# MISALLOCATION OF SCIENTIFIC CREDIT: THE ROLE OF HIERARCHY AND PREFERENCES. AN EXTENSION OF LISSONI ET AL. (2013)

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**Abstract** We extend the results in Lissoni et al (2013), which analyses the form of credit misallocation that occurs when the list of authors on a research output does not conform to the legal or social norms concerning scientific authorship and/or inventorship. Extending the analysis to European data, we confirm that, other things being equal, the probability of exclusion from inventorship declines with seniority and increases for women. In addition, we find that the senior scientists' power to exclude plays a more important role in explaining the patterns of exclusion than differences in authors' attribution preferences. The unfavourable treatment of young and female scientists emerges in particular when patents are owned by companies or individuals, thus providing a warning flag on those institutional arrangements that favour company or individual ownership of academic patents.

**Keywords:** economics of science; scientific credit; authorship; scientific misconduct; patent-publication pairs.

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## 1. Introduction

Once a classic topic in the sociology of science (Merton, 1968, 1988; Stephan 2012), scientific credit attribution has very recently come to the forefront of economic analysis (Bikard et al., 2015; Gans and Murray, 2014; Gans and Murray, 2013; Haussler and Sauermann, 2013; Lissoni et al., 2013; Gans et al. 2013; Biagioli 1998; Engers et al. 1999). This resurgence of interest follows the recognition that scientific research, as measured by scientific publications, is increasingly conducted by teams, rather than individuals, and that such teams have been increasing in size as well as organizational scope (Wuchty et al., 2007; Fortin and Currie, 2013; Wu et al., 2019). At the same time, though, individual scientists still feed their careers with personal credit, ultimately assigned by the authors of follow-up publications, by the funding agencies and their peer reviewers, and by perspective employers and consultancy services. All such third parties have a clear interest to assign credit to individuals when they deserve it (Li and Agha, 2015).

This note develops and extends the results contained in Lissoni et al (2013), who analyse a specific form of credit misallocation, namely the misalignment of scientific authorship and inventorship in patent-publication pairs (PPPs). Both authorship and inventorship can be conceived as 'attribution rights' (Lissoni and Montobbio, 2015), a form of intellectual property recognized both by the social norms of science (Merton, 1957) and by international conventions on "moral rights" of authors and performers (art. 11 in UNESCO, 2001; and art. 6 in WIPO, 2008). PPPs occur when the same research results, mostly obtained by universities or public research organizations (PROs), are both published in scientific journals and patented, with the scientists being both subject to some form of "publish-or-perish" pressure, but also engaged in the commercialization of their research results. Misalignment occurs when the lists of authors and inventors, respectively on the paper and patent, differ and do not conform to the legal or social norms concerning attribution rights.

Early qualitative studies (Zuckerman, 1968) and more recent, survey-based quantitative evidence (Flanagin et al., 1998) suggest that the misallocation of scientific credit is quite pervasive. Both instances of "guest" and "ghost" authorship are frequent, as when, respectively, the list of authors include scientists who have not really contributed to the paper, or it does include a significant contributor.

As for inventorship, it is generally found that authors of publications in PPPs generally outnumber inventors of related patents, so that some research team members are attributed authorship, but not inventorship (Haeussler and Sauermann, 2013, Lissoni et al., 2013). *Per se*, this is not evidence of mis-attribution, since norms for assigning inventorship are stricter than for those concerning authorship (most importantly, inventors qualify as such when contributing both the conception and reduction to practice of the inventive idea; Lissoni and Montobbio, 2015). But evidence of mis-attribution arises when it is found that the exclusion from inventorship is not decided on the basis of individual contribution to the invention, leading to "ghost" inventorship. In particular, based on a sample of 680 PPPs produced by 308 Italian academic inventors, between 1975 and 2002, Lissoni et al. (2013) find that first and last authors of the scientific papers are less likely to be excluded from the corresponding patent than middle authors. This is expected, since the prevailing social norms would prescribe the chief of lab (or the principal investigator of the specific project) to take the last position, and the team member who has contributed the most to the research to take the first one. At the same time, though, Lissoni et al. (2013) show that, *ceteris paribus*, junior and female scientists are more likely to be excluded from the patent, which is evidence of unfavorable treatment in credit allocation.

