret it as the result of two moves, one from A to B and one from B back to A? Or should we interpret it as the result of company A's decision, at time t, to perform some occasional contract or co-operative research for/with company B, and trust it to the inventor of its past and future patents?

Figure 1. Inventor's applicant sequence A-B-A



Information on *all* applicants served by one inventor may help solving these doubts. The case of an inventor's name appearing on 3 patents filed by three different companies (say A, B, and C) is more likely to signal job mobility than the A-B-A (figure.2)

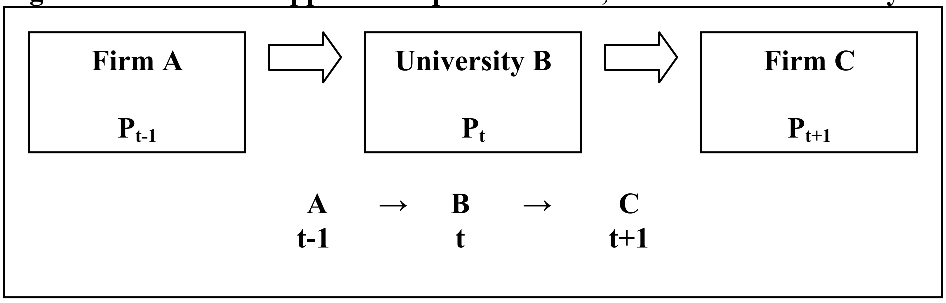
Figure 2. Inventor's applicant sequence A-B-C



An implication of this line of reasoning is that inventors who are observed to serve only two applicants (say A and B) can be hardly defined as mobile: is A merely a research contractor of B, or a company the inventors has left to move to B (and then to C)? Conservative estimates of inventors' mobility should consider only inventors with more than two patents, and at least three applicants.

Information on the nature of the applicants (business company vs university, or public research organization) can also be necessary. Consider the example in the figure 3, where an academic scientist works first in cooperation with company A (that takes a patent over the research results), than with company C (which also takes a patent), and in between on a federally funded project (whose results are patented by the scientist's university, B). This is not a case of mobility, but one wherein a technology market transaction has occurred, between A and B, and then A and C.

Figure 3. Inventor's applicant sequence A-B-C, where B is a university



This is not an unlikely case. Describing the mechanism of inventor relationship to the firm, Murray (2004) focuses on different typologies of academic inventor's affiliations, saying that an inventor can quit the academia and move to the applicant firm, or enter the firm while retaining an academic affiliation, or keep a full-time academic position with no involvement with any firm. Actually the relationship between academia and firms makes the analysis of mobility through patent data very complicated.

Patterns similar to those generated by academic inventors can also be observed when only firms are involved. Arora et al. (2001; pp.423-424) define markets for technologies as the "transactions for the use, the diffusion and the creation of technology. This includes transactions involving full technology packages (patents and other intellectual property and know-how) and patent licensing. It also includes transactions involving knowledge that is not patentable or not patented (e.g. software or the many non-patented designs and innovations)". The rise of these markets marks the decline of the model of organizing innovation characterized by in-house R&D , where R&D and the complementary assets required for innovation were integrated inside the firms. Therefore trade in technologies has become very common and it is due, among others, to an increase in licensing revenues earned by firms and to an upsurge in patenting activities which reflect an increased opportunities for technologies licensing (Kortum and Lerner, 1999).

Finally, information on property relationships between applicants may be also revealing. Consider the (frequent) case of an inventor whose patents appear first on A's and then to B's patents. If it turns out that in between the two patents' application dates A has merged with or has been acquired by B (or B's holding company), we can conclude that the inventor has not moved at all, nor she has generated any spillover. In fact, her intellectual assets has been bought along other assets of firm A.

It could also happen that when observing a "move" from A to B, one can take a closer look and find out that B is an A's spin-out, or that there is a Joint Venture in Research between A and B to develop one or more products of A's or B's pipelines. Only additional information about applicants can reveal in which case we stand.

All these cases can be summarised in the "multi-applicant taxonomy", which we present in table 1 and can be applied to all multi-applicant inventors with more than two patents and at least two applicants.

