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The Impact of Project Contributions and Social Factors on Authorship and Inventorship

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Abstract

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Jelcodes:L30,O31

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ABSTRACT

Using unique survey data from over 2,000 life scientists, 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. 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 contribution 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 managers, policy makers, and innovation scholars who often rely on patents and publications as measures of scientists' performance.

Keywords: Guest Authorship, Ghost Authorship, Attribution, Social Status, Project Contributions, Patent-Paper-Pairs

JEL-codes: O34, O31, L30

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 contributions listed authors and inventors have made to a project is becoming more and more difficult. Moreover, prior work suggests that authorship and inventorship 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). Discrepancies between substantive contributions and attribution have also been suggested in the realm of patents (cf. Lissoni and Montobbio, 2008; McSherry, 2003; Seymore, 2006).

While prior work has documented the existence of misattribution and has tried to quantify its prevalence (Ducor, 2000; Flanagin et al., 1998; Mowatt et al., 2002), a more general understanding of the determinants of authorship and inventorship status is lacking. A 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 authorships". Second, 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. Finally, much of the work on misattribution has been concerned with academic publications and little is known regarding similarities and differences in the factors associated with authorship on publications versus inventorship on patents. In particular, inventorship may be defined more strictly, perhaps leading to a stronger link between substantive contribution and inventorship attribution.

We complement prior work on the drivers of authorship and inventorship using novel survey data on life scientists working in Germany and the UK. We use data on over 2,000 academic and industrial scientists who indicated that they participated in projects that resulted in both a paper and a patent ("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).

We find that substantive contributions as well as social factors significantly shape attribution patterns. However, the drivers of authorship are not the same as those of inventorship. More specifically, inventorship appears to reflect 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 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: technical contributions are more likely to be rewarded with authorship if the focal scientist has a higher scientific or hierarchical status.

Our insights have important implications for institutional mechanisms that rely on a close link between substantive contributions and attribution. In the ideal "reward system of science", for example, publishing new knowledge leads to peer recognition, which in turn translates into additional benefits such as job security (tenure), funding for future research, or even opportunities to monetize knowledge via consulting or research collaborations with industry (Merton, 1973; Stephan, 2010b). Publications and the resulting indirect benefits thus serve as incentives to invest effort into the generation of new knowledge. If the link between substantive contributions and authorship is weak, however, this incentive mechanism is undermined (Lane, 2010; Rennie et al., 1997). Moreover, authorship reflects not only a reward, but it also establishes responsibility and accountability. As such, authorship serves as a basis of sanctions in cases of scientific misconduct, and disconnects between authorship and actual involvement in a project may impede the community's ability to enforce its norms (Zuckerman, 1988). Similar implications arise in the context of the patent system. Inventors who are listed in the patent document have the right to prevent others from using the invention, and the resulting financial returns can serve as an incentive for future research (Scotchmer, 2006). 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). Thus, flaws in the assignment of inventorship may directly affect the distribution of financial returns as well as professional recognition. 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)).

Our results also have important implications for the broader community of 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), individuals' movement 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 such studies, guest or ghost authorships are likely to increase measurement error and may lead to systematic biases if they are related to other variables of interest such as social status, network position, or past performance.

PROJECT CONTRIBUTIONS AND SOCIAL FACTORS AS DRIVERS OF ATTRIBUTION

Project Contributions

There is no generally accepted definition that specifies a minimum quantitative and qualitative level of contribution as a condition for being attributed authorship on scientific papers (Davidoff, 2000). However, the editors of a significant number of biomedical journals have formed the 'International Committee of Medical Journal Editors (ICMJE)', which has recommended specific criteria for authorship. According to these guidelines, there are three essential requirements for authorship attribution in a journal with peer review (ICMJE, 2010):

> *"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."*

However, even these guidelines are not free of ambiguity. Ducor's (2000) interpretation of these regulations is that the guidelines require that each author make a substantial contribution to the conception and design of a research project. Lissoni and Montobbio (2008), on the other hand, argue that the ICMJE guidelines allow for a high degree of heterogeneity in the contributions of authors. A closer look at the wording shows that the ambiguity arises due to the conjunction 'or' in (1) and (2). According to this more flexible interpretation, a conceptual contribution is not necessarily required and other types of contributions may also justifiably result in authorship.

