Research Policy 42 (2013) 688–703

Contents lists available at SciVerse ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Credit where credit is due? The impact of project contributions and social factors on authorship and inventorship

Carolin Haeussler[a], Henry Sauermann[b,*]

[a] University of Passau, Department of Economics and Business, Innstr. 27, 94032 Passau, Germany
[b] Georgia Institute of Technology, Scheller College of Business, 800 W. Peachtree St., Atlanta, GA 30308, USA

ARTICLE INFO

Article history:
Received 20 October 2011
Received in revised form 26 July 2012
Accepted 27 September 2012
Available online 6 November 2012

JEL classification:
O34
O31
L30

Keywords:
Guest authorship
Ghost authorship
Attribution
Social status
Project contributions
Patent–paper-pairs

ABSTRACT

We examine the extent to which different types of substantive project contributions as well as social factors predict whether a scientist is named as author on a paper and inventor on a patent resulting from the same project. Using unique survey data from over 2000 life scientists, we find that the predictors of authorship differ from those of inventorship. A wider range of project contributions may result in authorship, and social factors appear to play a larger role in authorship decisions than in inventorship decisions. We also find evidence that project contributions and social factors interact in predicting authorship, suggesting that the two sets of factors should be considered jointly rather than seen as independent determinants of attribution. In addition to providing novel insights into the functioning of the authorship and inventorship system, our results have important implications for administrators, managers, and policy makers, as well as for innovation scholars who often rely on patents and publications as measures of scientists' performance.

1. Introduction

The increasing specialization of scientists, the interdisciplinary character of scientific projects, and large resource requirements have turned science into a highly social and collaborative activity (Biagioli, 2003; Katz and Martin, 1997; Laudel, 2002; Wuchty et al., 2007). As a consequence, assessing what kind of substantive contributions listed authors and inventors have made to a project is becoming more and more difficult. Moreover, prior work suggests that authorship may not always reflect substantive contributions but may also be granted on the basis of social factors such as scientific eminence or hierarchical status in an organization (Birnholtz, 2006; Drenth, 1998; Flanagin et al., 1998; Mowatt et al., 2002; Rennie et al., 1997; Zuckerman, 1968). Far from being isolated incidents, such "guest authorships" may be involved in over 20% of papers in top biomedical journals (Flanagin et al., 1998; Wood, 2009). Studies also provide evidence of "ghost authorship", i.e., that individuals who have made important contributions are not included as authors (Flanagin et al., 1998; Laudel, 2002; Sismondo, 2009). While these issues have received considerable attention with respect to publishing, recent work suggests ambiguities in the relationship between substantive contributions and attribution also in the realm of patents (Lissoni and Montobbio, 2008; McSherry, 2003; Seymore, 2006).[1]

Despite significant efforts to document and quantify misattribution in the scientific community (Ducor, 2000; Flanagin et al., 1998; Mowatt et al., 2002), a more general understanding of the

---

* Corresponding author. Tel.: +1 404 385 4883; fax: +1 404 894 6030.
E-mail addresses: carolin.haeussler@uni-passau.de (C. Haeussler), henry.sauermann@scheller.gatech.edu (H. Sauermann).

[1] The terms "guest authorship" and "ghost authorship" invariably require the choice of a standard regarding which kinds of contributions should legitimately be rewarded with authorship. While formal standards have been specified by journal editors (see below), those standards may not be shared by all members of the community. The objective of this paper is not to categorize authorship practices as legitimate versus illegitimate, but to provide empirical insights into the types of contributions and social factors that lead to authorship and inventorship. While much of the use of the terms "guest" and "ghost" in the prior literature is based on formal guidelines as implicit standard, we remain agnostic as to whether there is an ideal standard and what it should look like. Regardless of the choice of standard, however, practices that violate a given standard undermine the functioning of the authorship system, as discussed in Section 2.1. In the final section of this paper, we will discuss mechanisms that may reduce some of the ambiguity inherent in the current system.

0048-7333/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.respol.2012.09.009

determinants of authorship and inventorship status is lacking. The key challenge in empirical work is that systematic information on the types and levels of individuals' contributions is often not available. The order of authorship provides some insights into relative contributions. However, the interpretation of authorship order is often ambiguous (Bhandari et al., 2003; Zuckerman, 1968) and it naturally is of limited use in trying to understand drivers of "ghost authorship". Second, much of the prior work has been concerned with publications and little is known regarding similarities and differences in the factors associated with authorship on publications versus inventorship on patents. It is conceivable that inventorship is defined more strictly than authorship, possibly leading to a stronger link between substantive contribution and inventorship attribution (Ducor, 2000). Finally, while a distinction has been made between substantive contributions and social factors as predictors of attribution, little attention has been paid to potential interactions between contributions and social factors.

We address these gaps using novel survey data on over 2000 life scientists working in Germany and the UK who participated in projects that resulted in both a patent and a paper ("patent–paper-pairs"). While many scientists were listed on the resulting patent as well as the paper, others were not. We relate authorship and inventorship status to scientists' types and levels of project contributions as well as to social factors. Since the publication and the patent are tied to the same project, we are able to directly contrast the determinants of authorship and inventorship controlling for the nature of the underlying research (cf. Ducor, 2000; Lissoni and Montobbio, 2008).

Our empirical findings suggest that substantive contributions as well as social factors significantly shape attribution patterns. However, the drivers of authorship differ from those of inventorship. More specifically, inventorship reflects primarily substantive contributions in the form of idea conception, while authorship may also reflect technical contributions and the provision of data or materials. Controlling for substantive contributions, prior scientific accomplishments strongly predict authorship but not inventorship, perhaps because an eminent co-author increases the chances of publication and visibility of a paper. Hierarchical status in an organization increases the likelihood of inventorship but not of authorship. In addition to the independent effects of substantive contributions and social factors, we find that the two sets of factors interact in predicting authorship: contributions in the forms of carrying out technical steps or laboratory work are more likely to be rewarded with authorship when made by scientists with higher hierarchical status or prior scientific accomplishments.

Our insights have important implications for institutional mechanisms that rely on a close link between substantive contributions and attribution, such as the reward system of science or the patent system as a mechanism to incentivize inventive effort. Our results also have important implications for social scientists who rely on patents and publications to measure constructs such as individuals' innovative performance (e.g., Levin and Stephan, 1991; Sauermann and Cohen, 2010), labor mobility across organizations or regions (e.g., Agarwal et al., 2009; Marx et al., 2009), or the composition of research teams (e.g., Bikard and Murray, 2011; Singh and Fleming, 2010).

In the following section, we briefly discuss the importance of authorship and inventorship and develop predictions regarding the influence of substantive contributions and social factors on the two types of attribution. In Section 3, we describe the data and measures. In Section 4, we discuss our main results as well as a series of auxiliary analyses and robustness checks. Section 5 provides a summary of the results as well as a discussion of implications and opportunities for future research.

2. Project contributions and social factors as drivers of attribution

2.1. The importance of authorship and inventorship attribution

Publications and patents are important elements of the institution of science and of national innovation systems. Their effective role in these institutions, however, depends on the degree to which authorship and inventorship attribution reflect substantive contributions to the production of new knowledge.

In the typical view of the institution of science, scientists share new knowledge in a timely manner with the community through publication. In return for their contribution, authors receive peer recognition, which in turn translates into additional benefits such as job security (tenure), higher salaries, funding for future research, or opportunities to monetize knowledge via consulting (Cole and Cole, 1967; Haeussler et al., 2011; Merton, 1973; Stephan, 2012). The important role of publications is reflected in notions such as "publish or perish" or of publications as a "currency" in the scientific community. Publications and the resulting indirect benefits thus serve as incentives to invest effort into the generation of new knowledge. At the same time, authorship also establishes responsibility and serves as a basis for sanctions in cases of scientific misconduct. Given these important functions, a weak link between substantive contributions and authorship can undermine incentives for research (Lane, 2010; Rennie et al., 1997) as well as the community's ability to enforce its norms and quality standards (Zuckerman, 1988).

Inventorship attribution on patents plays a similarly important role. In particular, inventors who are listed on the patent have the right to prevent others from using the invention and can typically secure a share of the financial value that might result from their work. Moreover, patents can be interpreted a sign of scientific productivity and may help the inventor to gain recognition in the professional community (Butkus, 2007; Dasgupta and David, 1987). These potential payoffs serve as an important incentive for research (Arora et al., 2008; Scotchmer, 2006). Flaws in the assignment of inventorship may thus directly affect the distribution of financial and nonfinancial returns and dilute incentives for future innovation. Moreover, in some countries such as the United States, patents with an inventorship defect may be invalid or unenforceable (e.g., Section 35 U.S.C. 102 (f)).[2]

2.2. Project contributions

Most scientific projects are collective efforts (Wuchty et al., 2007) and typically involve a division of labor. As such, different individuals are engaged in different (combinations of) tasks, such as the conception and design of the study, lab work and data acquisition, or the writing of the manuscript (Hackett, 2005; Latour and Woolgar, 1979; Laudel, 2002). Moreover, Latour (1987) reminds us that scientific activity is embedded in larger networks and that various external actors can also have positive (or negative) impacts

---

[2] Two common defects are "non-joinder" (individuals who should be listed on the patent are omitted) and "misjoinder" (individuals are listed but did not conceptually contribute). For example, in one case, Dr. Ellenbogen of American Cyanamid asked doctors at the University of Colorado to conduct a study on iron absorption for two prenatal multivitamin formulations. In the process, the CU scientists discovered a reformulation that increased absorption. The patent naming Dr. Ellenbogen as sole inventor was declared non-enforceable due to a non-joinder defect (see University of Colorado Foundation v. American Cyanamid, 342 F.3d 1298 (Fed.Cir.2003)). In another example, the court of Appeals of the Federal Circuit decided that a student who conducted experiments but neither discovered nor understood their underlying principle, is not an inventor (see Stern v. Trustees of Columbia University, 434 F.3d 1375 (Fed.Dir.2006)).

on the success of a particular research group. Which contributions to the development of a particular piece of new knowledge are rewarded with authorship may reflect both formal guidelines as well as informal norms and customs of the scientific community (Laudel, 2002). In the biomedical sciences, the most prominent formal guidelines are the recommendations by the International Committee of Medical Journal Editors (ICMJE). According to these guidelines,

> "*Authorship credit should be based on (1) substantial contributions to conception and design, 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. Authors should meet conditions 1, 2, and 3. Acquisition of funding, collection of data, or general supervision of the research group alone does not constitute authorship.*"[3]

Unfortunately, these guidelines are open to interpretation. Ducor's (2000) view is that the guidelines require that each author make a substantial contribution to the conception and design of a research project. Other scholars suggest that the conjunction "or" in (1) and (2) allows for a high degree of heterogeneity in the contributions of authors (Kwok, 2005; Lissoni and Montobbio, 2008). According to the latter interpretation, a conceptual contribution is not necessarily required and other types of contributions may also justify authorship.

Regarding informal practice, rich empirical studies of laboratory life suggest that authorship can be granted for a wide range of contributions, including those that are not conceptual in nature (Hackett, 2005; Laudel, 2002). In particularly interesting recent cases, authorship – using real names or a collective pseudonym – has been granted to non-professional "citizen scientists" who contribute to a research project primarily by collecting or coding data and typically have little understanding of the broader research project (for examples and a discussion, see Eiben et al., 2012; Lintott et al., 2009; Franzoni and Sauermann, 2012). While some of these informal authorship practices are inconsistent with formal guidelines such as those set by the ICMJE, they may reflect the increasing division of labor in science and the shared belief that even quite focused or unconventional types of contributions can be critical to project success and deserve recognition through co-authorship.