Column TYPE of the table reports what we regard as the main types of multi-applicant inventorship, namely "job mobility", "mergers and acquisitions (M&A)", and "market for inventions"; "other" is a residual category for all patterns of multi-applicant inventorship that do not lend themselves to immediate interpretation. Therefore the last category encompasses any residual cases, i.e. cases one can classify only with information on patents and their applicants. To each typology of multi applicant inventors correspond one or more sub-categories (column CATEGORY) which refer to specific patterns of multi-applicant inventorship (that we report in the column PATTERNS).

The last column (CASES) reports the most likely explanations for the observed patterns. To identify the distinct typologies of patterns of multi-applicant inventorship, we focus on the typologies of applicant, distinguishing them into three types: Open Science Organizations (OS), Private Technologies Organizations (PT) and Individuals (I). We think of OS as all the institutions which correspond to an Open Science Community setting, such as Universities, public research centre or public foundations. All firms belong to PT Organizations. We refer to Individuals patents as all the patents whose applicant is an individual.

Table 1 – Multi-applicant inventorship: a taxonomy

TYPE	CATEGORY	PATTERNS	CASES
MOBILITY	1	A→B→C, No A→B→A	Inventor moves form a firm to another one, then to a third one. No loop are observed
	2	A→B→C where A and C are Organizations, B is an Individual*** (or vice versa)	One possible explanation regards the case of start-ups created by an inventor
M&A	3	A→B→C, where A is merged with B	A merger or acquisition occurred between inventor's applicant
MARKET FOR INVENTIONS	4	A→B→A, where A or B is a OS* Organization	At least one inventor's affiliation is an university or a public research centre
	5	A→B→A, where A and B are both PT* or Individual	It might be the case that B performs contract research for, among others, A, as well as taking patents in its own name
OTHER	6	A→B→A and then A→ C→ D (or vice versa)	Patterns as a mix between mobility and other typologies. Further information are required
	7	A→B→B →B or A→A→A →B	It might be the case of an inventor who signed a first patent for an academic institution and then moving to a firm Also in this case further information is required

* OS=Open Science Organization: it includes universities and public research organizations
** PT= Private Technology Organization, i.e. business companies (incl. private laboratories)
*** Individual = individual inventors (the inventor's and the applicant's name coincide)

Therefore, combined with the identity of the applicant, the taxonomy described in table 1 allows us to identifies seven distinct typologies of patterns of multi-applicant inventorship:

1. A→B→C, where A,B, and C are all business companies (aka PT, Private Technology organizations): in this case we observe an inventor moving across three different applicants, i.e. she does not "go back" a previous applicant. It is the most likely pattern to signal job mobility.

2. A→B→C, where A and C are Organizations, B is Individual (or viceversa): this pattern maintains the same characteristic of pattern nr.1, that is the inventor does not go back to the previous assignees. It might refer to cases of ventures started-up by inventors.

3. A→B→C, where A (and/or C) is merged with B This is the category concerning all the case of mobility induced by phenomena of M&A processes. To reconstruct the stories of M&A processes of all firms one need to collect information about firms' organizational events.
4. A→B→A, where A or B is a Open Science (OS) organization, such as a university or a public lab: this pattern recalls the activity of what have been called academic inventors. It is very likely that it does not deal with a real mobility of the individuals from an organization to another one. It rather reflects the phenomenon of market for inventions.
5. A→B→A, where A and B are both PTs or A is a PT and B is an Individual (or vice-versa): it is a likely case of B performing contract research and, occasionally, taking patents in its own name
6. A→B→A and then A→ C→ D (or vice versa): this is a mixed pattern in which we observe in the first stage of inventors patenting activity a pattern which can excludes a case of mobility and in the second stage a pattern similar to pattern nr. 1. However, it is very challenging to assign such typology to a specific category of multi-applicant inventorship. At this stage of our research we consider this as a "residual" case.
7. A→B→B →B or A→A→A →B : this category encompasses cases in which one observes an inventor signing a first patent for an applicant and the remaining part of her patenting activity for a distinct applicant. As we will see in the paragraph of the empirical results, this is a very critical case. In fact this represents a very common case in which we observe an inventor's patenting activity characterised by a stable pattern of affiliation (the most part of patents are signed for the same assignee) and only one patent signed for a different assignee. At this stage of our research we consider this as a "residual" case.

To summarise the taxonomy, categories 1 and 2 shape the typology of "job mobility": we believe that it is very likely that an inventor following such pattern can be considered a true "mover", that is an inventor who has effectively changed employers.