The primary goal of this note is to disentangle the relative importance of the two mechanisms put forth by Lissoni et al. (2013) to account for their results, namely the chief of lab's or principal investigator's *power to exclude* other research team members from inventorship (as well as to assign positions in the authors' byline), and on the *relative preferences* for authorship and inventorship of senior vs. junior scientists. In addition, we extend Lissoni et al.'s (2013) results beyond the Italian case, by considering also Austria, France, Germany, Spain, Sweden and the UK. We also provide new evidence on exclusion from inventorship as we consider (1) the characteristics of the project leader, in particular gender and seniority of the last author, and (2) the institutional and cultural characteristics that differ across countries. The theoretical framework and the hypotheses are developed in Section 2. Section 3 presents the data, while the results are reported in Section 4. Section 5 concludes.

## 2. Theoretical framework and suggested hypotheses

### *2.1 The determinants of ghost inventorship: disentangling the mechanisms*

Lissoni et al. (2013) develop a theoretical model, which rests on the assumption that research, especially in the hard sciences and technology, is a team-based activity (Wuchty et al., 2007) and that team members both contribute differently to the research effort and differ in terms of seniority. This implies that two mechanisms for the distribution of attribution rights are *simultaneously* in place, both of which may eventually lead to excluding from inventorship of team members who, based on their relative contribution to included ones, would have otherwise deserved inclusion.

The first mechanism derives from the association of seniority with authority, by which one or more senior scientists take a number of decisions on behalf of the entire team, including the distribution of attribution rights. This implies both deciding the position of authors in the paper's by-line and a discretionary *power to exclude* other team members from inventorship, thus obtaining an allocation of attribution rights that is more favourable to them than what the legal norms would prescribe.

Senior scientists derive their authority from their more established position (e.g. tenure or full professorship) in the university of affiliation, as well as their superior reputation, social connections, and access to funding sources, all of which place them in positions such as chief of lab, project leader, or principal investigator. Moreover, junior scientists may be reluctant to enter into conflict with their team seniors, given the role they can have in their careers (Pezzoni et al., 2012).

The second mechanism is based on the *relative preferences* for authorship and inventorship associated to various degrees of seniority, and in the particular on the assumption that junior scholars need high visibility as authors if they wish to undertake an academic career, while they may lack the time and social capital that are necessary to commercialize a patent. Thus, they may be ready to trade inventorship for first authorship, that is accept exclusion from the list of inventors in a patent, in exchange for a more prominent position in the paper. The same argument may apply to female scientists, who, as the literature recognizes, share some of the junior scientists' difficulties when it comes to commercializing their research results (Ding et al., 2006; Murray and Graham, 2007). On the contrary, senior scientists may attach more importance to inventorship, as they are willing to "cash in" their reputation or increase their outside visibility as technologist, an objective for which they can also have better connections.

While Lissoni et al. (2013) provide a theoretical distinction between the two exclusion mechanism, they do not test them separately. However, each mechanism in isolation would suffice to lead to patent exclusion, albeit with different consequences for the stability of the team.

Absent the seniors' power to exclude, senior and junior (or female) scientists could still agree on an allocation in which the junior (female) scholar is excluded from the patent in exchange of a prominent position in the paper, which should go instead to the senior member himself or another team member. On the other hand, the power to exclude may trump the junior and female scientists' preferences. Suppose the latter to be the same for all scientists, irrespective of seniority, with all team members caring much more for inventorship than first authorship (contrary to the assumption in Lissoni et al., 2013). It can be shown that junior and female scholars might still be excluded from inventorship, when litigation costs are large enough (see the Supplementary Material, Appendix A, for a formal proof.).

Disentangling the relative importance of the two exclusionary mechanism becomes then an empirical question, which we tackle in two ways.

