Guest Authors or Ghost Inventors? Inventorship and Authorship Attribution in Academic Science

GUEST AUTHORS OR GHOST INVENTORS?
INVENTORSHIP AND AUTHORSHIP ATTRIBUTION IN ACADEMIC SCIENCE ⊗

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Abstract

We discuss the concepts of inventorship and authorship in academic science and derive some policy implications for the institutional mechanisms allocating scientific credit. Authorship and inventorship are the key *attribution rights* that contribute to a scientist's reputation. Both of them appear to be obsolete because they do not capture the increasing division of labour and responsibility typical of contemporary scientific research teams. The social norms that regulate the distribution of both of them do not reflect exclusively the relative contribution of each team member, but also the members' relative seniority or status. In the case of inventorship, such social norms appear to be as important as the legal norms whose respect is often invoked by technology transfer officers. As a result, the informative value of both authorship and inventorship attributions may be much more limited than assumed by recent evaluation exercises.

⊗ This paper belongs to a series of two (the other being Lissoni et al., 2013). Both originate from a working paper presented at conferences and seminars at Case Western Reserve University, SPRU-University of Sussex, University of Manchester, International Centre for Economic Research (ICER, Turin), Georgia Institute of Technology, Copenhagen Business School, Université Paris XIII, Njimegen University, Eindhoven University, Università del Piemonte Orientale, Gretha-Université Bordeaux IV, and Università di Bologna. The two papers share parts of section 2 and of the descriptive statistics from section 4. Besides discussants at various events, the guest editors of this special issue, and two anonymous referees, we thank Mario Biagioli, Marco Giarratana, Fiona Murray, Scott Stern, and Nicolas Carayol for their extended comments and encouragement. Usual disclaimers apply.

1. Introduction

Recent contributions to the economics of science have been largely based on the notion of "scientific credit" as derived from Robert K. Merton's classic sociological approach (Stephan, 1996; Audretsch et al., 2004). Scientific credit is the reputation bestowed by the academic community upon the researcher who contributes significantly to the advancement of knowledge in his or her field, and makes that advancement accessible, to the entire community and society at large, through one or more scientific publications (Merton, 1957; Dasgupta and David, 1994).

In a number of disciplines, academic scientists earn scientific credit also through patenting: being listed among the inventors of a well-known patent brings engineers, chemists, pharmacologists, and molecular biologists not only (highly uncertain) economic returns in the form of licensing fees, but also some gains in reputation. Patents are increasingly seen as proofs of the impact and creativity of the research conducted with public money, witness the increasing attention paid to them by research evaluation efforts[1]. In addition, recent research in both economics and business has highlighted the impressive growth of "academic patenting", both in the US (Henderson et al., 1998; Mowery et al., 2004), and in a few European countries (Meyer et al., 2003; Balconi et al., 2004; Gering and Schmoch, 2003; Saragossi and van Pottelsberghe, 2003; Van Looy et al. 2006; Lissoni et al., 2008). "Academic patents" are conventionally defined as patents covering inventions by university-employed scientists, and may be owned by the scientists themselves (as it often happens in countries whose legal system supports the "professor's privilege"), their universities (as most common in the US), or private and public sponsors of the scientists' research (as it happens most often in Europe).

When it comes to academic patents, authorship and inventorship do not proceed independently. It is often the case that inventions derived from academic research are both patented and described in one or more scientific publications. More generally, academic inventors are also highly productive scientists who do not feel that patenting stands much in the way of their freedom to publish (Azoulay et al., 2007; Breschi et al., 2007; Lissoni, 2008). Both authorship and

[1] This happened both in past and present evaluation programs run by governmental agencies and internally by universities. A recent report by the European Commission (EC, 2010) provides many examples of assessment exercises in Europe that make use of patents as indicators. For past national evaluation programs see the British Research Assessment Exercise or the Italian Valutazione Triennale della Ricerca (RAE, 2008; CIVR, 2006). Patents are also important in the forthcoming Research Excellence Framework (http://www.ref.ac.uk/) in Britain and in the Italian *Evaluation of Research Quality* (http://www.anvur.org/). In addition survey data (OECD 2003) show that in many countries (e.g. Denmark, Germany, Japan) intellectual property activities of researchers are considered for recruitment and affect career promotions and wages.

inventorship can be controversial, especially in the case of large research teams. Both are forms of intellectual property rights (legal or 'moral' rights of attribution, according to international conventions[2]); but both are largely administered on the basis of social norms, rather than strict legal rules (Zuckerman, 1968; Fasse, 1992).