The category 3 is what we call "M&A effect": in this case a change of assignee code is observed but actually no real move of the inventor occurred.

The categories 4 and 5 represent the realm of what we have called "market for inventions".

The categories 7 and 8 are residual categories. Nevertheless they deserve deeper scrutiny and empirical understanding.

3. Data

In order to test the usefulness of our taxonomy, we rely on the EP-CESPRI database on patenting activity at the European Patent Office (EPO). The database contains all the patent applications filed at EPO from 1978 to 2003, complete with information on inventors. We have selected information on inventors who have signed more than one patent applications in biotechnology-related fields, from 1990 to 2003, and with addresses and applicants from either one of the seven European countries with the highest number of biotech patents, namely Denmark, France, Germany, Italy, Netherlands, Switzerland, and the United Kingdom.

Biotechnology is a good field to test our taxonomy, since it is both patent-intensive and based upon a cumulative pattern of knowledge advancement: patent data, therefore, are a good indicator of both invention and innovation. It is also a field in which we may expect to find both mobile inventors, markets for technologies, and remarkable M&A activity. Following the OECD classification (Devlin 2003; van Beuzekom and Arundel, 2006), we define as biotech patents all those classified by EPO under the following 4-digit IPC (International Patent Classification) categories:

C12M	Apparatus for enzimology or microbiology
C12N	Micro-Organisms or enzymes. Compositions thereof. Propagating, preserving or maintaining micro-organisms. Mutation or genetic engineering. Culture media
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
C12Q	Measuring or testing processes involving enzymes or micro-organisms. Compositions or test papers therefor. Processes of preparing such compositions. Condition-responsive control in microbiological or enzymological processes
C12S	Processes using enzymes or micro-organisms to liberate, separate or purify a pre-existing compound or composition. Processes using enzymes or micro-organisms to treat textiles or to clean solid surface of materials

Both inventors and companies in the EP-CESPRI database come with a unique code, which is the result of automated data cleaning procedures (which correct for misspelling or use of societal forms in the names) and data users' feedbacks (Tarasconi et al., 2006). These codes were further refined through manual checks of all records.

Notice that, in order to keep the manual checking effort within manageable proportions, we did not examine inventors' activity prior to 1990, nor their activity outside the selected IPC classes[3]. This implies an underestimation not only of these individuals' inventiveness, but possibly of multi-applicant inventorship.

We do not believe this limitation may affect our results: considering the entire inventors' patent portfolios would have possibly helped us tracking more cases of multi-applicant inventorship, but not necessarily more cases of one phenomenon as opposed to another (say, job mobility vs markets for technologies).

[3] If we had considered all the patents (from all technological classes) signed by biotech inventors, from 1990 to 2003, we would have 18.413 patents, as opposed to 8.233 patents in our dataset. Furthermore, if we consider only the "mobile inventors", the total patents, all technological classes, of such inventors, are 2.098, vs 1.507 patents referring to the 5 technological classes we consider. It might mean that this specific category of inventors is more specialized in what we have defined as biotech, according to IPC we have taken into account.

Table 2. Inventors in European biotech, after 1990; by nr. of patents

Nr. of patents per inventor	Nr. of inventors	%
just 1 patent	9123	68,87
2	2137	16,13
3	836	6,31
4	402	3,03
5	207	1,56
6 or more	541	4,08
Total	13246	100

Source: Elaboration from EP-CESPRI data.

The final dataset we ended up with contains 13.246 inventors, who have signed 8.233 patents, for a total of 1.643 applicants (see table 2).

The distributions of patents per inventor is highly skewed: almost 70 % of inventors (9.123 inventors) signed just one patent, and are of no interest for our analysis. Of the remaining 4.123 inventors, we are interested in those who have changed applicants at least once.

These are 1508 individuals, that is more than one third (36,58 %) of all inventors with more than one patent (table 3). It may be worth noticing that this figure is very close to what found by Trajtenberg (2005) in an altogether different setting, namely USPTO patents in all technological classes, from 1975 to 1999.

Table 3 – Inventors in European biotech, after 1990; by nr. of applicants

Nr of applicants, per inv.	Nr of inventors	%
1	2615	63,42
2	1212	29,40
3	203	4,92
4	62	1,50
5	22	0,53
6	6	0,15
7	2	0,05
8	1	0,02
Nr of multi-applicant inventors	*1508*	*36,58*
Total	4123	100

Source: Elaboration from EP-CESPRI data.