In the first exercise, we identify a context in which the seniors' power to exclude is comparably lower. To this aim we exploit information on the institutional ownership of the patents, by arguing that patent ownership can play a role in the negotiation of attribution rights within the team. In particular, we distinguish between business firms and universities, both of which can be in the position of applicants for academic patents. We assume that the involvement of a university as patent applicant could favour the team members with lower bargaining power, by reducing their "litigation costs". This may happen as long as information about the relative contribution of each scientists is at least partially disclosed during the negotiation, and the university cares not just for the profits or visibility it may derive from the patent, but also for the welfare of agents with limited bargaining power. The same argument, to a large extent, may apply to patents owned by PROs. Companies, instead, are presumably less involved in the negotiation process among team members (especially those from the university). Most likely, they interact exclusively with the senior scientists, and are possibly less concerned with the welfare of scientists within the team. The same argument holds, *a fortiori*, for patents owned by individuals, who are most likely to coincide with the senior scientists.

For that reason, we run separate regressions for patents owned by companies or individuals and patents owned by universities or PROs. Finding similar results for the two samples, under the assumption that litigation costs differ across the two scenarios, would downplay the importance of power-based mechanism versus preference-based mechanism. On the contrary, if the unfavourable treatment of junior and female scientist in the allocation of inventorship right is significantly weakened in the case of patents owned by universities and PROs, we would interpret this result as evidence that a significant power to exclude is in fact an important condition to produce the observed patterns of exclusion.

Therefore, we bring theory to the data by looking for evidence for supporting, or discarding, the following hypothesis:

*H1: The probability of exclusion from inventorship of young and female scholars is reduced in contexts where the seniors' power to exclude is limited, such as when patents are owned by a universities or PRO.*

As a second exercise, we restrict the analysis to patents of high economic value. This is the case in which presumably all team members would prefer inventorship, matched to a less prominent position in the paper, rather than a leading position in the authors' by-line with exclusion from the corresponding patent. In this case, finding no difference in the results compared with the baseline model would downplay the importance of preference-based mechanism, since in this sample unfavourable treatment for juniors and women can only attributed to the seniors' power to exclude. In addition, for high value patents, we expect a higher probability that middle authors are in fact included in the patent, since team members may be generally reluctant to give up inventorship.[1] Therefore, we look for evidence for supporting, or discarding, the following hypothesis:

*H2: The probability of exclusion of middle authors is reduced when the patent value is high.*

### *2.2. The determinants of ghost inventorship: last author's characteristics and institutional and cultural factors*

Based on additional implications of our formal model and cross-country heterogeneity in our data set, we can formulate some additional hypotheses on how the characteristics of the chief of the lab or principal investigator (identified as the last author), as well as of institutional and cultural factors, may affect our main results.

The first two hypotheses concern the role of seniority. For the allocation of attribution rights, what matters is the *relative* bargaining power in the negotiation. When the last author is relatively young, his/her ability to extract rents from the other members of the team (e.g. by threatening careers opportunities) will be low, compared to the case of senior leaders. This leads to propose the following hypothesis:

*H3 When the last author is relatively young, the probability of exclusion of the other authors, and of the first author in particular, is smaller compared to the case where the last author is senior.*

The bargaining power of senior scientists vis-à-vis the junior ones depends on how much the latter's career depends on their seniors' decisions. This may vary across academic systems. Highly regulated systems, such as those in which academics have the status of civil servants and accede to tenured positions through public examinations, tend to give more power to senior scientists, who are disproportionately represented in the examination committees. This power increases when these systems, due to under-funding or political mismanagement, alternate long periods of "draught" (during which no examinations take place and recruitment into tenured positions is effectively stalled) to sudden recruitment "waves" (with examinations

[1] See the Supplementary Material, Appendix A, for a formal proof.

taking place to absorb the long queues of academics-in-wait that has formed during the draught). For instance, Pezzoni et al (2012) show that scientists' political capital, as captured by social ties to senior scientists, affects the probability of promotion in Italy, but not in France. Using Italian data, Bagues et al. (2015) confirm the importance of social connections. Zinovyeva and Bagues (2015) provide similar evidence for Spain. Therefore, we put forward the following hypothesis:

*H4 The probability of exclusion varies across countries, in accordance with the senior scientists' role.*

In particular, among the countries in our sample, we expect Italy and Spain to stand out as those in which the power of exclude is the highest, and our results the strongest.