The few existing studies on authorship, largely confined to biomedical sciences, suggest that these norms allow for negotiation and power struggles within academic research teams, which may result in mis-attributions and omissions (Biagioli et al., 1999). This can be highly prejudicial not only for individual scientists, but also for third parties (such as hiring universities and funding agencies), which may get unreliable reputation signals from the scientists' CVs. Some recent legal case studies suggest that the same may happen with inventorship (McSherry, 2003; Seymoure, 2006). These case studies suggest that, when research teams aim both at publishing and patenting, even the customary social norms of attribution may fail, in the sense that scientists cannot reach a consensus agreement on how to apply them.

This paper revises critically the literature on inventorship and authorship attribution in academic science, including the empirical evidence produced by the authors, and derives some policy implications on the institutional mechanisms allocating scientific credit. In particular, we discuss the norms which are generally followed by academic scientists for the joint attribution of inventorship and authorship rights; and to what extent those norms may be questionable from a social welfare perspective. In section 2 we introduce the concepts of co-inventorship and co-authorship, as they are presented, respectively, in the legal and sociological literature, as well as in the "grey" literature of journals' publication guidelines and technology transfer offices' recommendations to potential academic inventors. We also discuss the relative importance of social and legal norms in the allocation of scientific credit. In section 3 we survey the recent empirical evidence on the importance of social norms for the attribution of inventorship in teams of scientists. Section 4 concludes, derives policy implications providing a plea for recognition of the changing realities, the increasing complexity and growing diversity of roles, in the production of science and technology.

[2] The two international treaties that matter most in this respect are the International Covenant on Economic, Social and Cultural Rights (ICESCR) and the Berne convention. The former is an UN-administered agreement entered into force 1976, and it contributes to the International Bill of Rights; its article 11 protects 'the moral and material interests resulting from any scientific, literary or artistic production of which [a person] is the author' (UNESCO, 2001). The latter is an international treaty for the harmonization of national copyright laws, dating back to 1886 and now administered by WIPO, the World Intellectual Property Organization (WIPO, 2008); authors' moral rights are protected by article 6. The interpretation of moral rights, as defined by the Berne convention, is generally much more extensive in continental Europe (esp. France) than in the UK and the US (Fernandez-Molina and Pais, 2001; Fisk, 2006).

2. Authors and inventors: problems of attribution in large research teams

Multiple-authored publications are nowadays a common feature of many scientific and technical fields, and the average number of authors per publication keeps increasing (Weeks et al., 2004). Drenth (1998) estimates that in the biomedical field the mean number of authors per paper has increased steadily from 3.21 in 1975 to 4.46 in 1995. Similarly, Levsky et al. (2007) calculate a 23% increase from 1995 to 2005. Historians and sociologists of science have explained this trend with the changing nature of the scientific work, which is increasingly based on specialization, inter-disciplinarity, the sharing of data and facilities and closer engagement with commercial activities (Katz and Martin, 1997; Hackett, 2005; Jones, 2009). Some have suggested that the growing "publish-or-perish" pressure on faculty may induce the latter to trade authorship credits in order to keep up their publication record, thus inflating the number of authors per paper (Levsky et al. 2007).

The number of multi-invented patents has also increased significantly for quite a few years now (Wuchty et al., 2007). However, comparisons with publication data reveal that the average number of inventors per patent is well below the average number of authors per publication, even for comparable technological and scientific fields (Meyer and Bhattacharya, 2004). One common explanation for this difference is that while publications are the realm of academics, patents originate mostly from industrial research, funded by business companies and performed by their employees. It is then suggested that the proprietary nature of this research forces caution in looking for cross-firm collaboration, and in granting to industrial researchers the same freedom of choosing research team partners enjoyed by academic scientists. However, differences in the number of co-authors and co-inventors can be found also when comparing patent-publication pairs, that is patents and publications which originate from the same (academic) research team and programme (Ducor, 2000; Murray, 2002). In this case, the only possible explanation for the difference is that the qualifying criteria for being considered either an author or an inventor differ, or that some differences exist in the established practices of attribution. In what follows, we discuss such practices.

2.1 The social norms of co-authorship

The main reason of interest for the co-authorship phenomenon lies in the threat it poses to the incentive system of academic science, and to the damage it may inflict to its public image.

Concerns with the attribution of co-authorship are of two (related) kinds.

First, "the rapid increase of multi-authored papers [has introduced] *ambiguity* about the respective contributions of the joint authors" (Zuckerman, 1968; p.277 – emphasis is ours Multi-authorship introduces ambiguity to the extent that it treats all authors as the same, regardless of specialization and differences (in intensity) of their contribution. Non-alphabetical name ordering, a common practice in several disciplines, may alleviate the problem by highlighting the special role of first and last authors; but it conveys little information on the role of middle-authors, it ignores the problem of division of labour and specialization, and lends itself to manipulation (see below).