In contrast to the relatively ambiguous criteria for authorship, inventorship is a legal concept and is defined somewhat more clearly. 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. In Germany, like in many other European countries, there is no legal text that provides a specific definition of the term inventor (§6 PatG). However, it is possible to make the following approximation of "inventorship" from the European Patent Convention: "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). Consequently, fulfilling the criterion of inventorship implies a creative and constructive effort. Based on the above discussion, we predict that the degree to which an individual has made a conceptual contribution to a project significantly increases 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 data and materials may increase the likelihood of inclusion as an author but should not lead to the inclusion as an inventor. Figure 1 summarizes the predictions made in this and the following sections.

Social Factors

As discussed earlier, the criteria for authorship and, to a lesser extent, inventorship, leave room for interpretation. Moreover, even if criteria have been established – as in the case of the ICMJE – they are often ignored (Bates et al., 2004; Hwang et al., 2003; Stokes and

Hartley, 1989). To the extent that authorship and inventorship do not reflect substantive contributions, they may reflect various social factors.

First, individuals in higher hierarchical positions (e.g., laboratory heads) may be included as co-authors by their subordinates because this attribution creates a good relationship with the supervisor or might even "… be a matter of convention" (Shulkin et al., 1993, p. 688). It expresses respect and gratitude, strengthens the supervising efforts, and signals the laboratory head's approval of the content of the paper (Owen-Smith, 2001). Consistent with this notion, Tarnow (1999) and Claxton (2005) report instances of guest authorships that served the purpose of maintaining social ties or of acknowledging senior researchers who provided laboratory space or financial support. 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, whereby it does not matter if he or she has made a significant contribution. While these arguments suggest that junior authors may sometimes decide to "give" guest authorship to superiors, Zuckerman's (1968) work suggests that authorship decisions are often delegated to senior investigators, who base their judgment on both contribution and seniority, i.e., may in some cases "take" guest authorship.

Second, authorship attribution may also be a function of scientific accomplishment and status in the scientific community – as distinct from the hierarchical position in a particular organization. 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). High-status co-authors may also increase the visibility of a paper once published because other scientists use author names as a signal of quality when deciding which papers to read (cf. Simcoe and Waguespack, 2011). At the same time, accomplished co-authors may capture a particularly large share of the peer recognition, an effect commonly known as “Matthew effect” (Merton, 1973). The Matthew effect may offset some of the benefits of including senior authors from the junior authors’ perspective, and Zuckerman (1968) reports that senior scientists sometimes choose not to appear as co-authors to ensure that their junior colleagues receive proper credit (a rationale characterized as “noblesse oblige”). Moreover, while accomplished scientists may have an interest in further increasing their reputation by appearing as “guest authors” on publications, they run the risk of diluting their reputation if these publications turn out to be of low quality (Owen-Smith, 2001). While it is not clear ex ante how strong these potentially offsetting effects are empirically, we predict a positive net effect of status in the scientific community on authorship attribution, controlling for the focal scientist’s substantive contributions.

Even though much of the prior evidence on the role of social factors relates to the attribution of authorship on publications, they may also play a role in the context of inventorship on patents. For example, Seymore (2006) reports that senior scientist are often the ones who decide whose name appears on the inventor list, which might result in seniors being overrepresented. Similarly, individuals in higher hierarchical positions may be included as inventors to facilitate internal reviews and approvals of patent applications. In a recent study, Lissoni and Montobbio (2008) find 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. Despite this evidence that social factors may influence inventorship decisions, we expect that social factors play less of a role in the attribution of inventorship than in the attribution of authorship. One reason is that the criteria for inventorship are more clearly defined on the basis of a conceptual contribution, thus leaving less latitude to assign inventorship based on social criteria. Moreover, assigning guest inventorship may come at a considerable economic cost to those who made a substantive contribution because income from a patent typically has to be shared with all listed inventors (Harhoff and Hoisl, 2007). Finally, 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 may be less responsive to the inventor's status within the scientific community. Similarly, while senior co-authors may increase the visibility of a published paper, the financial value of a patent depends less on its visibility in the scientific community, thus reducing the benefits that can be gained from including an accomplished co-inventor.