In contrast to the relatively ambiguous formal criteria for authorship, formal definitions of inventorship are clearer and are typically codified in law. In the USA, a person should be attributed inventorship on a patent if he or she has contributed to the conception of the invention (Section 35 of U.S.C. 102 (f)). A patent with an inventorship defect is invalid or unenforceable. The European Patent Convention states that "An invention shall be considered as involving an inventive step if, having regard to the state of the art, it is not obvious to a person skilled in the art" (Art. 56 European Patent Convention EPC 2000), suggesting that inventorship status requires a creative and constructive effort. In Britain, the "inventor" is defined as "the actual deviser of the invention" (§7–3 UK Patents Act, 1977). Thus, a conceptual contribution is generally the key requirement for inventor status. We are not aware of prior empirical work examining the relationship between inventorship status and different types of substantive contributions. However, we expect that inventor attribution is reserved primarily for significant conceptual contributions for two reasons. First, as just discussed, a conceptual contribution is quite clearly defined as a legal requirement and violating this requirement may invalidate the patent. Second, while additional co-authors on papers lead to only a relatively small reduction in recognition for existing authors (Maciejovsky et al., 2009), taking on "unnecessary" co-inventors comes at a considerable economic cost since a fixed amount of financial income from patents is typically shared among all listed inventors (see Harhoff and Hoisl, 2007).

In summary, we predict that conceptual contributions to a project increase the likelihood that the individual will be listed as an author on any resulting papers and as an inventor on any resulting patents. Contributions of a non-conceptual nature, e.g., routine technical work or the provision of materials and data may increase the likelihood of inclusion as an author but should not lead to the inclusion as an inventor.

2.3. Social factors

Even though authorship and inventorship are typically thought to reflect substantive contributions to a research project, prior evidence suggests that they may also reflect social mechanisms that are relatively independent of actual contributions. In the following discussion, we will focus on two particularly salient aspects: mechanisms related to scientists' hierarchical position in an organization and mechanisms related to scientists' prior scientific accomplishments.

A first set of mechanisms may relate to the fact that some scientists – such as laboratory heads – have authority over a number of other scientists who depend on them for direction, material resources, employment, and career advancement (Hackett, 2005; Latour and Woolgar, 1979; Stephan, 2012). Throughout this paper, we conceptualize a scientist's "hierarchical position" as the number of individuals over whom she has such authority. As such, a scientist's hierarchical position reflects a combination of her level in a formal group hierarchy and the size of the group, i.e., a given number of subordinates may result from a high level in a small organization or a lower level in a large organization. Regardless of actual project contributions, subordinates may include individuals in higher hierarchical positions as co-authors because they expect that doing so creates a good relationship with the supervisor, expresses respect and gratitude, strengthens the supervising efforts, or signals the laboratory head's approval of the content of the paper (Mainous et al., 2002; Owen-Smith, 2001; Slone, 1996; Tarnow, 1999). Stokes and Hartley (1989) as well as Ward (1994) report that in some institutions, the senior scientist in a laboratory is always listed as a co-author on all publications, independent of his substantive contributions. While these arguments imply that junior authors may decide to "give" guest authorship to superiors, it has also been suggested that some senior scientists use their power to more or less explicitly "take" co-authorship, in what has been called "coerced" or "abusive" co-authorship (Kwok, 2005).[4]

A second set of social mechanisms may lead to the inclusion of co-authors based on their prior scientific productivity and accomplishments. First, listing a highly respected scientist on the by-line may increase the chances that an article is published, e.g., because editors are more willing to work with accomplished scientists and have a greater trust in their ability to address reviewers' concerns (Biagioli, 2003; Davidoff, 2000). Well-known co-authors may also increase the legitimacy and visibility of a paper once published because other scientists use author names as a signal of quality when deciding which papers to read (cf. Merton, 1973; Simcoe and Waguespack, 2011). Similarly, co-authors with experience and a proven track record can provide advantages to the extent that the success of new ideas depends not only on idea quality but also on persuasion, subjective evaluations by the scientific community, and outsiders' assessment of the expertise of the authors (Collins and

---

[3] http://www.icmje.org/ethical_1author.html accessed June 29, 2012.

[4] Similar opinions have been expressed on blogs and websites such as http://coauthorship.com/.

Evans, 2007; Kuhn, 1962; Latour and Woolgar, 1979). Finally, some accomplished scientists may have an interest in further increasing their publication count by appearing as “guest authors”, especially if prior output reflects a strong individual-level taste for publishing and peer recognition (Stern, 2004; Sauermann and Roach, 2012). At the same time, these social mechanisms may be limited by potential costs. In particular, “guest authors” run the risk of diluting their reputation if publications turn out to be of low quality (Cole and Cole, 1967; Owen-Smith, 2001). There may also be significant costs of including “guest authors” from the junior scientists’ perspective if accomplished co-authors capture a particularly large share of the peer recognition due to the “Matthew effect” (Merton, 1973). Despite these potential costs, we expect a positive net effect of a scientist’s prior scientific accomplishments on authorship attribution, controlling for the focal scientist’s substantive contributions.

Even though much of the discussion on the role of social factors concerns the attribution of authorship on publications, social mechanisms may also play a role in the context of inventorship on patents. For example, Seymore (2006) reports that senior scientists are often the ones who decide whose name appears on the inventor list, which might result in superiors being overrepresented. Similarly, individuals in higher hierarchical positions may be included as inventors to facilitate internal reviews and approvals of patent applications within the organization. Consistent with these arguments, a recent study by Lissoni and Montobbio (2008) finds that the seniority of an author is positively correlated with the probability that he or she is also listed on the corresponding patent in a patent–paper-pair. Since prior work does not independently observe individuals’ substantive contributions, however, it remains unclear if senior scientists serve as “guest inventors” or if they make more important substantive contributions that should legitimately result in inventorship attribution.

Despite the possibility that social mechanisms play a role in inventorship, we suggest that this role is more limited than in the case of authorship. As discussed earlier, formal inventorship guidelines are more clearly (and legally) defined, and the costs of violating these guidelines are likely to be high. Moreover, it is unlikely that the above-mentioned benefits of including a senior co-*author* apply as strongly in the case of a senior co-*inventor*. For example, patent applications are reviewed not by peers but by officials at patent offices who are likely less influenced by an inventor’s prior accomplishments.[5] Similarly, while well-known co-authors may increase the visibility and impact of a published paper (Merton, 1973), the financial value of a patent depends less on its visibility in the scientific community, thus limiting the benefits that can be gained from including a well-known co-inventor.

It is important to note that mere correlations between social factors and authorship or inventorship do not necessarily imply causal effects, i.e., they do not imply that scientists in higher hierarchical positions or with significant prior accomplishments appear on patents or papers *because* of these factors per se. Rather, these individuals may be more able and productive than others (Simcoe and Waguespack, 2011) and may be more likely to appear on a paper or patent because they have made important substantive contributions. In particular, senior scientists often provide the initial conceptual idea for a project while junior scientists carry out much of the laboratory work and data analysis (Hackett, 2005; Latour and Woolgar, 1979; Seymore, 2006). The empirical challenge is to properly account for differences in the nature of contributions when assessing the influence of various social factors on authorship and inventorship.

2.4. Interactions between substantive contributions and social factors

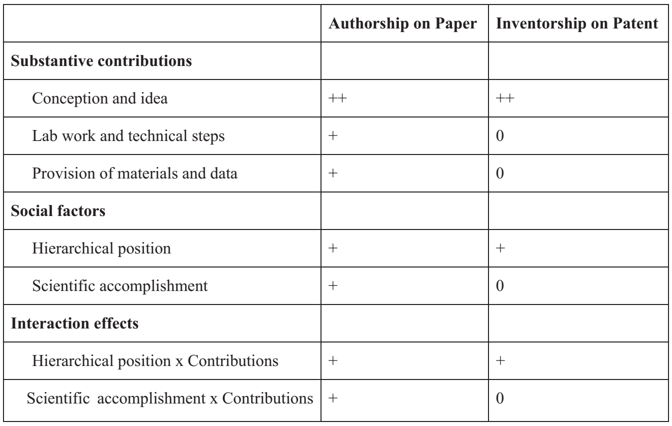
Substantive contributions and social factors are typically considered as independent (and competing) influences. We suggest that these two sets of factors may also interact in determining attribution. With respect to authorship, we conjecture that contributing a certain amount of time or effort to a project is more likely to result in authorship for a scientist with a high hierarchical position. Our rationale is that, if junior scientists desire to include superiors for reasons as those discussed above, then even a relatively small contribution by the senior scientists may provide a sufficient justification. Similarly, if it is the superior who seeks to become a co-author, a relatively small level of contribution may provide sufficient grounds to do so (Kwok, 2005). In contrast, the same level of substantive contribution by a junior scientist will increase her chances of authorship less. A similar logic may apply to scientific accomplishment, i.e., a given level of substantive contribution may have a stronger effect if made by a highly accomplished scientist.

Our predictions regarding interaction effects are less clear in the case of patents. As argued above, the main effects of social factors are likely to be more muted because the criteria for inventorship are more clearly defined. Some ambiguity remains, however, and we conjecture that extending “guest inventorship” to individuals in a higher hierarchical position may have certain benefits. In that case, even small levels of substantive contributions may provide a justification to do so, again suggesting a positive interaction between hierarchical position and (conceptual) contribution. In contrast, we predicted no significant benefits of including scientists with prior scientific accomplishments as inventors and we also do not expect an interaction between prior accomplishments and substantive contributions in predicting inventorship. Fig. 1 summarizes our predictions.

3. Data and measures

3.1. Sample and identification of patent–paper-pairs

Our empirical analysis draws on survey data from German and British life scientists. We identified potential respondents in two ways. First, we sampled life scientists that are listed between 2002



	Authorship on Paper	Inventorship on Patent
Substantive contributions		
Conception and idea	++	++
Lab work and technical steps	+	0
Provision of materials and data	+	0
Social factors		
Hierarchical position	+	+
Scientific accomplishment	+	0
Interaction effects		
Hierarchical position x Contributions	+	+
Scientific accomplishment x Contributions	+	0

Fig. 1. Summary of predictions.

---

[5] We are not aware of prior empirical research on the role of inventors’ social status in examiners’ decisions to grant a patent. We expect such effects to be weaker than in the case of publications for several reasons. First, examiners and inventors are parts of different professional communities, which may reduce the degree to which examiners are aware of an inventor’s prior accomplishments or the extent to which they personally share beliefs about particular individuals. Second, examiners’ decisions may be subject to a larger amount of scrutiny (including legal mechanisms) than publication decisions of editors and reviewers. Finally, while both patentability and publishability may involve subjective judgments, criteria for the former are more clearly defined (e.g., novelty, inventiveness, and industrial application in the European Patent Convention (Art. 52(1))).

and 2005 as authors in PubMed, the most prominent database of life scientific and medical abstracts. Nine thousand seventy four German scientists were identified along with 8189 British scientists who had published an article in the above timeframe in search categories related to the life sciences. Second, we sampled all inventors who had filed patents with bio-sciences IPC codes with the European Patent Office between 2002 and 2005, resulting in 8265 German and 4196 British inventors. We invited these scientists in 2007 to participate in an online survey, contacting them using email addresses provided on the publications and postal addresses from the patent application documents. We sent two follow-up reminders to non-respondents asking for their participation. Before fielding the survey, we pre-tested the instrument with scientists in both Germany and the UK who were part of our target population but are not included in the final sample.