We can look also at the differences between mono- and multi-applicant inventors in terms of patent count (from now on we will consider only mono-applicant inventors with at least two patents). On average, multi-applicant inventors sign more than 0.5 patents than mono-applicant ones (table 4). This confirms the importance of multi-applicant inventors, at least in terms of productivity.

Table 4 – Summary patent statisics, per type of inventor (European Biotech, after 1990)

	mono applicant inventors	multi applicant inventors
Mean nr. of patents	3,04	4,68
Median nr. of patents	2,00	3,00
Standard Deviations	2,56	4,58

Source: Elaboration from EP-CESPRI data.

In order to classify multi-applicant inventors according to the seven categories of the taxonomy presented in section 2, we further focussed our analysis on those multi-applicant inventors with at least three patents over time, for a total of 945 individuals.

In order to exploit also the seven category of the taxonomy we needed additional information on the M&A activities, and in general of the changes of property and/or name of all the patent applicants involved, that is for all firms holding at least one patent signed by the 945 multi-applicant inventors with at least three patents. We retrieved manually this information from a variety of sources.

We first visited retrieved company histories from all the websites of the patent applicants in our database, when available. In many cases we found detailed information on the chronological sequences of key M&As, plus all re-organizational processes into which the firm results to have been involved.

Secondly, the same websites contains the firms' annual reports which helped us to puzzle the missing information about events of dismissing or acquiring parts of firms' assets.

Finally, additional information by searching the web for papers and press releases on the companies touched upon multi-applicant inventorship.

4. Results

Table 5 presents the results of our taxonomic exercise, that is of the assignment of all multi-applicant inventors with at least three patents to one of the categories described in table 1. We first notice that the inventors who can be considered truly mobile, that is to have changed employer, represent less than one fifth of the total sample.

Table 5 - Multi-applicant inventorship in European Biotech, after 1990§

TYPE	CATEGORY	PATTERNS	# OF INVENTORS	% / TOT
MOBILITY	1	A→B→C, No A→B→A	174	186 (19,68 %)
	2	A→B→C, where A and C are Organizations, B is Individual (or vice versa)	12	
M&A	3	A→B→C, where A is merged with B	105	105 (11,11 %)
MARKET FOR INVENTIONS	4	A→B→A, where A or B is a OS* Organization	63	246 (26,03 %)
	5	A→B→A, where A and B are both PT** or Individual	183	
OTHER	7	A→B→A and then A→ C→ D (or vice versa)	39	408 (43,17 %)
	8	A→B→B →B or A→A→A →B	369	
TOTAL			945	945 (100 %)

§ Only inventors with at least 3 patents and two applicants are considered
* OS=Open Science Organization: it includes universities and public research organizations
** PT= Private Technology Organization, i.e. business companies (incl. private laboratories)
*** Individual = individual inventors (the inventor's and the applicant's name coincide)
Source: Elaboration from EP-CESPRI data.

By using the information that we collected on firms' M&A processes, we find out that a consistent number of inventors (around 11%) seem to be interested by an M&A-induced mobility.

The percentage of inventors whose mobility is only apparent, and who are indeed more likely to have contributed to the market for technologies, is around 26 %. Within such category, the more consistent sub-category is that concerning the multi-affiliation of inventors to the typology of applicant PT. It is likely that inventors belonging to such category are involved in a web of firm's relationships as result from a variety of research and technologies transactions: licensing in and out, firms' collaborations to jointly develop one or more products of firms' pipelines, market for patents etc.

Moreover, 63 cases of market for inventions involve one or more OS Organization, namely universities or public research centres. As already said, this reflects a partially different and, in a sense, complementary case of market for inventions, with respect to the previous one. It might refer to the cases of academic inventors who temporary collaborate with institutions (i.e. firms) for an R&D project, perhaps without missing the academic position.

The residual category brings many inventors (408 inventors out of 945), which is too high a percentage for allowing us to consider our taxonomy entirely satisfactory. However, until a deeper scrutiny will be done on what such category really refers to, it might be unfair to assign it to one of the specific category, whether movers or no movers, at least according to our restrictive criteria.