It is important to note that mere correlations between social factors such as status in the scientific community and authorship or inventorship do not necessarily imply causal effects, i.e., they do not imply that high-status individuals appear on patents or papers *because* of their status per se. Scholars of science have long argued that social status is positively related with ability and scientific productivity, whereby the causality may run in both directions (Cole and Cole, 1967; Fox, 1983; Simcoe and Waguespack, 2011). Thus, high-status scientists may be more likely to appear on papers not because they receive (or take) "guest authorship" but because they tend to make more important substantive contributions. In particular, high-status scientists may be more likely to provide the initial conceptual idea for a project while junior scientists carry out much of the laboratory work (Seymore, 2006). Even though conceptual contributions may take less time than laboratory work or other types of contributions, they are often seen as the most important type of contribution and should legitimately result in authorship and inventorship (see our discussion of authorship and inventorship guidelines above). Thus, 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. Before we turn to our empirical analysis, however, we consider the possibility that the effects of substantive contributions and social factors are not simply additive, but that these factors interact in more complex ways.

Interactions between Substantive Contributions and Social Factors

Substantive contributions and social factors are typically considered as independent (and competing) influences on authorship or inventorship. 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 than for a low-status scientist. Our rationale is that, if junior-level project contributors desire to include senior scientists 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 senior scientist who seeks to become an author, a relatively small level of contribution may provide sufficient grounds to do so. In contrast, the same level of substantive contribution by a junior scientist will increase her chances of authorship less strongly. A similar logic may apply to status based on scientific accomplishment, i.e., a given level of substantive contribution may have a stronger effect on authorship 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 tend to be more clearly defined than those for authorship. Some ambiguity remains, however, and 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 useful justification to do so, again suggesting a positive interaction between hierarchical status and (conceptual) contribution. In contrast, we predicted no significant benefits of including scientists with a high status in the scientific community as inventors and we also do not expect an interaction between substantive contributions and status in the scientific community in predicting inventorship. Figure 1 summarizes our predictions.

Figure 1 about here

DATA AND MEASURES

Sample and Identification of Patent-Paper-Pairs

Our empirical analysis draws on data from a survey administered in 2007 to a sample of German and British life scientists. We identified potential respondents in two ways. First, we sampled life scientists that are listed between 2002 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 8,189 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 life sciences IPC codes with the European Patent Office between 2002 and 2005, resulting in 8,265 German and 4,196 British inventors. We invited these scientists 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.

A total of 2,169 scientists identified through PubMed and 2,452 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, 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. Due to this desirable property, patent-paper-pairs have been used in prior work on scientific attribution. For example, Ducor (2000) performed a manual search of databases for proteins with specific genetic or aminoacid sequences. He identified 40 patent-paper-pairs and showed that the authors on the papers do not always match the inventors on the corresponding patents, providing first evidence that authorship and inventorship may be driven by different processes. 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 2,191 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, 2010; 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 empirical strategy over prior work using bibliometric measures is that we can examine not only one type of attribution but can directly compare potential drivers of both inventorship and authorship. Moreover, our survey data allow us to obtain measures of different types of project contributions and of social factors that are difficult to obtain from patent and publication records.

Measures

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

Table 1 about here

Authorship and inventorship

We asked respondents if they were named as author on the publication and as inventor on the patent resulting from the focal research project.[2] Ninety-five percent of the scientists

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[1] 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.

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. The rate of authorship is significantly higher than that of inventorship, consistent with prior work showing that the number of authors on papers tends to be higher than the number of inventors on patents (Ducor, 2000; Lissoni and Montobbio, 2008). It is also consistent with the notion that the criteria for inventorship are more strictly defined than those for authorship. At the same time, 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 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.

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). The variable *conception/idea* measures the extent to which the respondents agree that they have contributed to the inventive idea of the project and shows a mean of 3.81. The variable *laboratory work* measures the extent to which the respondents carried out the important technical steps or laboratory work required for the project (mean 3.16). Finally, the variable *material/data* measures the extent to which the respondents contributed important material or data.