The final set of hypotheses derives from a new feature of our extended model, with respect to Lissoni et al. (2013), concerning the propensity to comply with norms. Such propensity - in particular the one of the leading scientist to include their colleagues in patents when they deserve it - may depend on their identity and cultural attitude. In particular, we focus here on the gender dimension. First, we suggest that the pattern of exclusion may be affected by same-sex preferences. For example, in the context of public examination committees in Italy between 2008 and 2011, De Paola and Scoppa (2015) find that candidates whose gender is represented among the evaluators stand higher chances to pass. Casadevall and Handelsman (2014), by analyzing 460 symposia involving 1,845 speakers in two large meetings sponsored by the American Society for Microbiology, find that having at least one woman member of the convening team has a positive impact on the proportion of invited female speakers.[2] Therefore, we formulate the following hypothesis:

*H5 Male authors have a lower probability of exclusion than female authors when last authors are male, and female authors have a lower probability of exclusion than male authors when last authors are female*

Finally, European countries differ in their attitudes towards the role of women in the workplace and in the society. In particular, there is evidence that Mediterranean countries (Italy and Spain in our sample), and their males in particular, still retain a traditional view of gender roles, compared to other European countries (Glick et al., 2000; European Commission, 2013) and this may have an impact in economic settings, such the labour market (Fortin, 2005). Indicators using data from the European Values Studies have been used in sociological studies to measure gender role attitudes. For instance, Arpino et al. (2015), among others, used the answer to the question "When jobs are scarce, men should have more right to a job than women". To that question, the rate of positive answer is low for Scandinavian countries (including Sweden – where only 4,12% agree with this claim), and high for Mediterranean countries (Italy – 30,02%; Spain 23,42%, but also France – 21, 34%).[3] Putting together the various pieces of evidence, we formulate the following hypotheses.

[2] However, Bagues et al., (2017) found that female evaluators are not significantly more favorable toward female candidates in the case of Italian and Spanish national evaluation process, with the exception of evaluation for full professor in Spain. Their results is line with the so called "queen bee" hypothesis, for which women leaders in male-dominated contexts tend to reproduce rather than challenging existing gender hierarchies (Derks et al., 2016).

[3]Percentages refer to longitudinal dataset referring to the four EVS waves occurring between 1981 and 2008 (http://www.europeanvaluesstudy.eu/). Other questions can be used to measure gender attitudes. While using different indicators does not provide consistent ranking, a country like Italy is most often in the first positions. For instance, 57.84% of Italians in the dataset believe that "A woman has to have children to be fulfilled", a percentage which is inferior only the French data in the countries of our sample.

*H6 The probability of exclusion of female scientists also differ across countries, along with differences in gender roles.*

Again, among the countries in our sample, we expect Italy and Spain to stand in this respect.

## 3. Data and model

Our database contains patents and publications by academic scientists in Austria, Belgium, Spain, France, Italy, Sweden and the UK. We use identify instances of "double disclosures" (Murray and Stern, 2007), in which authors of the publications and inventors of the patents can be compared. Patent data come from the APE-INV database, which contains information on around 9000 EPO applications filed between 1997 and 2007, with at least one academic scientist designated as inventor, and a variety of applicants. For all the inventors on each patent we collected publication data from the Web of Science, for a time range starting two years before the focal patent's priority year, and ending two years after. We identify PPSs by matching patents and publications on the basis of text analysis of their titles and abstracts. After eliminating stop words, we transformed each patent and publication into a vector of words and calculated, for each possible patent-publication pair, a cosine index of similarity. By setting a very high similarity threshold, we ended up retaining 1154 patents and 2299 publications involved in at least one "double disclosure" instance. Due to several cases of N-to-M matches (N patents, M publications), these patents and publications patent-publications form only 952 sets (PPSs), each of which concerns one or a few inventions stemming from the same research project and team, and disclosed both through patents and publications (all the publications where the authors are listed alphabetically and those with a number of authors smaller than the total number of inventors are excluded: for a complete description of the dataset and the methodology used to build it, see the Supplementary Material, Appendix B). We then focus on the authors of the scientific papers in our sample, who may be either an active member of the research teams behind the paper or simple guests (we do not consider, because we cannot observe them, the ghost authors that belong to the team but do not appear on the paper). In particular, we estimate the probability of each author in our sample not to appear as inventor of any patent connected to his/her publications (exclusion from inventorship), as a function of his/her characteristics as well as those of other authors and of the institutional context.