Second, fears have been expressed over the extent of *mis-attribution* practices, such as 'guest' (or 'honorary') and 'gift' authorship, which occur, respectively, when a senior scientist is listed in the authors' by-line of a paper he/she has not contributed to, and a student or a technician are rewarded beyond their merits with the inclusion in the author's by-line. Even worse is the case of 'ghost' authors, who are typically junior scientists that contribute significantly to the published research, but are mentioned only in the acknowledgements section of the paper or not mentioned altogether (Rennie and Flanagin, 1994). Quantitative accounts of guest and honorary authorship are also provided by Flanagin et al. (1998), Hoen et al. (1998) and Mowatt et al. (2002). For detailed, interview-based evidence see Laudel (2002).

Ambiguity makes publications less useful as tools for distributing scientific credit, as it makes it impossible, for a reader, a perspective employer, or an evaluation agency, to establish clearly in which way and to what extent each co-author contributed to achieving the research results. As for mis-attribution, this undermines the credibility of authorship, since it breaks the link between actual participation to the research effort, and the attainment of the status of author. . Both contribute to dissociate credit from responsibility, to the extent that not all the listed authors (in a few cases none of them) can be held accountable for the ethical integrity of the entire research, the soundness of applied methods, and the quality of data (Biagioli, 1998).

These problems have been proved to be particularly severe in biomedical research, possibly because of the great importance of responsibility attribution in that field. As a consequence, the *International Committee of Medical Journal Editors* has published, since 1985, the 'Uniform Requirements for Manuscripts Submitted to Biomedical Journals'. In their latest version, the Requirements recommend the following criteria for authorship:

> "Authorship credit should be based on 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published […] Acquisition of funding, collection of data, or general supervision of the research group, alone, do not justify authorship" (ICMJE, 2007).

At a close look, the Requirements do not appear very restrictive, even though all three have to be met. They allow very heterogeneous co-authors to be listed together in the same by-line; for example, a scientist who has limited himself to an entrepreneurial role (such as chasing grants, "conceiving and designing" the paper, and revising it "critically") could be listed along with a colleague who has carried on most of the work (such as acquiring, analysing and interpreting the data, drafting the manuscript, and providing the technical expertise). Despite such latitude, the ICMJE Requirements have been largely ignored by the scientific community. For example, Bates et al. (2004) find that 60% of 72 articles surveyed in 2002 in the Annals of Internal Medicine and 21% of 107 articles in the British Medical Journal have at least one author who does not meet the first of ICJME criteria. Similar results have been found by Hwang et al. (2003) for the journal Radiology (see also references therein on studies on Lancet and the Dutch Medical Journal).

Lack of application of the ICMJE requirements is mainly due both to ignorance on the scientists' part (Bhopal et al., 1997) and to lack of enforcement by the journal editors. Authorship attribution remains a highly subjective decision, which is negotiated within research teams, according to customary rules that differ across disciplines and laboratories, and do not necessary match the journals' guidelines. In addition, researchers' lack of respect of authorship criteria can be hardly detected or sanctioned by the journal editors: when guest or gift authors are added to a publication, there is little risk of undermining the scientific validity of the article and the reputation that "true" authors may derive from it. As they stand, the ICMJE requirements are so prone to be violated that a few pharmaceutical companies have even managed to publish papers produced by internal ghost-writers, but "authored" and submitted by complacent guest authors from the academic ranks (Ross et al., 2008, and references therein).

Faced with such a loss of the informative value of authorship, another organization, the Council of Science Editors, set up in 1998 an 'Authorship Task Force', which in turn proposed quite radical recommendations, now embraced by leading medical journals such as JAMA, Lancet, British

Medical Journal, Radiology and Journal of Public Health (Biagioli et al., 1999; Rennie, 1998; Hackett, 2005). Authors who publish on those journals are now required to classify their individual contributions to the published paper according to a grid proposed by the editor, and to specify who among them take responsibility for the integrity of the entire study. More interestingly, proponents of this approach stress that in modern science the concept of 'authorship' is irreparably obsolete, and that 'contributorship' should take its place. Contributorship-based systems of credit rely on the pre-definition of a number of professional categories or professional tasks, which are then used to map each team member's role in the scientific enterprise. The first column of table 1 reports the contribution grid adopted by the journal Radiology, in accordance with the recommendations of the Authorship Task Force. Each team member can qualify for more than one category and at least one has to be identified in category 1 to assume responsibility for the integrity of the study.