A total of 2169 scientists identified through PubMed and 2452 identified through the European Patent Database responded. This translates into a response rate of 13% of publishing scientists and 20% of inventors. The search categories used for identifying scientists in the two databases were quite broad, however, and discussion with experts and a telephone survey of a random sample of non-respondents revealed that about 30% of authors and about 25% of the inventors captured in the original sample were not actually involved in life science research. Thus, these individuals were ineligible for the survey, which was explicitly addressed to life scientists. Adjusting for the percentage of people who were not involved in the life sciences, the resulting response rate was 17% for contacts extracted from publications and 26% for contacts extracted from patents. To assess potential non-response bias, we tested whether the answers to our key variables differ significantly between early respondents and late respondents (i.e., the first 10% versus the last 10% of respondents) (Armstrong and Overton, 1977; Rogelberg and Stanton, 2007). We find no significant differences between the subsamples with respect to the variables used in this study, mitigating concerns about non-response bias.

Since we are interested in directly comparing the predictors of authorship and inventorship, we rely on “patent–paper-pairs” as an empirical tool. Patent–paper-pairs are patents and papers that result from the same project, i.e., the knowledge resulting from the project is “inscribed in both a patent and a paper” (Murray, 2002, p. 1389). Given that the paper and the patent resulted from the same project, project characteristics as well as the contributions of individual scientists are essentially the same across the two types of output. Moreover, since both forms of output exist by definition, differences in project-level productivity, chances of success, or costs of disclosure should not affect comparisons of authorship and inventorship. Due to these desirable properties, patent–paper-pairs have been used in prior work on scientific attribution. For example, Ducor (2000) performed a manual search of patent and publication databases and identified 40 patent-paper-pairs related to specific genetic or amino acid sequences. Using these data, he showed that the authors on the papers do not always match the inventors on the corresponding patents, providing first evidence that different processes may drive authorship and inventorship. Lissoni and Montobbio (2008) used text-mining techniques to match publications to patents of Italian academic inventors and again show differences in the names appearing on patents versus the names that appear on the associated papers.

Prior work has identified patent–paper-pairs primarily using co-word analysis of publication and patent records (Ducor, 2000; Lissoni and Montobbio, 2008; Murray and Stern, 2007). This approach essentially identifies patents and papers that are very similar in content and are thus likely to have resulted from the same project. Our survey approach allowed us to identify patent–paper-pairs in a more direct way. We asked respondents “If you think about your past projects, has there been a project which resulted in both a patent filed and an article in a peer-reviewed scientific journal?”. Forty-eight percent of the respondents stated that they had been involved in such a project, resulting in a sample of 2191 scientists for our main analysis. Thus, patent–paper-pairs were a rather common phenomenon in our sample, consistent with the notion that the life sciences are characterized by an overlap between basic and applied research, and by a frequent use of multiple disclosure mechanisms (Gans et al., 2010; Sauermann and Stephan, 2012; Stokes, 1997; Vallas and Kleinman, 2008). At the same time, it has to be kept in mind that we explicitly sampled individuals who were active publishers or active patentees. While our results should apply to research active scientists, especially those who are involved in projects that result in patent–paper-pairs, we are cautious in generalizing our results beyond these boundaries. A key advantage of our survey data over the bibliometric data commonly used in prior work is that they include measures of different types of project contributions and of social factors that are difficult to obtain from patent and publication records.

Table 1
Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
Authorship (d)	0.95	n.a.	0	1
Inventorship (d)	0.92	n.a.	0	1
Conception/idea	3.81	1.19	1	5
Laboratory work	3.16	1.28	1	5
Material/data	4.10	0.97	1	5
Hierarchical position	2.92	1.24	1	5
Scientific accomplishment	3.19	1.18	0	6.5
Reputation from publication	3.58	1.04	1	5
Reputation from patents	2.58	1.04	1	5
Team size	6.19	5.26	1	100
% foreign lab members	20.09	22.97	0	100
Age	45.88	9.26	25	81
UK (d)	0.18	n.a.	0	1
Firm (d)	0.47	n.a.	0	1
Male (d)	0.85	n.a.	0	1

Note: 2191 observations; (d) indicates binary variable.

3.2. Measures

Table 1 provides summary statistics for key variables.[6]

3.2.1. Authorship and inventorship

We asked respondents with a patent–paper-pair if they were named as author on the publication and as inventor on the patent resulting from the focal research project.[7] Ninety-five percent of the scientists are listed as author on the paper (*authorship*=1) and ninety-two percent are listed as inventor on the patent (*inventorship* = 1). Eighty-nine percent of the scientists were listed on both the patent and the paper. While the higher rate of authorship is consistent with our expectation, the rate of inventorship is quite similar to that of authorship in an absolute sense, perhaps reflecting that respondents tended to focus on patent–paper–pair projects where they personally were listed on both the patent and the paper, rather than those projects where they were listed on just one of the resulting outputs. To the extent that this mechanism operated, our sample may understate the incidence of cases where individuals

---

[6] Some of our observations included missing data. Dropping those observation (i.e., listwise deletion) may result in sample-selection biases if data are not missing completely at random (MCAR) and also reduces statistical power (Fichman and Cummings, 2003; King et al., 2001). To address these issues, we imputed missing data using conditional mean imputation. Robustness checks using listwise deletion show very similar results.

[7] If more than one publication or more than one patent resulted from the project, we asked the respondents to refer to the most important publication or patent in their answer.

have made significant contributions but are not listed on the resulting output. Thus, we limit our examination of "ghost" authorship and inventorship to an auxiliary analysis (Section 4.2). Our main analysis focuses on the factors that lead scientists to be listed as authors or inventors, including potential cases of "guest" authorship and inventorship.

3.2.2. *Project contributions*

We asked respondents to indicate the level of their project contributions along three distinct dimensions, using rating scales ranging from 1 (disagree strongly) to 5 (agree strongly). More specifically, we asked "Thinking of your contribution to the project, to what extent do you agree or disagree with the following statements?", followed by three types of contributions: the variable *conception/idea* measures the extent to which the respondents agree to "I contributed the inventive idea for the project" and shows a mean of 3.81. The variable *laboratory work* measures the extent to which the respondents agreed to "I carried out all important technical steps of the project (e.g., I did most of the laboratory work)" (mean 3.16). Finally, the variable *material/data* measures the extent to which the respondents agreed to "I contributed important material/data" (mean 4.10). While the third type of contribution may involve the collection of data through laboratory work, our pre-tests suggest that respondents also thought about additional research inputs such as biological materials or external databases.[8]

Table 2 shows that the measures of project contributions are only moderately correlated; the correlation between *laboratory work* and *material/data* is 0.43, and the correlations between *conception/idea* and the other two types of contributions are below 0.1. These relatively low correlations signal discriminant validity; as intended, our measures of project contributions seem to capture different dimensions of project contribution rather than reflecting some overall level of contribution or common methods bias (cf. Pedhazur and Schmelkin, 1991; Podsakoff et al., 2003). In addition, these correlations suggest that some scientists tend to make primarily conceptual contributions, while others tend to make contributions in the form of both material/data and laboratory work. We will examine predictors of the type of contribution in auxiliary analyses.

A potential concern with self-reports of project contributions is that individuals may overestimate their importance in teams (Johnson and Orbach, 2002; Van den Steen, 2004). Such a bias should play a limited role for contributions that are relatively discrete and "observable", such as laboratory work or the provision of materials. However, it may be more problematic for contributions that require a subjective evaluation. Thus, overall levels of reported contributions should be interpreted with caution. As long as such reporting biases are shared among respondents and not systematically related to other key dependent or independent variables, they should not affect our correlational results. Moreover, we find that the measures of contributions have very different effects on the outcomes of interest, suggesting that a common reporting bias is unlikely the driver of our results. Finally, we will report below auxiliary analyses using an independent data set on project contributions to replicate key relationships observed in our data,

Table 2
Correlations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Authorship (d)	1													
2. Inventorship (d)	0.1**	1												
3. Conception/idea	0.12**	0.26**	1											
4. Laboratory work	−0.02	0.04*	0.05*	1										
5. Material/data	0.04*	0.05*	0.09**	0.43**	1									
6. Hierarchical position	0.09**	0.09**	0.17**	−0.24**	−0.12**	1								
7. Scientific accomplishment	0.27**	0.06**	0.19**	−0.25**	−0.12**	0.34**	1							
8. Reputation from publications	0.10**	−0.02	0.06**	0.03	0.05*	0.02	0.28**	1						
9. Reputation from patents	−0.06**	0.07**	0.05*	0.02	0.04	−0.00	−0.25**	−0.18**	1					
10. Age	0.00	0.08**	0.13**	−0.25**	−0.16**	0.17**	0.47**	−0.05*	0.06**	1				
11. Log team size	0.01	−0.07**	−0.23**	−0.23**	−0.08**	0.02	−0.01*	−0.07**	0.04	−0.07**	1			
12. % foreign lab	0.06**	0.00	0.07**	0.01	−0.01	0.01	0.12**	0.10**	−0.09**	−0.03	0.01	1		
13. UK	0.04	0.00	0.09**	−0.01	−0.02	−0.07**	0.11**	0.09**	−0.11**	−0.03*	0.1**	0.19**	1	
14. Firm	−0.12**	0.07**	−0.05*	−0.03	0.00	−0.05*	−0.41**	−0.41**	0.43**	0.04	0.13**	−0.18**	−0.11**	1
15. Male	0.03	0.03	0.1**	−0.11**	−0.03	0.11**	0.13**	−0.05*	0.02	0.14**	−0.01	−0.05*	−0.04*	0.1**

* $p<0.05$.
** $p<0.01$.

---

[8] A potential concern is that our three measures of project contributions do not capture all possible types of contributions. In particular, senior researchers may play an important role in acquiring grants and other resources (Schafer and Graham, 2002). While we have no measure of such contributions to a particular project, respondents indicated in a different question what percentage of their work hours they spend on acquiring funding and grants. As a robustness check, we included this variable both in its original form (as a percentage) and as a dummy indicating whether a respondent spent more than 10% of her time (the mean) on this activity. Neither measure has a significant effect on authorship or inventorship and including this measure has no noticeable effect on our core results.

providing further evidence of the validity of our contribution measures.

Despite their limitations, our measures of contributions provide important complementary insights to other approaches. In particular, a common alternative approach relies on the order of authorship to identify individuals' types and levels of contributions (e.g., Lissoni and Montobbio, 2008). This approach is based on certain assumptions regarding the order of authorship, e.g., that the first author is the junior scientist who has made the greatest contribution to the project, whereas the last author is the head of the research team who supervised the project. The validity of these assumptions is debated in the literature (Bhandari et al., 2003; Zuckerman, 1968). More importantly, the drawback of that approach is that authorship order is likely to simultaneously reflect social factors and project contributions and may thus provide little insight into their relative role.