For each author $i$ and PPS $j$ we know whether he/she is excluded or not from the patents related to PPS $j$. Our dependent variable $y$ is the exclusion event, with $y_{ij}= 1$ if author $i$ of a publication in $PPS_j$ is excluded from the inventorship of a patent in the same PPS, and $y_{ij}= 0$ otherwise. $\Pr(y_{ij}= 1 | x)$ is the probability that author $i$ is excluded from a patent in $PPS_j$, conditional on a set of variables $\mathbf{x}$. The main explanatory variables are:

- The position of the author in the publication's by-line, namely: *first*, *middle*, *last*; where *middle* indicates any position in between the first and the last author, and is the reference case. Having excluded from our sample all papers whose authors are listed alphabetically, we interpret such positions as indicative of the role attributed to teams members with the respect to the production of the paper.

- *female*, which indicates the author's gender. We interact it with the author's position in the by-line, with male middle authors (*male middle*) as the reference case.
- A continuous measure of *relative scholarship*: $\frac{stock_{ik}-\min(stock_k)}{\max(stock_k)-\min(stock_k)}$, where $stock_{jk}$ is the number of publications by co-author *i* at the time of paper *k* and *min(stock$_j$)* [*max(stock$_j$)*] is the minimum (maximum) value for the same variable among those of all co-authors of paper. This measure ranges from 0 (for the bottom scholar) to 1 (for the top scholar).[4]
- *most_junior*, which takes a value of 1 for the co-author whose first publication is the most recent one (all other cases as references).

Our control variables are: the time lag between the patent and the publication, the level of similarity between the patent and the publication, the number of authors in the publication, the number of inventors of the related patent, the technological field dummies, the country dummies of the academic inventor in the patent (see the Supplementary Material, Appendix B, for exact variables definition and summary statistics).

In order to test H1 and H2, we introduce additional characteristics of the PPSs. In particular we take into account the institutional ownership of the patents and the economic value of the patents in the PPSs, measured by the length of patent renewal[5]. So we run separate regressions for patents owned by companies and individuals and patents owned by universities (and PROs), and a set of regressions restricted to the sample of PPS with higher patent economic value. "High value" PPSs are defined as the ones that have the length of patent renewal above the average. To test H3 and H5 we perform separate analysis by distinguishing for the seniority and gender of the last authors and, finally, we run a set of regressions interacting country dummies with seniority and gender, in order to test our hypothesis H4 and H6.

## 5. Results

*5..1 Understanding the mechanism behind exclusion: testing H1 and H2*

Table 1 and Table 2 report the results of various specifications, all estimated with OLS (Linear Probability Model).[6]

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[4] A second measure *(relative_seniority)* considers each co-author's date of first publication, distinguishing the most junior co-author, whose first publication is the most recent one, from all the others. This measure is used to calculate the dummy *most_junior*, for which *relative_seniority* is equal to zero. The two measures capture different aspects of seniority: the former measures experience in publishing, and may be relatively high for a young researcher with an intense publishing activity; the latter is a better proxy for age, as with an aged co-author with few publications (for example a laboratory technician occasionally rewarded with authorship). In the regression we have decided to include *most_junior* and *relative_scholarship*. Including relative seniority instead of relative scholarship has no impact on the regression results.

[5] The OECD patent renewal indicator corresponds to the simple count of years during which a granted patent has been kept alive, i.e. the latest year in which it has been renewed or until it has lapsed or has been withdrawn (OECD, 2013). Years are counted starting from the year in which a patent has been applied. We also have performed a set of robustness checks using the technological value of patents. We used the number of forward citations and the number of claims (with a 5-year and a 7-year window after the priority date) and the number of claims (OECD,2013; Lanjouw and Shankerman, 2004; Haroff et al. 2003).

[6] In all regressions standard errors are clustered by PPS. The table with full results is reported in Appendix C of the Supplementary Material.