The second column of table 1 reports the three necessary conditions to be met in order to qualify as "author" according to the ICMJE guidelines. Note that the concept of contributorship is such that credit can be given also to research team members who do not qualify as authors, since they meet only one of the ICMJE conditions. On the other hand, the ICMJE conditions fail to mention explicitly the problem of responsibility, and fail to give due credit to research team members whose contribution may be substantial, but not falling in the category of "authorship".

A second-order problem of attribution relates to name-ordering. Although general authorship guidelines, such as the ICMJE's, do not provide mandatory recommendations, two major traditions exist in this respect: alphabetical ordering (which is typical, for example, of social sciences) and contribution-related ordering, which is most common in the hard sciences and is explicitly recommended by some learned societies. Pure seniority-based criteria, according to which senior authors are listed last, irrespective of their contribution, are less common but not rare, and often used to temper conflicts within the team.

Table 1 – Contributorship categories vs. authorship requirements in medical journals

Contributorship categories (from: Radiology)	Authorship criteria (all to be met; from ICMJE)
1. Guarantors of integrity of entire study 2. Study concepts 3. Study design 4. Literature research 5. Clinical studies 6. Experimental studies 7. Data acquisition 8. Data analysis/interpretation	I. Conception & design or acquisition of data or data analysis & interpretation
9. Statistical analysis 10. Manuscript definition of intellectual content 11. Manuscript preparation	II. Draft or critical revision of the paper (for important intellectual content)
12. Manuscript editing 13. Manuscript revision/review 14. Manuscript final version approval	III. Final approval of the paper version to be published

Source: Hwang et al. (2003)

In their study on medical publications, Mowatt et al. (2002) calculate that 76% of by-lines list the person contributing primarily to the study first, while only 2% list authors alphabetically. Of the remaining 22%, seniority criteria were involved, such as listing the senior author last. Some professional societies, the ICMJE among them, explicitly recommend to list authors according to their contribution (Rennie and Flanagin, 1994; Drenth, 1998). Zuckerman's (1968) seminal work on Nobel laureates' authorship practices reveals that name ordering decisions are most often delegated to senior investigators, who base their judgement both on contribution and seniority. In particular, the Nobel laureates interviewed by Zuckerman (who come from all disciplines) point out that precise measurement of relative contributions is impossible, so that a pure contribution-based ordering effort would produce conflicts within the research teams: ambiguity is necessary to temper tensions within the team.

This suggests that while the message conveyed by the first and last position in a non-alphabetical by-line is relatively unambiguous (the first author being usually the junior scientist who has contributed most to the paper; the last being the senior investigator, who runs the lab, chases the grants, and sets the research strategy) the same cannot be said for the authors in between. These may be either effective contributors to the paper (although less important or more senior ones than the first author), but they may also be guest authors of many sorts (such as laboratory technicians rewarded for their dedication, or very senior scientists listed as a sign of deference).

Besides being useful for our research (see below), this discussion of name ordering reveals that the latter is of limited help in sustaining the notion of authorship and its usefulness for the attribution of scientific credit; in fact, it provides only a mild correction to the misattribution problem, and no correction at all to the problem of responsibility.

2.2 The "Muddy Metaphysics" of Co-Inventorship

Unlike scientific authorship, inventorship is a legal concept whose violation may have some direct economic consequences. In the US, a patent may be declared invalid if the designated inventors' contribution does not match with the legally defined one. In addition, the inventors' names can be changed after a patent is granted only as long as the error was made without deceptive intent. This norm applies also to foreign patents, when extended to the US.

According to section 35 of the US constitution (as amended in 1984), two individuals can be designated as inventors on the same patent only if they have worked "jointly" and provided some kind of "inventive" contribution (Fasse, 1992, pp. 172-173). Of the two criteria, only the latter can be responsible for the eventual exclusion of an author of a scientific paper from the related patent. In particular *each* person named on a patent must have contributed to the *conception* step in the invention (as defined by the claims). Conception is "the formation, in the mind of the inventor of a definite and permanent idea of the complete and operative invention, as it is to be applied in practice" (Hybritech Inc. v. Monoclonal Antibodies, Inc.).

In Europe, even with patents issued by the European Patent Office (EPO), inventorship is ultimately defined by the various national legislations. For example, in the United Kingdom the term inventor is defined as the "actual deviser of the invention..." and the actual deviser is the person(s) who contribute(s) to the novelty or inventive step of the invention (s7-3 Patents Act, 1977). In Italy, as in many other countries, no specific definition of inventor is provided by legal

texts. As a matter of fact, author and inventor coincide, with the latter being simply defined as the "author of an invention" (the latter being such only if an inventive step exists); mis-attribution of inventorship does not appear to threaten the validity of the patent, but it may cause re-allocation of the property rights.