3.2.3. Social factors

We measure hierarchical position using respondents' answer to the following question: "How many full time employees are you currently responsible for, or rather how many employees currently report directly to you?". The variable *hierarchical position* equals one if no employee is directly reporting to the respondent, two if 1–3 employees report, three if 4–7 employees report, four if 8–15 employees report and five if more than 15 employees report. As noted earlier, our conceptualization of hierarchical position may reflect both the hierarchical level in an organization as well as the size of the organization/research group. While we are unable to separate these two aspects, it is their joint influence with which we are primarily concerned.

We use respondents' number of peer-reviewed publications as our proxy for *scientific accomplishment*, obtained in response to the survey question "To date, how many scientific articles in peer-reviewed journals have you published?". Note that this measure captures primarily the quantity of output and does not provide direct insights into the quality of publications or the degree to which a respondents' research is recognized in the broader scientific community. However, prior work suggests a strong positive relationship between the quantity of output and peer recognition (Cole and Cole, 1967; Merton, 1973) as well as between the number of publications and the number of high impact contributions (Simonton, 2003). In auxiliary analyses below (Section 4.2), we also draw on additional citation data available for a subset of our respondents to examine potential differences in the effects of the quantity versus quality dimensions of scientific accomplishment (Cole and Cole, 1967; Costas and Bordons, 2008).

The average scientist in our sample has 47 publications, with a median of 25. Given the considerable skew of publication output, we use the natural log in our empirical analysis.[9] Table 2 shows that scientific accomplishment and hierarchical position are correlated positively ($r = 0.34$, $p < 0.01$), consistent with the idea that scientific accomplishment is an important predictor of career advancement. However, scientific accomplishment does not guarantee a higher hierarchical position, especially in the life sciences where labor markets are characterized by a large supply of qualified scientists (Stephan, 2012; Vallas and Kleinman, 2008). We interpret the medium (rather than high) correlation between hierarchical position and scientific accomplishment as evidence of discriminant validity, i.e., that the two measures capture distinct constructs and can be examined as separate predictors of attribution.

3.2.4. Control variables

We include additional variables to control for characteristics of the research project, of scientists, and of their employing organizations.

Team size indicates the number of researchers involved in the focal research project. We conjecture that the contributions an individual makes to a project may decrease with the size of the team, potentially reducing the likelihood of authorship and inventorship. The average team size is 6.19. Since this measure is skewed, we use the natural log in our regressions.

We include the variable *%foreign lab members* to control for the possibility that attribution patterns depend on the composition of the research team in terms of nationality. The average respondent worked in a team with 20% foreign members.

To control for potentially different roles of patents and publications across institutional environments (Haeussler and Colyvas, 2011), we asked respondents how important they thought patents and publications are to gain reputation among their peers. Both measures (*reputation from patents* and *reputation from publications*, respectively) are measured on 5-scales ranging from 1 (not important) to 5 (extremely important). On average, publications are rated as more important (3.58) than patents (2.58). Not surprisingly, the importance of publications is rated significantly higher in academia, while the importance of patents is rated significantly higher in industry (Table 2). We expect that individuals for whom patents and publications are more important are more likely to insist on inventorship/authorship and are thus more likely to be listed as inventors or authors.

We include the variable *age* in order to control for possible age effects. The average age is 46 years.

Male is an indicator variable equal to one if the respondent is male. Eighty-five percent of our respondents are male.

Firm is an indicator variable that is equal to one if the scientist is full time employed in a firm and equal to zero if the scientist is full time employed at a university or a non-university public research organization (e.g., Max Planck in Germany, Wellcome Trust in the UK). We include this variable to account for the possibility that firm scientists are generally more likely to appear on a patent than academics, but less likely to appear on publications (Ducor, 2000; Rennie et al., 1997; Sauermann and Stephan, 2012). In our sample, 47% of respondents work in industry. We report regressions separately for industry and academia as an auxiliary analysis; given that we find few differences across sectors, our main analysis features regressions using the pooled sample.

Finally, *UK* is an indicator variable that is equal to one if the scientist is employed in the UK (18%) and equal to zero if the scientist is employed in Germany (82%). This variable captures any existing systematic differences across countries, including potentially different roles of patents and publications in the scientific system.

4. Multivariate analysis

4.1. Main analysis

Table 3 provides the results for the determinants of authorship and inventorship. We estimate these regressions using a bivariate probit model because our two dependent variables are observed for the same individuals and the error terms may be correlated across equations (Wooldridge, 2001).

Model 1 regresses authorship and inventorship on control variables and the three types of project contribution. Conceptual contributions are strongly linked to both authorship and inventorship; we observe no significant relationship between *laboratory work* or *materials/data* and attribution. Model 2 includes the controls as well as social factors. *Hierarchical position* has a significant

---

[9] To assess the validity of self-reported publication counts, we collected independent publication data for a random subsample of thirty scientists using PubMed. We find a correlation of 0.84 between the two measures, increasing our confidence in the self-reported measure.

Table 3
Authorship and inventorship (bivariate probit).

Variables	1		2		3		4	
	Author	Inventor	Author	Inventor	Author	Inventor	Author	Inventor
Conception/idea	0.234**	0.356**			0.168**	0.332**	0.198**	0.334**
	(0.044)	(0.036)			(0.048)	(0.037)	(0.059)	(0.039)
Laboratory work	−0.068	0.030			−0.000	0.055	0.154*	0.034
	(0.048)	(0.040)			(0.053)	(0.041)	(0.068)	(0.043)
Material/data	0.101	0.058			0.127*	0.059	0.149*	0.062
	(0.058)	(0.049)			(0.063)	(0.049)	(0.068)	(0.051)
Hierarchical position			0.049	0.134**	0.029	0.094*	0.051	0.105*
			(0.048)	(0.039)	(0.049)	(0.042)	(0.057)	(0.045)
Scientific accomplishment			0.544**	0.097	0.539**	0.052	0.589**	0.009
			(0.057)	(0.050)	(0.059)	(0.054)	(0.064)	(0.060)
Sci. accomplish × Conception/idea							0.005	−0.059
							(0.039)	(0.033)
Sci. accomplish × Laboratory work							0.127**	−0.002
							(0.042)	(0.035)
Sci. accomplish × Material/data							0.059	−0.074
							(0.049)	(0.044)
Hierarchical position × Conception/idea							0.016	0.034
							(0.041)	(0.033)
Hierarchical position × Laboratory work							0.105**	−0.062
							(0.041)	(0.035)
Hierarchical position × Material/data							−0.053	0.011
							(0.049)	(0.044)
Reputation from publications	0.105	−0.026	0.001	−0.021	−0.010	−0.037	−0.004	−0.040
	(0.054)	(0.047)	(0.059)	(0.045)	(0.061)	(0.048)	(0.062)	(0.049)
Reputation from patents	−0.050	0.064	0.046	0.094*	0.022	0.069	−0.008	0.067
	(0.054)	(0.049)	(0.058)	(0.047)	(0.060)	(0.050)	(0.062)	(0.051)
Age	−0.003	0.012*	−0.028**	0.007	−0.028**	0.008	−0.027**	0.009
	(0.006)	(0.005)	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)
Log team size	0.182*	−0.006	−0.121	−0.241**	−0.015	−0.028	−0.065	−0.011
	(0.088)	(0.077)	(0.088)	(0.068)	(0.098)	(0.078)	(0.100)	(0.079)
% foreign lab members	0.003	−0.000	0.002	0.001	0.002	−0.000	0.002	−0.001
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
UK	0.012	−0.053	0.037	0.100	−0.038	−0.022	−0.074	−0.023
	(0.157)	(0.117)	(0.166)	(0.113)	(0.171)	(0.119)	(0.175)	(0.120)
Firm	−0.444**	0.222*	−0.016	0.313**	−0.023	0.284*	−0.122	0.317**
	(0.130)	(0.108)	(0.144)	(0.110)	(0.149)	(0.115)	(0.157)	(0.118)
Male	0.147	−0.012	0.003	0.006	−0.040	−0.043	−0.070	−0.056
	(0.140)	(0.117)	(0.149)	(0.112)	(0.154)	(0.118)	(0.164)	(0.120)
Constant	1.535**	0.933**	3.363**	1.263**	3.427**	1.217**	3.783**	1.134**
	(0.403)	(0.359)	(0.462)	(0.373)	(0.483)	(0.400)	(0.507)	(0.406)
Arthro	0.303**		0.358**		0.288**		0.347**	
Observations	2191		2191		2191		2191	
Chi^2	199.8		187.7		280.9		196.3	
ll	−813.7		−815.9		−737.0		−760.1	

Note: Standard errors in parenthesis.
* $p < 0.05$.
** $p < 0.01$.

positive effect on inventorship but not on authorship. In contrast, *scientific accomplishment* has a positive effect on authorship but not inventorship.[10] As discussed earlier, positive coefficients of *hierarchical position* and *scientific accomplishment* may reflect “guest” attributions due to social mechanisms, but they may also reflect that these individuals make more important substantive contributions to the focal project. In an attempt to separate the two mechanisms, model 3 additionally includes the measures of contributions. We observe that the positive effect of hierarchical position on inventorship is reduced once we include contributions, suggesting that some of this relationship is due to the fact that scientists in a higher hierarchical position (e.g., lab leaders) are more likely to make a strong conceptual contribution. However, controlling for contributions does not noticeably change the effect of scientific accomplishment on authorship.[11] Model 3 also shows that contributions in the form of material/data have a positive effect on authorship once social factors are included in the regression.

Finally, we suggested that substantive contributions and social factors may interact in predicting authorship and, to a smaller extent, inventorship. To examine this possibility, we include in model 4 the interactions between these sets of variables.[12] Two significant interaction terms emerge in the authorship regression.

---

[10] When *hierarchical position* and *scientific accomplishment* are entered separately, both are significant and positive in the authorship and inventorship regressions.

[11] The positive relationship between scientific accomplishment and authorship does not simply reflect a scientist's higher ability or productivity as common underlying cause. First, our dependent variable indicates whether a scientist is included on a paper in an *existing* patent-paper-pair, i.e., all focal projects resulted in successful publication and our analysis does not consider variation in project output as such. Second, model 3 controls for substantive contributions, i.e., differences in the ability (or effort) to contribute to the project are controlled for.

[12] We mean-centered the component measures such that the main effects can be interpreted as the effects of a focal variable for a scientist with the average score on the other variable involved in the interaction (Jaccard et al., 1990). For example, the significant coefficient of 0.154 on *laboratory work* in the authorship regression (model 4) suggests that contributions in the form of laboratory work have a positive effect on the likelihood of authorship for individuals with average hierarchical status and average scientific accomplishment. Since estimated interaction effects in nonlinear models may be misleading, we verified our results using linear probability models.

Table 4
Omission from authorship and inventorship (bivariate probit).