What emerges from this exercise is that, as we expected, the core of what can be defined as mobile inventors is very small, indeed it is the least populated set among the four we describe, in terms of number of inventors. If we calculate the weight of such category on the whole sample of inventors with at least 2 patents, that is those who in theory might move, they do not represent a very common case (12,33%). It is enough to suspect that inventors' mobility has so far been grossly over-estimated by the existing literature relying on patent data.

In section 2 we suggested that different kind of multi-applicant inventorship provide different kinds of knowledge transfer. In a related paper, we explore this claim by looking at the citation rates and the identity of citing companies for patents coming from multi-applicant inventors. Here, we content ourselves to show how the way applicants are connected to each other by multi-applicant inventors change a lot, according to the type of phenomenon described in tables 4 and 5.

In particular, we focus on two of the four categories of multi-applicant inventors' taxonomy, namely "mobility" and "M&A", whose resulting networks are described in figures 4 and 5, respectively. In both figures, nodes represent patent applicants, with a distinction between Private Technology organizations (that is, business companies: grey nodes) and Open Science Organization (black nodes)[4]. Nodes' size reflect the applicant's number of bio-technology patents[5].

The uni-directional arrows represent the ties between applicants, that is the flows of mobile inventors from one node (the organization who loses one or more inventor) to another (the organization that receives the inventors from the losing organization). The thickness of arrows reflect the number of inventors exchanged between nodes.

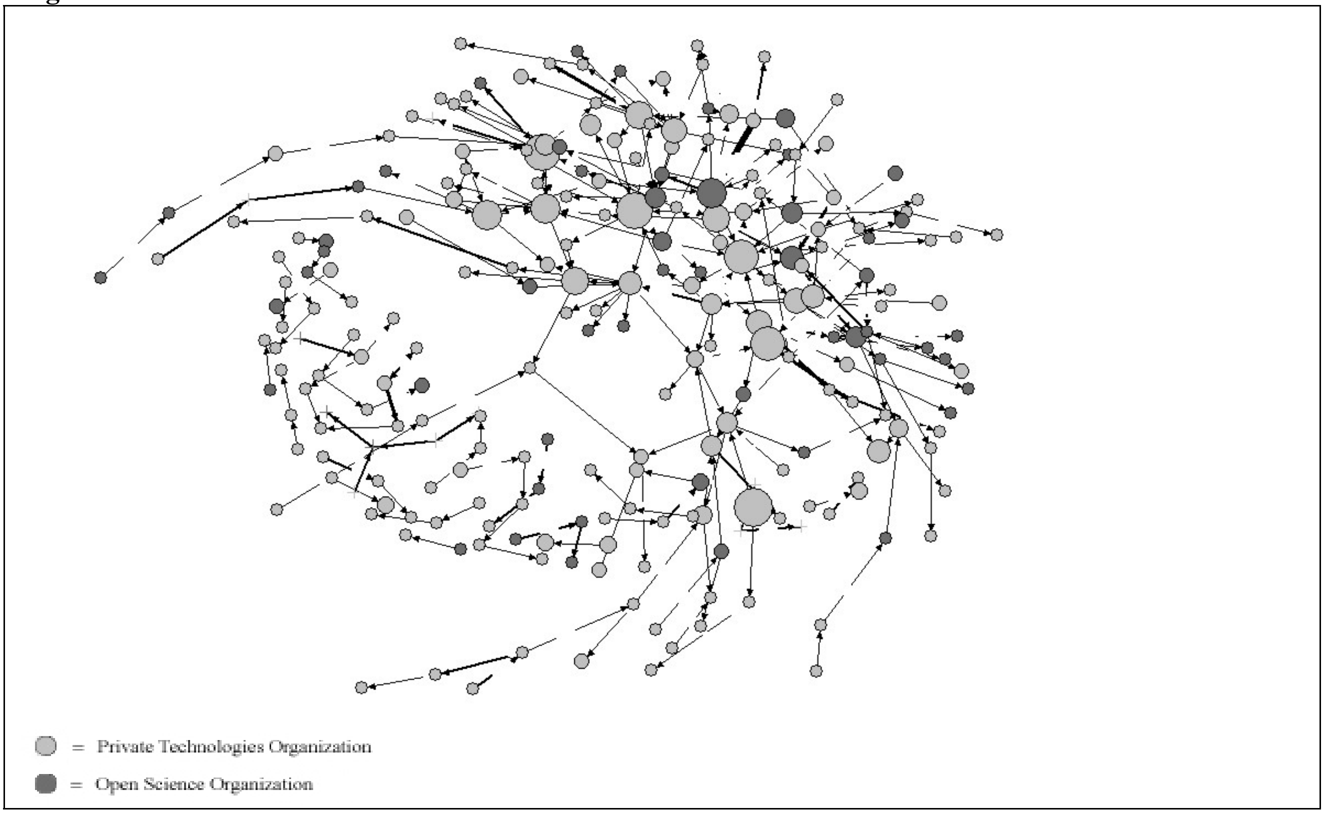
The resulting networks are strikingly different.