[Table 1 about here]

[Table 2 about here]

First of all, we are able to reproduce the original results of Lissoni et al. (2013) in our enlarged dataset. The explanatory variables that point at a potential mis-attribution of inventorship allocation are the seniority and gender of authors. As for seniority, columns (1), (2) and (3) of Table 1 show that, as expected, the coefficient of *relative_scholarship* is negative and the coefficient of *most_junior* is positive. Both of them are statistically different from zero. Column (2) shows that female authors have 6% more probability to be excluded from inventorship, *ceteris paribus*. The number of observations drops when moving from column (1) to column (2) and (3), due to the inclusion of gender among regressors, for which we have missing observations.

In column (3) of Table 1 and in columns (1) and (2) of Table 2, we interact gender and seniority with position. In principle, the higher probability of exclusion for *female* and *most_junior* could be explained by the heterogeneity of the *middle* position. When considering authors in intermediate position in the article by-lines (*middle*=1, which is the omitted reference case) we cannot measure their relative contribution to the research effort, because the exact position in the by-line (second rather than third or fourth, but in any case, never last) is not informative. So, if women and junior scholar perform less important tasks when they are middle authors, their exclusion from the patent could be motivated not by gender or seniority *per se*, but by their lower contribution. Results in Column (3), however, prove that this is not the case. The estimated coefficients for male and female first authors significantly differ: in particular, male first authors have a lower probability of exclusion than female ones, while female first authors are as likely to be excluded as male middle ones (their estimated coefficient not being significantly different from zero). The same type of result occurs also for junior scholars, as reported in Table 2: non junior first authors have a lower probability of exclusion than junior ones (note that there can be more than one most junior author in the same publication, because seniority is based on the year of the first publication).[7]

In order to test hypotheses H1 and H2, Table 1 reports the results of the baseline model, but distinguishes between PPSs in which all patents are owned by companies or individuals (column 4) and PPSs in which at least one patent is owned by a university or PRO (column 5). The two sub-samples are of similar size. The results in column (4) are very similar to the results obtained in the full sample, especially in terms of the magnitude of the coefficients and the significance of the variables associated to gender and seniority. In column (5), instead, we observe that the dummy variable *female first* turns out to be negative and significant, which means that female who are first authors have a lower probability of exclusion that male middle authors, as expected in light of their superior contribution. At the same time, the coefficient for the dummy variable *most_junior*, while significant in the full sample and for patents owned by companies or individuals, becomes insignificant in the university and PROs sample. Similarly, Table 2 (columns 3 and 4) shows that junior scholars, when first and last, are systematically less excluded when the patent is owned by a university of by a PROs. Therefore, the empirical evidence supports H1, suggesting that the chief of lab's or principal

[7] Appendix D in the Supplementary Material reports an extensive set of robustness checks.

investigator's power to exclude is a key explanation of our results. In other words, differences in team members' preferences cannot explain alone the observed patterns of exclusion.

To test H2, we run a set of regressions, equivalent to those in columns (1) to (3) in Table 1, but restricted to the sample of PPSs with high patent value. Results are reported in Table 3.

[Table 3 about here]

By comparing Table 3 and 1, we find that coefficients for *first* and *last* are very similar and the results concerning our variable of interest (seniority and gender) are broadly consistent with the results in the baseline model, in that junior and female scholars have a higher probability of exclusion (although the significance of *most_junior* is lost in Table 3 when the measure of patent value based on the years of renewal). The estimated coefficients for male and female first authors significantly differ: in particular, male first authors have a lower probability of exclusion than female ones. The same gender difference in the probability of exclusion takes place for middle authors. In line with the discussion in Section 2.1, we interpret this result as evidence that the senior's power to exclude plays a relatively more important role in the explaining the results.

*5.2 Impact of last authors' characteristics: testing H3 and H5*

In this section, we discuss the impact of the last authors' characteristics on patent exclusion (H3 and H5). The full details, including tables, are reported in the Supplementary Material, Appendix E. First of all, our results show that in the projects where last authors are all juniors, junior first authors are less likely to be excluded, relative to the projects where last authors are all seniors. Therefore, H3 is confirmed. Conversely most junior authors seem to be mostly penalized when there is a complex composition in the PPSs (some last authors are junior, some are not, which occurs typically when PPSs are composed by many publications and many authors).