As a result, criteria for defining inventorship turn out to be more restrictive than those defining authorship. Being involved in the conception of the invention is a requirement for inventorship that some authors of scientific publications may fail. For example, current interpretations of the US law suggest that "merely suggesting a desired result" or "having entrepreneurial involvement" do not qualify as inventorship (Fasse 1992, pp. 192ff). For example, a scientist whose contribution to a research project was limited to raising funds, conceive the initial experiment, and revising the draft paper would qualify as author of a project-related paper (see the ICMJE guidelines we described above), but not as inventor of any project-related patent. At the opposite end, "following the complete instructions" of a colleague or superior does not qualify anybody as an inventor; and joining a research team too late, after its members have conceived the key characteristics of the desired invention, may be a reason for exclusion from inventorship. The latter cases remind naturally to situations in which a junior scientist or a graduate student may be rewarded with authorship for her brilliant assistantship, but not with inventorship (Fasse 1992; Seymore 2006).

Scientific journals often publish papers on inventorship attribution for science-based inventions, which are by and large written by consultants and technology transfer offices (Bennett and Biswas, 1997; Vinarov, 2003; Hutchins, 2003). These papers aim at setting straight a number of legal issues related to inventorship, so that scientists who read them will not extend to inventorship attribution the same social norms attached to authorship, thus running the risk of invalidating the patent.

However, both the concept of inventorship and its application are much more controversial than may appear from such legal opinions. It is very likely that decisions on inventorship attribution, very much like those on authorship, depend heavily upon the discretionary judgement of the most senior scientists in the team, who most often manage the economic details of the research enterprise and exercise authority, and whose opinion may carry a heavy weight within the team. When faced with the difficult task of evaluating their junior colleagues' contribution towards obtaining some research results, these scientists may be tempted to stretch their judgement in a

favourable direction when confronted with the problem of authorship attribution (which entails only a reputational reward), and in the opposite direction when deciding upon inventorship (which may also lead to more tangible economic benefits). In doing so, senior authors may also be affected by a tendency to overvalue their own contribution to patents, a tendency which a questionnaire survey by Jaffe et al. (2000) has shown to be quite common (McSherry 2003).

The practicalities of inventorship attribution also leave much room for mistakes and abuses. Very much like journal editors, patent office examiners trust entirely the identification of legitimate inventors to the individuals who submit their applications. At most, signed declarations are required. If not challenged in court (either by some excluded individuals, or by some included ones, who contest the unfair inclusion of others) these initial attributions remain un-scrutinized: patent offices, in fact, pay attention only to the technical contents of the patents they are called to judge, and not to the people behind them. It is doubtful that a junior scientist, excluded from a patent (but possibly rewarded with authorship), will find it convenient to sue a senior colleague, upon whom her career prospects may depend heavily.

2.3 Authorship and inventorship: two sides of the same coin?

Summing up the previous discussion, we may expect that when a team of scientists achieve a research result which is susceptible of both patenting and publishing, the number of authors of the publication(s) will be higher than the number of inventors listed on the related patent(s). In addition, we can hypothesise that the exclusion of some authors from inventorship will possibly depend on a combination of legal reasons and on a within-the team negotiation process concerning the overall distribution of attribution rights (for a formal treatment see Lissoni et al., 2013).

In particular, we can sketch four different categories of authors at risk of being “excluded” from inventorship:

I. Senior scientists whose contribution to the research enterprise has been largely of an entrepreneurial kind, so that they qualify for authorship (according to journals’ guidelines) but not for inventorship (according to the rule of law);

II. Laboratory technicians and other assistant figures (including graduate students and junior scientists in charge of minor tasks), whose contribution qualifies them for authorship, but not for inventorship;

III. Laboratory technicians and other assistant figures (including graduate students and junior scientists in charge of minor tasks), who have been rewarded with "gift" authorship, and senior scientists honoured with "guest" authorship (none of whom, of course, qualify as inventors)

IV. Junior and female scientists who qualify both for authorship and inventorship, but are excluded from the latter as a consequence of a team's decision based on non contribution-based criteria. Notice that this case is compatible with the some apparently contradictory evidence from the literature. For example, it has been found that senior scientists may grant first authorship or, less commonly, cede authorship altogether to junior colleagues for whom they act as mentors (Zuckerman, 1968; Haussler and Sauermann, 2013). This does not exclude that, on a companion patent, they will keep inventorship for themselves, possibly as a compensation for having given up on (first) authorship[3]. This possibility is reinforced by the fact that, for a young or female academician, whose academic status is weaker than that of senior and male colleagues. Authorship may be more valuable than inventorship, so that they may agree (more or less explicitly) on giving up inventorship in exchange of (first) authorship. This observation is reinforced by the greater difficulties a young or a female scientist may face when trying to enter markets for technologies (Murray and Graham, 2007; Whittington and Smith-Doerr, 2008).