[4] The figure does not include the (few) cases of individual inventors moving to or from an organization. We also neglected nodes and ties involving Italian companies, which again are too few to change to overall network pattern.
[5] By " bio-technology patents" we exclusively mean the patents we consider in our dataset.

The network created by job mobility is wide (it involves 280 applicants, and 346 inventors' moves), highly connected (all nodes belong to one giant component), with a very short average geodesic distance, very much along the lines of "small world" networks spotted in science by Newman (2001). Notice that although the network is more dense around the applicant-major patents holders, there is not a core of applicants which exchange the most of mobile inventors. As a consequence, we may expect knowledge exchanges induced by job mobility to be as sparse and wide-ranging as they are often depicted in the literature.

We also notice that although most of inventors exchanges occur between PT Organizations (177 moves), the number of moves in which at least an OS Organization is involved is far from negligible (122 moves).

Figure 4. Flows of Mobile Inventors



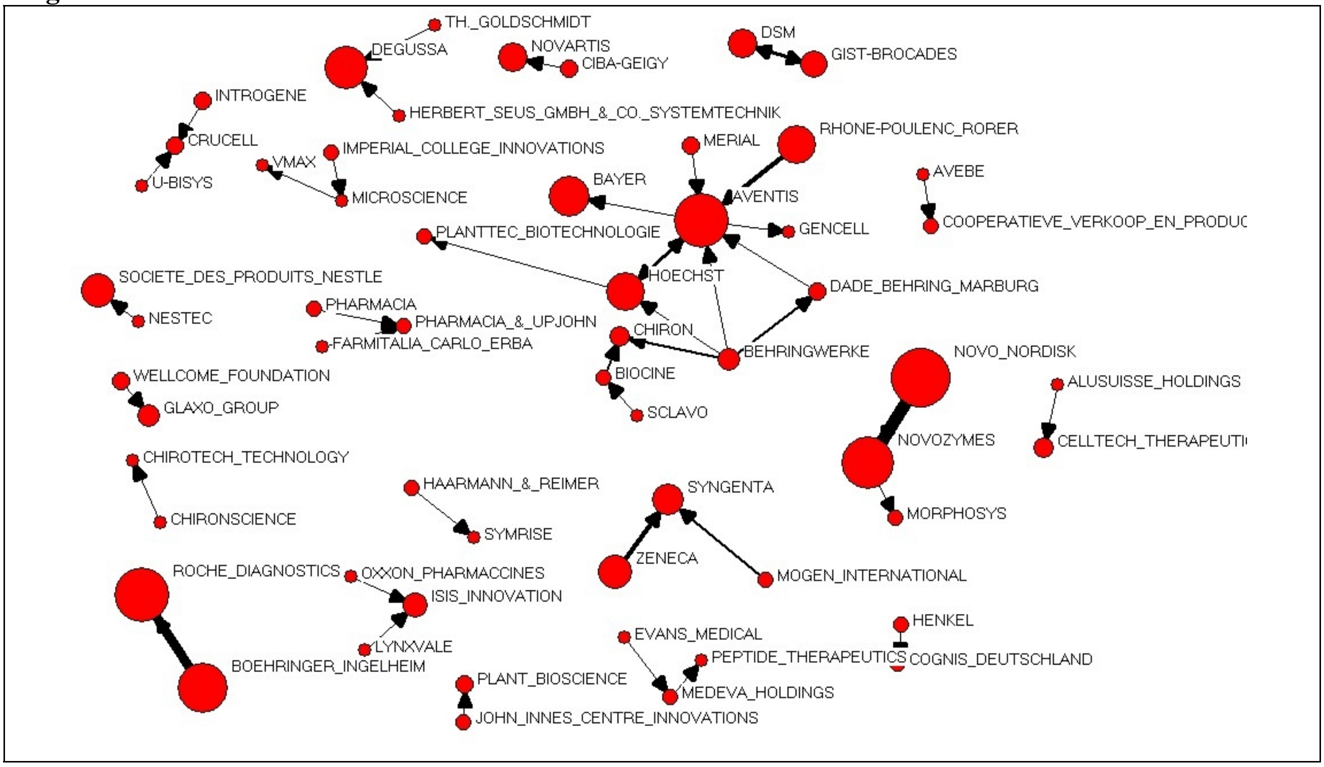
The picture emerging from multi-applicant inventorship explained by M&As is much different (figure 5). First, although the number of inventors involved is less than half the number of inventors involved in job mobility (186 vs 105 in figure 4), the applicants involved are much fewer (only 66 against 280). As a result, the network in figure 5 is made of a relatively few node that, with a few exceptions, exchange inventors with just another node. These exchanges are often more sizeable than those due to job mobility (compares the thickness of lines with that of figure 4).