As for the impact of last authors' gender, when last authors of all the publications in the PPS are male, female ones are significantly more excluded, regardless of their position in the by-line. In projects where all last authors are women, no significant difference is detected between male and female scholars, thus providing partial support to H5. Bearing in mind that last authors are presumably the chiefs of labs or principal investigators, who play a crucial role in the decisions on attribution, our results suggest that their characteristics have an impact on the probability of exclusion. On the one hand, when senior authors are male, they tend to show a lower propensity to exclude the scientists in their own category. On the other hand, the more senior they are, the more likely it is that junior scholars will be excluded, a result which we explain by referring to the higher bargaining power associated to seniority.

*5.3 Exploring institutional (and cultural) differences: testing H4 and H6*

In Section 2.2 we claim that cross-country institutional differences could impact on the pattern of exclusion (H4 and H6). First, we find that junior scholars are more likely to be excluded in Italy, relative to senior scholars, irrespective of the institutional arrangement concerning patent ownership (in Belgium this occurs only when patents are owned by companies or individuals). The effect for Spain is very small and cannot be considered significantly different from zero. No other country differences are detectable. Therefore, we find only very limited support for H4 (full details in the Supplementary Material, Appendix E).

As for the interactions country-gender, we find that women are more likely to be excluded relative to men in particular in Spain and Italy, in accordance with H6. However, we find a higher level of exclusion also in France, for patents owned by universities and PROs and in the total sample, and in Belgium, but only when patents are owned by companies or individuals.

## 6. Conclusions

Individual scientists increasingly obtain their scientific credit by contributing to collective, team-based research. This raises difficulties with attribution rights, both because assigning research results to different team members becomes inevitably harder, and because team members may engage in negotiations that result in a departure from accepted legal or social norms of attribution. We have tackled this problem by documenting one specific case of mis-attribution, in which some research team members contributing to a published research results are denied inventorship in a related patent (exclusion from inventorship). Our findings provide several insights on how the specific characteristics of teams (affecting the internal hierarchy and decision-making) may interfere with the legal and social norms that prescribe attribution to be entirely determined by contribution.

Extending Lissoni et al. (2013) to European data, we have provided evidence of unfavourable treatment in credit allocation for junior scholars and female scientists. In addition, the senior scientists' power to exclude appears to be a more important factor than differences in preferences over patents and publications in explaining the patterns of exclusion. From the welfare point of view, this result suggests that the misallocation of credit is not only detrimental for third-parties using attribution rights as signals, but also for those scientists which are excluded from the patent.

On the policy side, our results suggest that the national evaluation agencies (such as the English UKRI, the Italian ANVUR, or the French HCERES) should be wary of treating bibliographic information as an objective measure of contribution to research and invention, especially because we suggest an unfavourable treatment for scientists who are typically in a weak position (junior and women). The same applies to university administrators, when they decided to distribute rewards for authorship and inventorship not just to teams or collections of teams (such as departments or faculties), but to individuals therein. At the same time, our results suggest that the direct involvement of universities and public research organization in the negotiation process may in fact mitigate the misallocation of attribution rights, by limiting the power of senior scientists. Different European models of academic patenting and technology transfer by universities may have an effect on the size of inventorship misattribution. In fact, the unfavourable treatment of young and female scientists emerges when patents are owned by companies or individuals. Our results provide a warning flag on those institutional arrangements that favour company or individual ownership of academic patents. This effect can be considered along others factors that determine the relative efficiency business vs university ownership of academic patents (Kenney and Patton, 2009).