Variables	1		2		3	
	om-Author	om-Inventor	om-Author	om-Inventor	om-Author	om-Inventor
Conception/idea	−0.163	−0.198			−0.042	−0.179
	(0.162)	(0.145)			(0.184)	(0.146)
Laboratory work	0.033	0.140*			−0.017	0.122
	(0.073)	(0.068)			(0.084)	(0.070)
Material/data	−0.089	−0.016			−0.132	−0.020
	(0.091)	(0.089)			(0.101)	(0.090)
Hierarchical position			−0.054	−0.127*	−0.068	−0.099
			(0.072)	(0.064)	(0.074)	(0.065)
Scientific accomplishment			−0.557**	0.000	−0.563**	0.014
			(0.081)	(0.085)	(0.083)	(0.086)
Reputation from publications	−0.083	0.083	0.021	0.076	0.033	0.079
	(0.078)	(0.073)	(0.091)	(0.075)	(0.092)	(0.076)
Reputation from patents	0.053	−0.266**	−0.011	−0.247**	0.000	−0.262**
	(0.076)	(0.084)	(0.085)	(0.082)	(0.086)	(0.084)
Age	0.004	0.004	0.031**	−0.001	0.029**	0.003
	(0.008)	(0.008)	(0.010)	(0.009)	(0.010)	(0.010)
Log team size	−0.196	−0.079	0.056	−0.107	0.012	−0.078
	(0.129)	(0.116)	(0.137)	(0.112)	(0.149)	(0.117)
% foreign lab members	−0.003	0.004	−0.001	0.004	−0.002	0.004
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)
UK	0.152	0.011	0.187	−0.028	0.191	−0.019
	(0.211)	(0.168)	(0.231)	(0.169)	(0.236)	(0.171)
Firm	0.701**	−0.020	0.219	−0.056	0.182	−0.047
	(0.211)	(0.175)	(0.244)	(0.185)	(0.248)	(0.186)
Male	−0.159	−0.093	−0.104	−0.126	−0.065	−0.101
	(0.238)	(0.197)	(0.254)	(0.193)	(0.259)	(0.197)
Constant	−1.891**	−1.483*	−3.880**	−1.323*	−3.798**	−1.431*
	(0.642)	(0.578)	(0.722)	(0.627)	(0.772)	(0.655)
Arthro	0.410*		0.411*		0.457*	
Observations	1355		1355		1355	
Chi^2	51.17		91.12		97.51	
ll	−321		−294.4		−290.4	

Note: Standard errors in parenthesis. Sample limited to scientists with high scores (4 or 5) on *conception/idea*.
* $p < 0.05$.
** $p < 0.01$.

More specifically, the results indicate that the impact of laboratory work on authorship is stronger for scientists in higher hierarchical positions and for individuals with higher scientific accomplishments. These positive interactions are in line with our conceptual discussion suggesting that even small substantive contributions may provide sufficient justification to gain authorship when made by scientists with high social status but less so for scientists with low social status. In contrast, neither hierarchical position nor scientific accomplishments moderate the effects of project contributions on inventorship.

Before we turn to auxiliary analyses to provide further insights, we briefly comment on some control variables. First, older scientists are less likely to appear as co-authors once we control for hierarchical position and scientific accomplishment.[13] A potential interpretation is that older scientists have a shorter career horizon and are therefore less eager to appear on the publication than scientists at the beginning of their careers (cf. Levin and Stephan, 1991). Older scientists might even cede authorship to younger scientist whose careers are more open and less secure – an effect called “noblesse oblige” (Zuckerman, 1968). However, due to the cross-sectional nature of our data, we cannot disentangle age effects from potential cohort effects, e.g., older scientists may have been socialized into different norms regarding authorship than their younger colleagues (Wuchty et al., 2007). Second, firm scientists are more likely to be listed as co-inventors, even controlling for social factors and project contributions. While firm scientists are also less likely to be listed on the paper, that effect disappears once we control for social factors. We report separate regressions for industrial and academic scientists below as an auxiliary analysis. Lastly, we find no authorship or inventorship differences between scientists working in the UK versus Germany, or between female and male scientists.[14]

4.2. Auxiliary analyses and robustness checks

Since our main analysis focuses on authorship and inventorship as dependent variables, it provides only limited insights into “ghost” authorship or inventorship, i.e., cases where scientists are *not* included on the by-line even though they have made important contributions. To explore this issue, we coded two new dummy variables indicating whether a scientist was omitted from the list of authors (om-author = 1) and from the list of inventors (om-inventor = 1), conditional upon having made a strong or very strong conceptual contribution (*conception/idea* score of 4 or 5). Table 4 shows the results of bivariate probit regressions using the smaller sample of scientists who have made strong conceptual contributions and using the indicators of omission as dependent variables.

---

[13] We tested for the presence of nonlinearities by including *age squared* but did not find a significant effect.

[14] The error terms of the authorship and inventorship equations have a positive correlation (estimate of rho in Table 3). Thus, controlling for the variables included in our various models, scientists who are more likely to be listed as authors are also more likely to be listed as inventors. While we cannot further explore which characteristics of scientists lead them to be more likely to appear on both types of output, the absence of a negative correlation provides no evidence of trade-offs in the sense that scientists who want to appear as authors do not like to appear as inventors, or that team-members systematically “trade” inventorship against authorship.

Table 5
Project contributions (ordered probit).

Variables	1 Conception/idea	2 Laboratory work	3 Material/data
Hierarchical position	0.108**	−0.148**	−0.080**
	(0.020)	(0.020)	(0.020)
Scientific accomplishment	0.088**	−0.150**	−0.039
	(0.027)	(0.027)	(0.028)
Age	0.006*	−0.017**	−0.015**
	(0.003)	(0.003)	(0.003)
UK	0.284**	−0.051	−0.051
	(0.064)	(0.062)	(0.064)
Firm	−0.027	−0.217**	−0.073
	(0.054)	(0.052)	(0.054)
Male	0.197**	−0.131*	0.018
	(0.067)	(0.066)	(0.070)
Observations	2191	2191	2191
Chi^2	136.6	273.4	72.57
ll	−3048	−3300	−2688

Note: Standard errors in parenthesis.
* $p < 0.05$.
** $p < 0.01$.

We find that individuals with higher prior scientific accomplishment are less likely to be omitted from publications. Thus, it appears that prior accomplishment increases authorship attribution not only because it may result in "guest authorships" but also because it reduces "ghost authorships". Hierarchical position has a small negative effect on omission from patents but this effect becomes insignificant once we control for contributions. Interestingly, the degree to which patents matter for reputation among peers (*reputation from patents*) is negatively related to omission from inventorship. Thus, it appears that scientists who have made significant contributions and for whom patenting is important insist more strongly on inventorship to avoid becoming "ghost inventors".

In a second set of auxiliary regressions, we examine how project contributions are related to social factors. Towards that end, we now regress the three contribution measures on *hierarchical position* and *scientific accomplishment* as well as on control variables (Table 5). Consistent with our expectation, we find that scientists in higher hierarchical positions are more likely to make significant conceptual contributions, but less likely to make strong contributions in the form of laboratory work or by providing data or materials. Prior scientific accomplishment is positively associated with conceptual contributions and negatively associated with laboratory work but has no relationship with contributions in the form of materials or data. In conjunction with our main results, these results support the notion that *hierarchical position* is associated with inventorship partly because higher-status individuals tend to make stronger conceptual contributions, i.e., conceptual contributions mediate the relationship between hierarchical position and attribution (cf. Baron and Kenny, 1986). In contrast, while *scientific accomplishment* also predicts stronger conceptual contributions, this fact does not explain why highly accomplished scientists are more likely to be included as co-authors on papers (the coefficient of scientific accomplishment changed little once contributions were included in the main regressions in Table 3).

The results in Table 5 also speak to a large literature on the impact of age on scientific productivity (Jones and Weinberg, 2011; Lehman, 1953; Stephan and Levin, 1992). One common notion in that literature is that age is systematically related to scientific productivity because scientists' ability to make particular contributions changes over the life cycle. For example, Weinberg and Galenson (2005) distinguish between abstract/deductive contributions and inductive/empirical contributions and argue that the latter require a greater amount of experience, giving older scientists an advantage in empirical work. Jones (2009) suggests that major contributions require foundational knowledge and that older and more experienced scientists may be better equipped to make important contributions, especially in mature fields with a large stock of accumulated knowledge. Finally, Simonton (2003) develops a theory of creativity as constrained stochastic behavior, arguing that the likelihood that an idea is successful does not change over the life cycle. However, older scientists may be able to create a larger number of ideas, therefore also increasing the number of successes. While our results do not speak to publication productivity, the results in Table 5 provide unique insights into the particular types of contributions made by older and more experienced scientists to a given project, thus speaking to some of the mechanisms hypothesized in prior work. By showing that senior scientists are much less likely to conduct empirical work and more likely to make conceptual contributions, our results suggest that experience may provide more of an advantage for conceptual work than for empirical contributions, perhaps because formulating research ideas and hypotheses requires intimate knowledge of the body of prior work or of the way in which the field evaluates scientific contributions (Merton, 1973). Alternatively, it may be that age provides more of a (relative) disadvantage in empirical work, perhaps because methodological knowledge depreciates faster, providing junior scientists who acquire the newest methods a comparative advantage over older colleagues (Jones and Weinberg, 2011; Levin and Stephan, 1991). In a more general sense, our study suggests two potentially important nuances. First, rather than being either conceptual or empirical in nature, most studies require both conceptual and empirical contributions, at least in fields such as the life sciences. Second and related to the prior point, many projects involve more than the focal individual, raising the opportunity to divide project tasks among multiple collaborators. As such, future work on age effects may fruitfully study the relationships between age and collaboration as well as the division of labor.

In a third set of analyses, we explore whether drivers of authorship and inventorship attribution differ between scientists working in industry and those working in academia. Some authors suggest that industrial and academic science share key features, including the important role of publications as a signal of research performance (Stern, 2004; Stuart and Liu, 2010). At the same time, it has been argued that the "logics" of industrial and academic science differ with respect to factors such as the organization of research labs and the division of labor, the role of patents, or the importance of publications as a measure of individuals' performance (Blume, 1974; Fini and Lacetera, 2010). In Table 6, we split

Table 6
Authorship and inventorship – by sector (bivariate probit).