Of course these four categories do not describe all possible situations and there will always be cases that are difficult to place into any one of these categories. Nevertheless, in what follows we will review several studies which make use of bibliometric information in order to assess the relative importance of these four causes of an author's exclusion from a patent.

3. Inventorship attribution in academia: recent evidence

The growing importance of academic patenting has raised a number of questions on the criteria followed by university scientists in distributing inventorship rights within research teams. Two lines of research have been developed so far, one that addresses directly the issue of inventorship attribution in academic research teams, the other that compares the attribution norms used by academic scientists in publications (authorship) as opposed to patents (inventorship).

[3] Notice that this does not exclude that, in other occasion (such as when a paper may earn them a scientific prize or other forms of outstanding recognition), the same senior scientist will keep (first) authorship for themselves (Zuckerman, 1968).

3.1 Faculty's vs. non-faculty's inventorship at Stanford University

In a study of technology transfer at Stanford University, Colyvas (2007) shows how practices of inventorship attribution among senior life scientists at that university changed over time and across teams, in order to reflect strategic concerns. According to Colyvas, a study of archival data on patent disclosures suggests at least four models of patenting behaviour and inventorship attribution:

1. "Team effort". In this model, which dates back to the early days of technology transfer from the life science, the invention disclosure was not signed by the principal investigator. In fact, most disclosures referred not to biological materials, but to the experimental devices built by technicians. Also for this reason, inventorship attribution was not regarded as bringing reputation within the scientific community (that is, it did not produce any scientific credit)

2. "Clear boundaries". In this model, inventorship is attributed first and foremost to the scientist (principal investigator) who came up with the idea. Most often, no technical staff was included among the inventors. This was (and is) especially applied to inventions covering consumer applications from which the principal investigator wishes not so much to earn a profit, but scientific credit through widespread (unrestricted) application. By excluding other research team members from the patent, the principal investigator retains as much control as possible over licensing practices and development.

3. "Non-faculty career". In this model patenting is seen as a reputational asset for non-faculty careers, inside or outside universities, to be left entirely with technicians and laboratory engineers, and not appropriated by academic scientists

4. "Fair share". In this model, which has seen increasing diffusion over time, the patented invention relates directly to the results of basic research, and all the research team members are seen as entitled to the economic and reputational benefits that may derive from it (notice that, given the patent matter, inventorship attribution brings scientific credit).

Colyvas and Powell (2008) have produced some quantitative evidence on the distribution of inventorship credits between faculty and technical staff at Stanford over the years, which resulted from the relative importance given to the four models. They find that the faculty's inventorship

share (measured as the percentage of inventors listed on the patent disclosures filed at Stanford technology transfer office) has risen from around 30% in the 1970s to almost 50% in the 1990s, while the laboratory technicians' share has collapsed from 46% to 11% over the same years (the other shares being those of students and scientists from other universities or from companies). Overall, these results suggest that inventorship distribution in university settings does not descend uncontroversially from the legal definition of inventor, but from complex attribution criteria depending on the contents of the patented invention, the changing attitude towards inventorship as a reputational reward in the scientific community, and social norms regarding fairness and due concern for the technicians' careers.

3.2 Authorship-inventorship in patent-publication pairs

Scientific papers and patents differ widely in contents, since scientific publications describe a set of theories and/or experimental results, of which they emphasize the originality and neatness according to some rhetorical rules, while patents describe the features of a new product or process, of which they emphasize the novelty and utility by laying out a list of claims. However, in so-called "science-based" technologies and in engineering, it is often the case that a patentable advancement is also worth of publication in refereed journals. In this case, we may expect highly specific words to be present both in the patent and in the publications that report on the advancement. As a consequence, text analysis of patents and publications sharing at least one inventor/author may be revealing of the existence of some patent-publication pairs (PPPs).

A patent and a paper form a pair when the same idea is described to some extent in both documents, and at least one author and one inventor are the same person. This happens when a new scientific idea coincides with a solution to a technical problem and has some degree of industrial applicability. However, it may be that the two sets of authors and inventors differ, as when some authors of the paper are not listed among the inventors or vice versa. Measuring the extent and the reasons of such differences may cast light on the determinants of both authorship and inventorship attribution[4].

[4] The PPP methodology has also been applied to investigate the anti-commons effect of academic patenting. In particolar, Murray and Stern (2007 and 2008) compare 340 articles published in *Nature Biotechnology* between 1997 and 1999 with their authors' patents at the USPTO, ending up with 169 PPPs, all of them selected through careful reading of both types of documents. A previous study by Murray (2002) concerned a single patent-paper pair on tissue engineering in cartilage, which served as a case study on the co-evolution of scientific and technological networks.