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**Table 1. Dependent variable: probability of exclusion from inventorship in the PPS (OLS estimates)**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Full sample | With gender | Gender + position | Company and individuals | University and PROs |
| First | -0.14*** | -0.13*** | | | |
| | (0.028) | (0.031) | | | |
| Last | -0.21*** | -0.19*** | | | |
| | (0.025) | (0.026) | | | |
| Female | | 0.06*** | | | |
| | | (0.016) | | | |
| female middle | | | 0.06*** | 0.05** | 0.06*** |
| | | | (0.014) | (0.021) | (0.018) |
| male first | | | -0.16*** | -0.13*** | -0.20*** |
| | | | (0.038) | (0.044) | (0.053) |
| female first | | | -0.04 | -0.02 | -0.08** |
| | | | (0.031) | (0.043) | (0.040) |
| male last | | | -0.19*** | -0.18*** | -0.20*** |
| | | | (0.029) | (0.041) | (0.030) |
| female last | | | -0.16*** | -0.17*** | -0.15** |
| | | | (0.041) | (0.049) | (0.071) |
| relative_scholarship | -0.41*** | -0.40*** | -0.40*** | -0.37*** | -0.45*** |
| | (0.036) | (0.043) | (0.043) | (0.058) | (0.063) |
| most_junior | 0.05*** | 0.05*** | 0.05*** | 0.07*** | 0.02 |
| | (0.014) | (0.017) | (0.017) | (0.017) | (0.026) |
| Constant | 0.89*** | 0.73*** | 0.73*** | 0.75*** | 0.76*** |
| | (0.052) | (0.071) | (0.071) | (0.099) | (0.103) |
| All other controls included | Y | Y | Y | Y | Y |
| Observations | 14,244 | 9,141 | 9,141 | 4,762 | 4,379 |
| R-squared | 0.216 | 0.238 | 0.239 | 0.214 | 0.283 |
| F-test | 106.4 | 70.74 | 67.35 | 43.45 | 55.07 |

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

**Table 2. Seniority and position in the by-line (OLS estimates). Dependent variable: probability of exclusion from inventorship in the PPS. Columns (3) and (4): specifications by ownership of the patents in the PPS.**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | all_countries | all_countries + gender | Company and individuals | University and PROs |
| junior middle | 0.05*** | 0.06*** | 0.07*** | 0.03 |
| | (0.017) | (0.019) | (0.021) | (0.024) |
| first (non junior) | -0.14*** | -0.13*** | -0.11** | -0.17*** |
| | (0.033) | (0.036) | (0.048) | (0.043) |
| junior first | -0.10*** | -0.09** | -0.02 | -0.16*** |
| | (0.033) | (0.041) | (0.044) | (0.056) |
| last (non junior) | -0.21*** | -0.19*** | -0.18*** | -0.19*** |
| | (0.029) | (0.028) | (0.041) | (0.030) |
| junior last | -0.22*** | -0.19*** | -0.15* | -0.26*** |
| | (0.053) | (0.059) | (0.080) | (0.085) |
| Constant | 0.89*** | 0.73*** | 0.74*** | 0.75*** |
| | (0.051) | (0.071) | (0.099) | (0.102) |
| All other controls included | Y | Y | Y | Y |
| Observations | 14,244 | 9,141 | 4,762 | 4,379 |
| R-squared | 0.216 | 0.238 | 0.213 | 0.283 |
| F-test | 100.9 | 67.62 | 42.87 | 49.05 |

All others controls included in the regressions. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

**Table 3. Dependent variable: probability of exclusion from inventorship in the PPS. Specifications by economic value of the patents in the PPS (OLS estimates).**

| | (1) | (2) | (3) |
|---|---|---|---|
| | PPSs with patents high economic value (renewal) | PPSs with patents high economic value (renewal) | PPSs with patents high economic value (renewal) |
| First | -0.17*** | -0.17*** | |
| | (0.029) | (0.036) | |
| Last | -0.22*** | -0.21*** | |
| | (0.028) | (0.030) | |
| Female | | 0.09*** | |
| | | (0.020) | |
| female middle | | | 0.06*** |
| | | | (0.019) |
| male first | | | -0.22*** |
| | | | (0.047) |
| female first | | | -0.02 |
| | | | (0.037) |
| male last | | | -0.22*** |
| | | | (0.029) |
| female last | | | -0.12 |
| | | | (0.076) |
| relative_scholarship | -0.45*** | -0.44*** | -0.44*** |
| | (0.054) | (0.064) | (0.064) |
| most_junior | 0.02 | 0.02 | 0.02 |
| | (0.020) | (0.026) | (0.025) |
| Constant | 1.00*** | 0.95*** | 0.96*** |
| | (0.065) | (0.080) | (0.079) |
| All other controls included | Y | Y | Y |
| Observations | 5,914 | 4,124 | 4,124 |
| R-squared | 0.251 | 0.297 | 0.299 |
| F-test | 67.74 | 67.74 | 67.74 |

Robust standard errors in parentheses ; *** p<0.01, ** p<0.05, * p<0.