Variables	Industrial scientists						Academic scientists					
	1		2		3		4		5		6	
	Author	Inventor	Author	Inventor	Author	Inventor	Author	Inventor	Author	Inventor	Author	Inventor
Conception/idea	0.210**	0.419**			0.151*	0.399**	0.289**	0.313**			0.207*	0.294**
	(0.058)	(0.063)			(0.063)	(0.065)	(0.078)	(0.045)			(0.086)	(0.047)
Laboratory work	−0.076	0.006			−0.032	0.021	−0.088	0.067			0.036	0.090
	(0.059)	(0.065)			(0.066)	(0.065)	(0.088)	(0.053)			(0.099)	(0.055)
Material/data	0.179*	0.116			0.193*	0.112	−0.030	0.016			0.006	0.018
	(0.071)	(0.076)			(0.077)	(0.077)	(0.115)	(0.066)			(0.121)	(0.066)
Hierarchical position			0.039	0.144*	0.021	0.115			0.133	0.131*	0.097	0.090
			(0.057)	(0.056)	(0.059)	(0.060)			(0.098)	(0.056)	(0.105)	(0.060)
Scientific accomplishment			0.618**	0.113	0.614**	0.032			0.524**	0.019	0.504**	0.005
			(0.071)	(0.070)	(0.073)	(0.079)			(0.116)	(0.076)	(0.122)	(0.080)
Reputation from publications	0.093	0.006	−0.040	0.006	−0.058	0.010	0.131	−0.030	0.031	−0.020	0.031	−0.041
	(0.066)	(0.075)	(0.074)	(0.071)	(0.077)	(0.079)	(0.100)	(0.063)	(0.105)	(0.061)	(0.108)	(0.064)
Reputation from patents	−0.033	0.031	0.085	0.085	0.054	0.026	−0.134	0.089	−0.090	0.097	−−0.102	0.092
	(0.065)	(0.073)	(0.072)	(0.068)	(0.074)	(0.075)	(0.105)	(0.070)	(0.107)	(0.066)	(0.112)	(0.070)
Age	0.006	−0.009	−0.014	−0.012	−0.013	−0.012	−0.023*	0.028**	−0.056**	0.026**	−0.058**	0.026**
	(0.007)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.011)	(0.007)	(0.013)	(0.009)	(0.014)	(0.009)
Log team size	0.395**	0.030	0.079	−0.198	0.182	0.015	−0.329	−0.020	−0.691**	−0.258**	−0.555**	−0.030
	(0.111)	(0.119)	(0.112)	(0.103)	(0.125)	(0.122)	(0.182)	(0.103)	(0.193)	(0.093)	(0.210)	(0.104)
% foreign lab members	0.006	−0.003	0.005	−0.001	0.004	−0.003	−0.001	0.000	−0.002	0.001	−0.003	0.000
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)
UK	−0.066	−0.185	−0.002	0.008	−0.059	−0.150	0.155	0.005	0.201	0.144	0.107	0.042
	(0.207)	(0.202)	(0.226)	(0.193)	(0.234)	(0.206)	(0.271)	(0.145)	(0.287)	(0.142)	(0.295)	(0.149)
Male	0.110	0.056	−0.051	0.094	−0.096	0.016	0.189	−0.018	−0.022	−0.005	−0.050	−0.025
	(0.186)	(0.207)	(0.200)	(0.196)	(0.205)	(0.211)	(0.229)	(0.142)	(0.248)	(0.138)	(0.260)	(0.145)
Constant	0.338	2.116**	2.484**	2.281**	2.548**	2.340**	3.480**	0.195	5.929**	0.461	5.954**	0.348
	(0.482)	(0.544)	(0.557)	(0.560)	(0.585)	(0.616)	(0.793)	(0.497)	(1.042)	(0.541)	(1.068)	(0.568)
Arthro	0.359**		0.441**		0.366**		0.283		0.349*		0.298	
Observations	1032		1032		1032		1159		1159		1159	
Chi^2	85.55		109.2		155.0		107.7		75.74		123.4	
ll	−406.4		−390.1		−360.6		−387.4		−403.1		−375.3	

Note: Standard errors in parenthesis.

* $p < 0.05$.

** $p < 0.01$.

Table 7
Quantity vs. quality of scientific accomplishment (bivariate probit, limited sample).

Variables	Limited sample							
	1		2		3		4	
	Author	Inventor	Author	Inventor	Author	Inventor	Author	Inventor
Conception/idea			0.165*	0.417**			0.168*	0.424**
			(0.078)	(0.057)			(0.077)	(0.058)
Laboratory work			0.049	0.065			0.050	0.054
			(0.090)	(0.065)			(0.090)	(0.066)
Material/data			0.159	0.129			0.161	0.147
			(0.119)	(0.073)			(0.118)	(0.075)
Hierarchical position	−0.027	0.187**	−0.048	0.109	−0.024	0.174**	0.045	0.091
	(0.083)	(0.064)	(0.080)	(0.071)	(0.081)	(0.064)	(0.079)	(0.072)
Scientific accomplishment (quantity)	0.271*	0.156	0.300*	0.130	0.272*	0.146	0.301*	0.119
	(0.137)	(0.095)	(0.140)	(0.105)	(0.137)	(0.094)	(0.141)	(0.104)
Scientific accomplishment (quality)					−0.001	0.009	−0.002	0.012
					(0.003)	(0.006)	(0.003)	(0.007)
Reputation from publications	−0.016	−0.043	−0.050	−0.079	−0.018	−0.028	−0.052	−0.067
	(0.108)	(0.064)	(0.099)	(0.071)	(0.108)	(0.066)	(0.099)	(0.072)
Reputation from patents	0.063	0.083	0.020	0.048	0.059	0.105	0.015	0.078
	(0.109)	(0.074)	(0.118)	(0.085)	(0.110)	(0.076)	(0.119)	(0.089)
Age	−0.036**	0.005	−0.037**	0.006	−0.036**	0.004	−0.037*	0.005
	(0.013)	(0.011)	(0.014)	(0.012)	(0.013)	(0.011)	(0.014)	(0.012)
Log team size	−0.158	−0.491**	−0.050	−0.291*	−0.154	−0.513**	−0.044	−0.322*
	(0.156)	(0.121)	(0.176)	(0.132)	(0.158)	(0.122)	(0.179)	(0.134)
% foreign lab members	−0.002	0.005	−0.003	0.002	−0.002	0.005	−0.003	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
UK	−0.119	0.218	−0.194	0.109	−0.114	0.171	−−0.190	0.046
	(0.228)	(0.183)	(0.236)	(0.203)	(0.228)	(0.178)	(0.237)	(0.200)
Firm	−0.069	0.628**	−0.065	0.638**	−0.067	0.615**	−0.063	0.632**
	(0.284)	(0.169)	(0.290)	(0.180)	(0.285)	(0.168)	(0.290)	(0.180)
Male	0.118	0.121	0.130	0.168	0.122	0.119	0.136	0.172
	(0.238)	(0.176)	(0.243)	(0.197)	(0.239)	(0.176)	(0.245)	(0.196)
Constant	3.791**	1.580*	3.965**	1.625*	3.799**	1.549*	3.975**	1.627*
	(0.860)	(0.661)	(0.838)	(0.712)	(0.865)	(0.651)	(0.841)	(0.706)
Arthro	0.351*		0.238		0.357*		0.235	
	(0.152)		(0.177)		(0.153)		(0.181)	
Observations	892		892		892		892	
Chi^2	72.21		160.0		75.50		164.9	
ll	−309.9		−274.6		−307.7		−271.9	

Note: Standard errors in parenthesis.
* $p < 0.05$.
** $p < 0.01$.

the sample and estimate key regressions using industrial and academic scientists separately. Most of our key results hold in both sectors, including the positive relationship between conceptual contributions and both types of attribution, the positive relationships between scientific accomplishment and authorship, and that between hierarchical position and inventorship.[15] One notable difference is that contributions in the form of material are associated with authorship in industry but not in academia. One possible interpretation is that firm scientists subscribe more strongly to norms of exchange, thus expecting authorship in return for the provision of data or materials. Consistent with this idea, Von Hippel (1987) and Schrader (1991) observed that engineers who shared information informally expected some form of reciprocation from the other party. Similarly, Haeussler (2011) compares information sharing among academic and industry-based scientists and finds that expected reciprocity is a more important driver of information sharing among industrial scientists.

We also find that age has a negative effect on authorship and a positive effect on inventorship in academia, but no effects in industry. This difference may reflect that career incentives to appear on publications versus patents change over time for those employed in academia (cf. Jensen and Pham, 2011; Levin and Stephan, 1991), but remain relatively constant over time for those in industry. Of course, our cross-sectional analysis does not allow us to separate age effects from potential cohort effects. Overall, we find only minor differences in the drivers of authorship and inventorship across sectors, consistent with arguments that industrial and academic science are more similar than often thought (Sauermann and Stephan, 2012), and that the two sectors may "converge", especially in the life sciences (Murray, 2010; Vallas and Kleinman, 2008).

In a fourth set of analyses, we draw on citation data to more clearly distinguish the quantitative versus qualitative dimension of scientific accomplishment. First, we obtained from ISI Web of Science the total citation counts for the respondents in our sample. A common problem with publication matching is that the search by author name results in an overcount of output for authors with common names (cf. Trajtenberg et al., 2006). To mitigate this problem, we excluded respondents with the 200 most common names, reducing the sample to 892 cases. We then computed a measure of publication quality by dividing total citation counts by the total number of publications (*scientific accomplishment – quality*). Table 7 shows key regressions using this quality measure in addition to the previously used measure of publication counts. The results show that the quantity of publications continues to have a positive coefficient, while the measure of publication quality does not have a significant effect. We also included an interaction between quantity and quality but find no significant effect. Thus, the quality of

---

[15] Using the academic subsample, we used a variable indicating whether the respondent held a professorship as an alternative indicator of hierarchical status. We find no significant effect of this variable, suggesting that inventorship depends less on formal status per se, but rather on the number of people who are actually subordinated to a particular individual.

publications does not appear to be related to authorship or inventorship. One possible interpretation is that senior authors with high quality publications may be less likely to accept invitations to serve as guest author out of a concern about the dilution of their quality in the eyes of the scientific community. In contrast, authors focusing on producing a high quantity of output ("mass producers" in the terminology of Cole and Cole (1967)) may more readily accept (or seek) guest authorship.[16] While this interpretation is intriguing, these results should be considered highly preliminary since the sample size is significantly reduced compared to our featured analysis and some name matching ambiguities are likely to remain. However, the results suggest the potential value of future work using separate indicators of quality and quantity.[17]

In a final set of analyses, we address the concern that our survey measures of contributions may be affected by reporting biases.[18] While we do not have independent assessments of contributions for our sample, we can compare basic patterns of contributions in our primary data set with patterns observed in a second data set. For that purpose, we collected data from PLoS Biology, one of the leading peer reviewed journals in the life sciences. PLoS Biology requires that all articles detail the particular (sets of) contributions made by each author. The journal pre-defines the five categories "conceived and designed the experiments", "performed the experiments", "analyzed the data", "contributed reagents/materials/analysis tools", and "wrote the paper". While contributions are still reported by the authors, these reports should be less affected by biases than survey measures because they are official written statements and because they are likely to reflect an agreed-upon assessment of contributions by the full team of authors. We sampled 100 papers from the 2008 issue as well as 100 papers from the 2010 issue and coded the contributions made, author position, as well as the total number of authors on the article. The median paper had 7 authors (1 first, 5 middle, 1 last). Using these data, we make two important observations. First, we find that 92% of last authors are listed as having conceived and designed the experiment, compared to only 33% of middle authors and 90% of first authors. On the other hand, last authors were much less likely to have performed the experiment (25% versus 59% for middle authors and 98% for first authors). Assuming that last authors tend to be scientists with higher hierarchical position (Bhandari et al., 2003; Kwok, 2005; Shulkin et al., 1993), the results are consistent with our findings regarding project contributions reported in Table 5, i.e., that senior scientists indicate higher involvement in idea generation and less involvement in laboratory work. As such, this finding mitigates the concern that the observed strong relationship between social factors and conceptual contributions in our data is simply due to senior scientists' overestimating their conceptual contributions. Second, we find that 52% of all PLoS authors are listed as having "conceived and designed the experiments", suggesting that 48% of authors did not make a conceptual contribution. Of the latter group, 62% had performed the experiment, 44% had analyzed the data, 34% had contributed reagents/materials/analysis tools, and 14% had written the paper. This result is consistent with our finding that authorship is strongly predicted by conceptual contributions but may also result from contributions in the form of laboratory work or materials/data (Table 3). Overall, the analysis of PLoS data reinforces our main findings and points to interesting opportunities for future research combining survey data with bibliometric data.