While inventors' job mobility has the potential to give rise to a widespread knowledge diffusion mechanism, the same does not happen with M&As.

As an example, let's consider the thickest area in figure 5, which involves firms such as Aventis, Hoechst, and Behringwerke, among others.

Many “moves” have been identified from and to Aventis (26 to and 11 from Aventis). The information on firms’ re-organizational process (mainly M&A processes) allows us to reconstruct the firms’ events. In fact, in 1996 Chiron Corporation acquired the 49% of Behringwerke A.G., a subsidiary of Hoechst: a new company was created Chiron Behring GmbH & Co. In 1998 Chiron Corporation acquired Sclavo. In 1998 Chiron Corporation completed the acquisition of Behringwerke when it acquired the residual Hoechst AG’s interest in Chiron Behring Gmbh & Co.In 1999 Rhône-Poulenc S.A. merged with Hoechst Marion Roussel, which itself was formed from the merger of Hoechst AG with Roussel Uclaf and Marion Merrell Dow. The merger led to the creation of Aventis. This is just a part of the story explaining the exchange of inventors among such firms.

Figure 5. Flows of Inventors - M&A



If we consider another case, that of the firms Novo Nordisk and Novozymes, we find that a slightly different typology of re-organizational process occurred and that explain the “apparently” flows of inventors. In fact in 1989 Novo Nordisk was created through a merger between two Danish companies – Novo Industri A/S and Nordisk Gentofte A/S. In 2000 Novo Nordisk is split into three separate companies operating under the umbrella of the Novo Group: Novo Nordisk A/S, Novozymes A/S and Novo A/S. This would explain why we have identified 30 moves from Novo Nordisk to Novozymes.

In both our examples, we have a large number of apparently mobile inventors, who indeed harldy moved and certainly did not contribute to diffuse their knowledge beyond the boundaries of the bilateral negotiations involving the firms which they worked for. Counting them along truly mobile inventors, such as those described by figure 4, may lead to grossly overestimated both mobility and the knowledge diffusion that goes with it.

5. Conclusions

The aim of this paper was two-fold. The first aim was a methodological one: we meant to contribute methodologically to the empirical literature on inventors' mobility. We have argued that not all the phenomena behind what we called "multi-applicant" inventorship may be equated to genuine, "job" mobility. By applying our taxonomy to EPO patent data in biotechnology, we have found that both the existence of markets for inventions and M&A activity contribute to explain what the existing literature has hurried to put under one label only, that of mobility. We also found that mobility of inventors is far from being the dominant force behind multi-applicant inventorship.

The second aim of the paper was to provide at least a hint of the reason why it is important to tell apart the various phenomena behind multi-applicant inventorship, namely that these phenomena bear different consequences in terms of knowledge diffusion. In this respect, we showed that the firms' network generated by truly mobile inventors is very different from that created by M&A-induced multi-applicant inventorship. It is likely that such phenomenon signals the capacity of mobile inventors to connect more firms and institutions, than other categories of inventors, therefore providing a powerful mechanism of knowledge diffusion.

In future research, we will further explore the impact of the different sources of multi-applicant inventorship by looking at the citation rates impact of both mono- and multi-applicant inventors, and of different categories of multi-applicant inventors.

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