The first paper based upon the PPP methodology was Ducor's (2000), who performed a manual search of various databases for proteins with specific genetic or aminoacid sequences, finding 40 pairs. in all but two of cases, Ducor's PPPs have more authors than inventors, with average figures respectively equal to 10 and 3. Ducor also finds that the position of an author in the by-line of the paper is indicative of the risk of exclusion from the patent run by the same author, with being the least at risk, followed by first ones. As an explanation for his findings, Ducor indicates the abuse of guest/gift authorship practices as well as the possibility of arbitrary exclusions from inventorship.

In Lissoni et al. (2013), we build upon Ducor's PPP methodology, but substitute the manual search procedure with an automated text-mining technique, with the aim of building a large sample, representative of different scientific fields. We focus on Italian academic inventors from the KEINS database (see Lissoni et al., 2006 and 2007), from the four disciplinary fields with the highest share of academic inventors over the total number of professors in the field; namely: Chemical Engineering (which includes technology of materials, such as macromolecular compounds), Biology, Pharmacology, and Electronics & Telecommunications, for a total of 308 academic inventors and 552 patents (see also Breschi et al. 2005, 2007). PPPs were then obtained by matching publication data from the ISI *Science Citation Index* for such academic inventors to their patents, on the basis of a comparison of the titles and abstracts of patents and publications through a variety of "co-word analysis" techniques (Leopold et al. 2004; Bassecoulard and Zitt, 2004). Time restrictions were also applied, so that no publication was selected for the matching exercise, which appeared in a journal more than two years before/after the priority date of the patent.

Table 2 shows that the average number of inventors per PPPs is on average between 3 and 4, while the number of authors is significantly higher (around 5). These results are indicative of the existence of a process of exclusion. They also suggest the existence of significant differences across disciplines, the average difference between the number of authors and the number of inventors being significantly higher than zero only in *Biology* and *Pharmacology*. In Chemical Engineering and Material Technology and Electronics & Telecommunications the average number of authors and inventors are roughly the same, and the median value of the difference across PPPs is equal to 0.

Table 2: Difference between number of authors and inventors in PPPs, by disciplines

	Average nr. of authors	MIN/MAX nr. of authors	Average nr. of inventors	MIN/MAX nr. of inventors	□ authors inventors (avg value)[(a)]	MIN/MAX □ authors inventors [(a)]	□ authors inventors (median)[(a)]
Pharmacology	6,47	2/14	3,75	1/10	2,71	-5/12	2
Biology	6,32	2/42	3,60	1/21	2,72	-18/37	3
Chemical Eng. & Materials Tech.	4,54	1/8	4,67	2/11	-0,13	-4/5	0
Electronics and Telecom	3,63	1/19	2,99	1/6	0,63	-3/16	0
ALL	5,00	1/42	3,36	1/21	1,64	-18/37	1

[(a)] These columns refers to average min max and median value of the difference between the nr. of authors and inventors in each PPP

Source: elaborations from Lissoni et al. (2013)

As for patterns of exclusion, these were examined by focussing only on PPPs wherein the authors of the publications were not listed in alphabetical order, and by adding to the available information on individual authors their stock number of publications at the date of the patent, and the year of appearance of their first publication, both derived from the ISI *Science Citation Index*. While an author's stock of publication can be taken as indicative of her academic status, the time elapsed between the patent date and the year of first publication is a proxy of the author's seniority.

With these data in hands, we then proceeded to estimate the "risk of exclusion" of an author of a publication in a PPP from the patents included in the same PPP, as function of the position of the author in the publication by-line (first or last vs. middle positions), her seniority , gender and a number of controls such as the time distance between the patents and the publications in the PPP (as a proxy of overlapping between the two), as well as field, time, and journal dummies.

We found that both first and last authors have a significantly lower probability to be excluded from inventorship than middle authors. Contrary to Ducor, we find that first authors' probability of exclusion is lower than last authors'. We also find that the probability of exclusion is significantly lower the higher the author's seniority. In particular, a ten year increase in seniority decreases the probability of exclusion of a first authors by approximately 0.16, and by approximately 0.13 for a last author. This is in line with the view of first authors as those who contribute more, and more creatively, to the publication. It is also in line with the view that the last authors have contributed to the publication more than the middle authors. However, the contribution is lower than that of

first authors, a fact which is reflected in their comparatively higher probability of exclusion from the patent. Thus, seniority gives some bargaining power that allows any author to be granted inventorship even if he or she contributed less. Put differently: given the same contribution to the publication, a junior scientist is more at risk of being excluded from the patent.