In addition to providing insights regarding the contributions of individuals listed as authors, PLoS publications also provide insights into contributions of individuals who are not listed as authors. In particular, most papers include a section that acknowledges the help of other individuals and often details what specific type of help was provided (see also Laudel, 2002; Oettl, 2012). While a systematic analysis of these contributions is beyond the scope of this paper, we found that acknowledged contributions span a broad range, including, for example, the critical reading of manuscripts, providing materials or data, or helping with specialized research equipment. As observed in our main analysis, some of these contributions are also sometimes rewarded with authorship, raising the question as to what level of a contribution is typically (or should be) considered the "cutoff" for authorship versus less visible acknowledgement. Our analysis of interactions between contributions and social factors (column 4 in Table 3) suggest that these cutoffs may not be universal but also depend on characteristics of the contributing individual. Unfortunately, our primary data do not include information on acknowledgements, while the PLoS data do not include information on the levels of contributions made by authors vs. individuals who are acknowledged. Future research using data sources with both sets of information could fruitfully examine the role of authorship versus acknowledgements as alternative reward mechanisms, tying them to different types and levels of contributions as well as social factors.

5. Discussion and conclusion

A growing body of work has documented misconnects between substantive contributions and authorship attribution, as reflected in the terms "guest" and "ghost" authorship. Despite the increasing attention to these issues in the scientific community, large scale studies of the drivers of attribution are rare. We complement the existing literature in several ways. First, while much of the prior work has focused on authorship, we directly contrast the predictors of authorship on papers and of inventorship on patents. Second, our survey data allow us to measure various dimensions of project contributions and to separate such contributions from social factors such as scientists' hierarchical position or scientific accomplishments. As such, our approach improves upon prior work that has used proxies of project contributions such as the order of authorship on published papers. Finally, our detailed measures of contributions and social factors allow us to examine not only the main effects of these two sets of factors, but also potential interactions.

Our findings provide several insights. First, both authorship and inventorship are strongly predicted by contributions of a conceptual nature, in line with common authorship guidelines and legal definitions of inventorship. However, authorship is also related to contributions made in the form of technical/laboratory work and the provision of materials and data. Second, we find that prior scientific accomplishment strongly predicts authorship, even controlling for the nature of a scientist's contributions. This result is consistent with the notion that junior scientists may include accomplished colleagues to build social relationships or to increase the visibility of a paper. While the hierarchical position a scientist holds within an organization does not predict authorship, it does predict inventorship. The latter relationship is to some extent explained by the fact that individuals in higher positions are more

---

[16] This observation raises the possibility that prior scientific accomplishment may already reflect some of the very processes we investigate here. As such, while we interpret prior publication output as scientific accomplishment in a positive sense, it may also partly reflect individual-level unobserved factors driving authorship such as a general tendency to "push" oneself onto publications. Unfortunately, our data do not allow us to examine this possibility.

[17] A recent trend towards using the H-index illustrates the scientific community's recognition that both quality and quantity aspects should be considered (Hirsch, 2005). While the H-index parsimoniously captures a researcher's accomplishments in a single number, treating the quality and quantity dimensions separately provides more detailed insights for the purpose of our study.

[18] We thank an anonymous reviewer for suggesting this analysis.

likely to make conceptual contributions. Third, we find interactions between project contributions and social factors; more specifically, contributions in the form of laboratory work are more likely to be rewarded with authorship when made by accomplished scientists or by those in higher hierarchical positions.

Taken together, our results suggest that authorship on publications reflects a heterogeneous set of factors including conceptual contributions but also other types of substantive contributions as well as social factors. Inventorship, on the other hand, is more clearly related to conceptual contributions, and social factors appear to play a more limited role.

These results have several implications. First, users of patent and publication measures (whether peers, administrators, managers, or social scientists) need to be aware of the various factors that may drive authorship and inventorship and should take those influences into account when interpreting and evaluating patent and publication output. In particular, studies using patents and publications as measures of scientific performance need to consider that the same type of output (e.g., a publication) may reflect very different types and levels of contributions on the part of individual co-authors. While a publication may reflect creative performance for one co-author, it may reflect laboratory work for another. To the extent that social status leads to “guest authorship”, studies using publications as performance measure may also systematically over-estimate the performance of accomplished scientists. Indeed, our findings of a strong relationship between prior accomplishments and authorship, even controlling for substantive contributions, suggest that accomplished scientists may benefit not only from a “Matthew effect” in the sense that they get disproportional credit once they appear as co-authors on a paper (Merton, 1973), but also in the sense that they are more likely to be named as co-authors in the first place. Patent and publication measures have also been used as proxies for constructs other than performance. For example, an increasing number of studies rely on co-authorship and co-inventorship patterns as measures of social networks or of the composition of research teams (Meyer and Bhattacharya, 2004; Singh and Fleming, 2010). In the presence of “guests” and “ghosts”, such measures may be noisy indicators of the individuals who actually contributed to a project. More importantly, our results suggest that the resulting measurement error may be systematically related to factors such as social status, which may lead to biases if such factors (or their correlates) are of substantive interest to a study.

While some of our results could be interpreted as reflecting undesirable deviations from formal standards (implicit in the use of the terms “guest” and “ghost”), they could also be interpreted as evidence that the current formal guidelines are limited in their ability to accommodate the complex nature of collaborative research and the division of labor between project participants. Either way, misconnects between guidelines and scientific practice create ambiguities regarding the interpretation of authorship and inventorship. A promising approach towards improving the current system is the idea of “contributorship”. Rennie et al. (1997, p. 583) propose to use the term “contributor” rather than “author”, where a contributor is a person who “has added usefully to the work”. Publications should also clearly identify the actual work that was done by each of the contributors. In addition to providing credit for specific contributions, this system would provide information about individuals’ responsibility for particular tasks, which may help in fighting scientific misconduct and fraud (Deichmann and Muller-Hill, 1998; Lacetera and Zirulia, 2011). While some journals such as Nature, the Proceedings of the National Academy of Sciences, and PLoS Biology have moved in this direction, many journals – especially outside of the biomedical sciences – still rely on traditional attribution practices.

Several limitations of our study have to be kept in mind. First, following prior research on attribution (Ducor, 2000; Lissoni and Montobbio, 2008), we used patent–paper-pairs as a tool that allowed us to directly contrast predictors of authorship and inventorship in the life sciences. It is not clear, however, to what extent our findings generalize to projects that do not result in both patents and papers. Moreover, it is not clear if our findings generalize to other fields, which may be characterized by a different organization of research as well as different authorship and inventorship practices (Cronin, 2005; Stokes and Hartley, 1989; Wuchty et al., 2007). We expect that general mechanisms hold across fields, but future work is needed to validate our results in other contexts. Indeed, future research could examine whether differences across fields with respect to factors such as average team size or the basic versus applied nature of research moderate the effects observed in this study. Second, our measures of project contribution were reported by the respondents themselves and may suffer from a tendency to overestimate one’s own contribution. We do not expect any such biases to systematically affect our correlational analyses and we showed in an auxiliary analysis that alternative measures of contributions from an independent data set support our general findings. A related limitation is that we only observed a limited set of contributions and are unable to assess the role of other types of contributions that may also be seen by some scientists as legitimate reasons for authorship or inventorship. Finally, while more detailed than often-used bibliometric measures, our measures provide limited insights into the specific mechanisms that link social factors to authorship and inventorship decisions. In particular, our conceptual discussion raised constructs such as recognition and visibility in the scientific community as potential mediators between scientific accomplishment and attribution, but a lack of measures prevented us from more clearly examining these mediating mechanisms. Similarly, future research is needed to examine the degree to which the positive relationship between social factors and attribution reflects that junior scientists voluntarily include senior scientists to gain various types of benefits versus senior scientists actively “pushing” to be included on patents or papers.

Despite these limitations, our results provide novel insights into the functioning of the current authorship and inventorship system. As such, they may be useful for scientists themselves, as well as for administrators, policy makers, and social scientists who rely on patent and publication measures for a variety of purposes. Our findings may also be of use in efforts to improve the system for the benefit of all parties involved.

Acknowledgements

We thank Annamaria Conti, Aldo Geuna, Stuart Graham, Dietmar Harhoff, Diana Hicks, Francesco Lissoni, Elisabeth Mueller, Olav Sorenson, and Paula Stephan for valuable comments. C. Haeussler gratefully acknowledges financial support from the German Research Foundation (SFB TR 15) and from the Munich Center for Health Sciences. Both authors contributed equally to this paper.

References

Agarwal, R., Ganco, M., Ziedonis, R.H., 2009. Reputations for toughness in patent enforcement: implications for knowledge spillovers via inventor mobility. Strategic Management Journal 30 (13), 1349–1374.

Armstrong, J., Overton, T., 1977. Estimating nonresponse bias in mail surveys. Journal of Marketing Research 14 (3), 396–402.

Arora, A., Ceccagnoli, M., Cohen, W.M., 2008. R&D and the patent premium. International Journal of Industrial Organization 26 (5), 1153–1179.

Baron, R.M., Kenny, D.A., 1986. The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 51 (6), 1173–1182.

Bhandari, M., Einhorn, T., Swiontkowski, M., Heckman, J., 2003. Who did what?: (Mis) perceptions about authors’ contributions to scientific articles based on order of authorship. The Journal of Bone and Joint Surgery 85 (8), 1605–1609.

Biagioli, M., 2003. Rights or rewards. In: Biagioli, M., Galison, P. (Eds.), Scientifc Authorship – Credit and Intellectual Property in Science. Routledge, New York, pp. 253–279.

Bikard, M., Murray, F., 2011. Is collaboration creative or costly? Exploring tradeoffs in the organization of knowledge work. Working Paper.

Birnholtz, J., 2006. What does it mean to be an author? The intersection of credit, contribution, and collaboration in science. Journal of the American Society for Information Science and Technology 57 (13), 1758–1770.

Blume, S.S., 1974. Behavioural aspects of research management – a review. Research Policy 3, 40–76.

Butkus, B., 2007. Texas A&M's use of tech commercialization as basis for awarding tenure gains traction. biotechTransfer week. August 6, 2007 ed.

Cole, S., Cole, J.R., 1967. Scientific output and recognition: a study in the operation of the reward system in science. American Sociological Review 32, 377–390.

Collins, H.M., Evans, R., 2007. Rethinking Expertise. University of Chicago Press, Chicago and London.

Costas, R., Bordons, M., 2008. Is g-index better than h-index? An exploratory study at the individual level. Scientometrics 77 (2), 267–288.

Cronin, B., 2005. The Hand of Science: Academic Writing and its Rewards. Scarecrow Press, Lanham, MD.

Dasgupta, P., David, P., 1987. Information disclosure and the economics of science and technology. In: Feiwel, G. (Ed.), Arrow and the Ascent of Modern Economic Theory. New York University Press, New York, pp. 519–542.

Davidoff, F., 2000. Who's the author? Problems with biomedical authorship, and some possible solutions. Science Editor 23, 111–119.

Deichmann, U., Muller-Hill, B., 1998. The fraud of Abderhalden's enzymes. Nature 393 (6681), 109–112.

Drenth, J., 1998. Multiple authorship: the contribution of senior authors. Journal of the American Medical Association 280, 219–221.

Ducor, P., 2000. Coauthorship and coinventorship. Science 289 (5481), 873–875.

Eiben, C.B., Siegel, J.B., Bale, J.B., Cooper, S., Khatib, F., Shen, B.W., Players, F., Stoddard, B.L., Popovic, Z., Baker, D., 2012. Increased Diels-Alderase activity through backbone remodeling guided by Foldit players. Nature Biotechnology 30 (2), 190–192.