We interpret these results as a confirmation that inventorship attribution cannot be entirely explained by a scientist's contribution to a research project, as it should be according to the rule of law. Seniority matters, in the sense that junior colleagues are more at risk of exclusion even when they contribute the same as the senior ones. Room for abuse and litigation is likely to exist, as first suggested by Ducor (2000). At the same time, the frequent exclusion from inventorship of authors listed in between the first and last position of a publication by-line provides one more hint at the possible existence of widespread practices of guest and gift attribution, as discussed above.

More recently, Häussler and Sauermann (2013) for a sample of British and German life scientists, do not find any evidence of a relationship between the distribution of attribution rights and gender, while finding some for seniority. They also compare the behaviour of industry scientists to that of academics, and find no substantial differences.

4. Conclusions

In this paper, we have discussed and then explored the determinants of inventorship attribution in academic patents, and compared them to those of authorship attribution. Our results are both of practical and of theoretical interest. They reinforce mounting doubts on the efficiency of current reputational systems in science, especially in the medical field. They also send a word of caution to all policy makers who are currently pushing for linking the distribution of research funds to automated or quasi-automated bibliometric assessments of scientific productivity, since such exercises rely too heavily on the questionable concept of authorship for being accepted as sensible solutions to the complexity of the economics of science.

Facing the changing realities of scientific conduct, the increased range of activities that contributes to successful discoveries create tensions and paradoxes within laboratories and research groups (Laudel, 2002; Hackett, 2005). Larger research groups challenge not only the current notion of authorship but all the standards used for credit allocation and personnel evaluation. We believe that an in-depth discussion of mechanisms such as contributorship, stronger rules in terms of acknowledgement and more explicit guidelines or ethical codes would

help to improve the allocation of scientific credit and the efficiency of the labour market of scientists.

On the theoretical side, the literature we surveyed contributes to the criticism of the economic and social value of the concept of authorship, and extends it to that of inventorship. With the transformation of science into a collective enterprise, a loss of correspondence between individual papers and authors has arisen, so that the concept of authorship has become increasingly problematic. Far from being self-evident, authorship is the result of a complex web of social and legal conventions, some of them dating back to XVIII century, when scientists had to carve a role for themselves in society, and were keen on building a public image of the researcher as an heroic individual (McSherry, 2001; Galison, 2003). While academic science still cherishes the idea that the scientific discovery is the result of an individual's spark of genius, other fields of human creativity have abandoned that idea (Fisk, 2006). In fields such as movie-making, for example, it is taken for granted that a division of labour exists between the various professional figures, so that specialized credits are awarded to each of them (directors, screenwriter, choreographers, sound makers….); at the same time, some ranking within the same professional categories is allowed (director, assistant director....). As mentioned in section 2.1, some steps in the same direction have been undertaken by a few scientific journals (e.g. JAMA, The Lancet, British Medical Journal and Radiology), which now require contributors not merely to identify themselves as "authors", but also to specify the exact contents of their contribution (see Table 1). Social and economic conventions in science, however, have not yet fully incorporated and elaborated upon this tendency.

Patent laws may run into the same type of problems with the concept of inventorship. The legal figure of the inventor may also be an obsolete one, that dates back to a time – the XIX century - when the existence of patents had been put into question, and was defended by the creation of a public image of inventors as "heroes of the industrial revolution" and individuals whose rights ought to be defended (Machlup and Penrose, 1950; Long, 1991; Bracha, 2005; MacLeod, 2008). Recent critical revisions of the "myth of the sole inventor" have produced much historical evidence on: (i) the pervasive phenomenon of invention simultaneity (which occur when several inventors achieve independently the same result); and (ii) the importance of "collective innovation" processes, in which technologists and entrepreneurs give up patenting (or patent enforcing) and mutually disclose the details of their inventions in order to speed up cumulative technological change (Bessen and Nuvolari, 2011; Lemley, 2012). Such evidence question the

existing legal and economic rationales for the existence of the patent system, or at least for any call to strengthen it.

Our analysis suggests that, even in the absence of invention simultaneity or free sharing of knowledge, inventive activities, very much like scientific research ones, are increasingly based on division and specialization labour. While this observation may not challenge the overall rationale for patents, it calls into question the economic efficiency of the inventor concept. Inventive activity is the result of a large number of tasks that are distributed among several individuals in a team. In the absence of a specific recognition of the value of these tasks, team members may have too much latitude in negotiating how to share credit. Besides leading to possible abuses against weaker team members, this latitude results in diffusing inaccurate or too vague information on the professional skills of inventors. In this respect, inventorship is plagued by the same problems that have long ago recognized to affect scientific authorship. The same steps taken to replace the latter with contributorship should be taken, with evaluation agencies taking an active role in promoting them.

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