Fichman, M., Cummings, J.N., 2003. Multiple imputation for missing data: making the most of what you know. Organizational Research Methods 6 (3), 282–307.

Fini, R., Lacetera, N., 2010. Different yokes for different folks: individual preferences, institutional logics, and the commercialization of academic research. In: Libecap, G. (Ed.), Spanning Boundaries and Disciplines: University Technology Commercialization in the Idea Age, vol. 21. Emerald Group Publishing Limited, Santa Barbara, pp. 1–25.

Flanagin, A., Carey, L., Fontanarosa, P., 1998. Prevalence of articles with honorary authors and ghost authors in peer-reviewed medical journals. Journal of the American Medical Association 280 (3), 221–224.

Franzoni, C., Sauermann, H., 2012. Crowd science: the organization of scientific research in open collaborative projects. Working Paper.

Gans, J., Murray, F., Stern, S., 2010. Contracting over the disclosure of scientific knowledge: intellectual property protection and academic publication. Working Paper.

Hackett, E.J., 2005. Essential tensions. Social Studies of Science 35 (5), 787–826.

Haeussler, C., 2011. Information-sharing in academia and the industry: a comparative study. Research Policy 40 (1), 105–122.

Haeussler, C., Colyvas, J.A., 2011. Breaking the ivory tower: academic entrepreneurship in Germany and the United Kingdom. Research Policy 40 (1), 41–54.

Haeussler, C., Jiang, L., Thursby, J., Thursby, M., 2011. Sharing among competing researchers. Working Paper.

Harhoff, D., Hoisl, K., 2007. Institutionalized incentives for ingenuity – patent value and the German Employees' Inventions Act. Research Policy 36, 1143–1162.

Hirsch, J.E., 2005. An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United states of America 102 (46), 16569.

Jaccard, J., Wan, C., Turrisi, R., 1990. The detection and interpretation of interaction effects between continuous variables in multiple regression. Multivariate Behavioral Research 25 (4), 467–478.

Jensen, R., Pham, H., 2011. A stochastic life cycle model of academic research and patent licensing. Working Paper.

Johnson, J., Orbach, M., 2002. Perceiving the political landscape: ego biases in cognitive political networks. Social Networks 24 (3), 291–310.

Jones, B., 2009. The burden of knowledge and the "death of the renaissance man": is innovation getting harder? Review of Economic Studies 76 (1), 283–317.

Jones, B.F., Weinberg, B.A., 2011. Age dynamics in scientific creativity. Proceedings of the National Academy of Sciences of the United States of America 108 (47), 18910–18914.

Katz, J., Martin, B., 1997. What is research collaboration? Research Policy 26, 1–18.

King, G., Honaker, J., Joseph, A., Scheve, K., 2001. Analyzing incomplete political science data: an alternative algorithm for multiple imputation. American Political Science Review 95 (1), 49–69.

Kuhn, T.S., 1962. The Structure of Scientific Revolutions. University of Chicago Press, Chicago.

Kwok, L., 2005. The White Bull effect: abusive coauthorship and publication parasitism. Journal of Medical Ethics 31 (9), 554–556.

Lacetera, N., Zirulia, L., 2011. The economics of scientific misconduct. Journal of Law, Economics, and Organization 27, 568–603.

Lane, J., 2010. Let's make science metrics more scientific. Nature 464 (25), 488–489.

Latour, B., 1987. Science in Action: How to Follow Scientists and Engineers Through Society. Harvard Univ Press, Cambridge.

Latour, B., Woolgar, S., 1979. Laboratory Life: The Social Construction of Scientific Facts. Sage, Beverly Hills.

Laudel, G., 2002. Collaboration and reward: what do we measure by co-authorships? Research Evaluation 11 (1), 3–15.

Lehman, H.C., 1953. Age and Achievement. Princeton University Press, Princeton.

Levin, S.G., Stephan, P.E., 1991. Research productivity over the life cycle: evidence for academic scientists. American Economic Review 81 (1), 114–132.

Lintott, C.J., Schawinski, K., Keel, W., Van Arkel, H., Bennert, N., Edmondson, E., Thomas, D., Smith, D.J.B., Herbert, P.D., Jarvis, M.J., 2009. Galaxy Zoo:'Hanny's Voorwerp', a quasar light echo? Monthly Notices of the Royal Astronomical Society 399 (1), 129–140.

Lissoni, F., Montobbio, F., 2008. Inventorship and authorship in patent-publication pairs: an enquiry into the economics of scientific credit. CESPRI – University Bocconi. Working Paper.

Maciejovsky, B., Budescu, D.V., Ariely, D., 2009. The researcher as a consumer of scientific publications: how do name-ordering conventions affect inferences about contribution credits? Marketing Science 28 (3), 589–598.

Mainous, A.G., Bowman, M.A., Zoller, J.S., 2002. The importance of interpersonal relationship factors in decisions regarding authorship. Family Medicine 34 (6), 462–467.

Marx, M., Strumsky, D., Fleming, L., 2009. Mobility, skills, and the Michigan non-compete experiment. Management Science 55 (6), 875–889.

McSherry, C., 2003. Who Owns Academic Work? Harvard University Press, Cambridge, MA.

Merton, R.K., 1973. The Sociology of Science: Theoretical and Empirical Investigations. University of Chicago Press, Chicago.

Meyer, M., Bhattacharya, S., 2004. Commonalities and differences between scholarly and technical collaboration. Scientometrics 61 (3), 443–456.

Mowatt, G., Shirran, L., Grimshaw, J., Rennie, D., Flanagin, A., Yank, V., MacLennan, G., Gotzsche, P., Bero, L., 2002. Prevalence of honorary and ghost authorship in Cochrane Reviews. Journal of the American Medical Association 287, 2769–2771.

Murray, F., 2002. Innovation as co-evolution of scientific and technological networks: exploring tissue engineering. Research Policy 31, 1389–1403.

Murray, F., 2010. The Oncomouse that roared: hybrid exchange strategies as a source of distinction at the boundary of overlapping institutions. American Journal of Sociology 116 (2), 341–388.

Murray, F., Stern, S., 2007. Do formal intellectual property rights hinder the free flow of scientific knowledge? Journal of Economic Behavior and Organization 63, 648–687.

Oettl, A., 2012. Reconceptualizing stars: scientist helpfulness and peer performance. Management Science 58, 1122–1140.

Owen-Smith, J., 2001. Managing laboratory work through skepticism: processes of evaluation and control. American Sociological Review 66 (3), 427–452.

Pedhazur, E.J., Schmelkin, L.P., 1991. Measurement, Design, and Analysis: An Integrated Approach. Lawrence Erlbaum Associates, Hillsdale, NJ.

Podsakoff, P.M., MacKenzie, J.Y., Lee, J.Y., 2003. Common methods bias in behavioral research: a critical review and recommended remedies. Journal of Applied Psychology 88 (5), 879–903.

Rennie, D., Yank, V., Emanuel, L., 1997. When authorship fails: a proposal to make contributors accountable. Journal of the American Medical Association 278, 579–580.

Rogelberg, S., Stanton, J., 2007. Understanding and dealing with organizational survey nonresponse. Organizational Research Methods 10, 195–209.

Sauermann, H., Cohen, W., 2010. What makes them tick? Employee motives and industrial innovation. Management Science 56 (12), 2134–2153.

Sauermann, H., Roach, M., 2012. Not all scientists pay to be scientists: Heterogeneous preferences for publishing in industrial research. Working Paper.

Sauermann, H., Stephan, P., 2012. Conflicting logics? A multidimensional view of industrial and academic science. Organization Science, http://dx.doi.org/10.1287/orsc.1120.0769, in press.

Schafer, J.L., Graham, J.W., 2002. Missing data: our view of the state of the art. Psychological Methods 7 (2), 147–177.

Schrader, S., 1991. Informal technology-transfer between firms – Cooperation through information trading. Research Policy 20 (2), 153–170.

Scotchmer, S., 2006. Innovation and Incentives. MIT Press, Cambridge.

Seymore, S., 2006. My patent, your patent, or our patent? Inventorship disputes within academic research groups. Albany Law Journal of Science and Technology 16, 125–167.

Shulkin, D., Goin, J., Rennie, D., 1993. Patterns of authorship among chairmen of departments of medicine. Academic Medicine 68 (9), 688–692.

Simcoe, T., Waguespack, D., 2011. Status, quality, and attention: what's in a (missing) name? Management Science 57 (2), 274–290.

Simonton, D.K., 2003. Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. Psychological Bulletin 129 (4), 475–494.

Singh, J., Fleming, L., 2010. Lone inventors as sources of breakthroughs: myth or reality? Management Science 56 (1), 41–56.

Sismondo, S., 2009. Ghosts in the machine. Social Studies of Science 39 (2), 171–198.

Slone, R., 1996. Coauthors' contributions to major papers published in the AJR: frequency of undeserved coauthorship. American Journal of Roentgenology 167 (3), 571–579.

Stephan, P., 2012. How Economics Shapes Science. Harvard University Press, Cambridge.

Stephan, P.E., Levin, S.G., 1992. Striking the Mother Lode in Science. Oxford University Press, Oxford.

Stern, S., 2004. Do scientists pay to be scientists? Management Science 50 (6), 835–853.

Stokes, D., 1997. Pasteur's Quadrant: Basic Science and Technological Innovation. Brookings Institution Press, Washington, DC.

Stokes, T., Hartley, J., 1989. Coauthorship, social structure and influence within specialities. Social Studies of Science 19 (1), 101–125.

Stuart, T., Liu, C., 2010. Boundary spanning in a for-profit research lab: an exploration of the interface between commerce and academe. Working Paper.

Tarnow, E., 1999. The authorship list in science: junior physicists' perceptions of who appears and why. Science and Engineering Ethics 5 (1), 73–88.

Trajtenberg, M., Shiff, G., Melamed, R., 2006. The "names game": Harnessing inventors' patent data for economic research. NBER Working Paper # 12479.

Vallas, S.P., Kleinman, D.L., 2008. Contradiction, convergence, and the knowledge economy: the confluence of academic and commercial biotechnology. Socio-economic Review 6, 283–311.

Van den Steen, E., 2004. Rational overoptimism (and other biases). American Economic Review 94 (4), 1141–1151.

Von Hippel, E., 1987. Cooperation between rivals: informal know-how trading. Research Policy 16 (6), 291–302.

Ward, B., 1994. Undue credit for supervisors. Nature 368, 579.

Weinberg, B.A., Galenson, D.W., 2005. Creative careers: the life cycles of Noble laureates in economics. NBER Working Paper # 11799.

Wood, S., 2009. Ghost authorship on the wane, but guest authorship still common. Heartwire News, 9/11/2009 ed.

Wooldridge, J.M., 2001. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge.

Wuchty, S., Jones, B., Uzzi, B., 2007. The increasing dominance of teams in the production of knowledge. Science 316 (5827), 1036–1039.

Zuckerman, H., 1968. Patterns of name ordering among authors of scientific papers: a study of social symbolism and its ambiguity. American Journal of Sociology 74 (3), 276–291.

Zuckerman, H., 1988. The sociology of science. In: Smelser, N.J. (Ed.), The Handbook of Sociology. Sage, Newbury Park, CA, pp. 511–574.