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[2] 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.

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 are likely 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). While overall levels of reported contributions should be interpreted with caution, we do not expect such reporting biases to be systematically related to other key dependent or independent variables. 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 underlying driver of our results. However, respondents' tendency to inflate their own contributions may reduce the variation in our measures of project contributions, potentially leading to conservative estimates of the effects of these variables. Despite its limitations, our approach provides important complementary insights to other approaches. In particular, an 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 status and project contributions and may thus provide little insight into the relative role of these two factors.

Social Factors

Our conceptual discussion distinguished two types of social factors: (1) hierarchical position within an organization and (2) status in the scientific community. As a proxy for the former, we use the number of individuals directly reporting to the focal scientist. The variable *hierarchical position* equals one if no employee is directly reporting to the respondent, two if 1 to 3 employees report, three if 4 to 7 employees report, four if 8 to 15 employees report and five if more than 15 employees report to the respondent.

We do not have a direct measure of status in the scientific community. However, we suggest that a measure of scientific accomplishment such as the number of peer-reviewed publications can serve as a useful proxy. There is a long line of literature suggesting that publications lead to peer recognition and status in the scientific community; indeed, the positive effect of publications on status and recognition is the key incentive mechanism in the institution of science (Cole and Cole, 1967; Merton, 1973; Stephan, 2010b). The positive correlation between scientific accomplishments and status may be further increased due to “cumulative advantage”, e.g., if status provides access to resources for research and thus facilitates future performance (Arora et al., 1998; DiPrete and Eirich, 2006; Merton, 1973). Assuming that publications and status in the scientific community have a significant positive correlation, we use respondents’ self-reported total number of peer-reviewed publications as proxy for status in the scientific community. 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 (*scientific accomplishment*).[3]

Table 2 shows that scientific accomplishment and hierarchical position are correlated positively (0.27, 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, 2010a; 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.

Control Variables

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

Teamsize 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

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[3] 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.

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, 2010). 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.

Table 2 about here

MULTIVARIATE ANALYSIS

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).

Table 3 about here

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 positive effect on inventorship but not on authorship. In contrast, *scientific accomplishment* has a positive effect on authorship but not inventorship. As discussed earlier, positive coefficients of *hierarchical position* and *scientific accomplishment* may reflect "guest authorships" due to status per se, but they may also reflect that high-status individuals make more important substantive contributions to the focal project. In an attempt to separate the two mechanisms, model 3 includes the measures of contributions in addition to the measures of status. 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. Controlling for contributions does not noticeably change the effect of scientific accomplishment on authorship, suggesting that status in the scientific community may indeed increase authorship attribution, even controlling for the nature of an individual's contribution. Model 3 also shows that contributions in the form of material/data have a positive effect on authorship once status measures are included.

Finally, we suggested that substantive contributions and social status 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. Two significant interaction terms emerge in the authorship regression. 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 status in the scientific community. These positive interactions are in line with our conceptual discussion suggesting that even small substantive contributions may provide sufficient justification to gain authorship for 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. 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 (Levin and Stephan, 1991). 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 do not find any authorship or inventorship differences between scientists working in the UK versus Germany, or between female and male scientists.[4]

Auxiliary Analyses

Since our main analysis focuses on authorship and inventorship as dependent variables, it provides only limited insights into “ghost authorship”, 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. 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

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[4] 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 as co-authors and co-inventors, 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.

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 unreported 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 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 technical/laboratory work or by providing data or materials. Prior scientific accomplishments are positively associated with conceptual contribution and negatively associated with laboratory work but not with contributing data or materials. 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 reported in table 3).

Finally, we entertain the possibility that the drivers of authorship and inventorship attribution differ between scientists working in industry and those working in academia. For this purpose, we split the sample and estimate key regressions using the subsamples of industrial and academic scientists, respectively (table 6). Most of our key results hold across sectors, including the positive relationship between conceptual contributions and both types of attribution as well as the positive relationships between scientific accomplishment and authorship, and between hierarchical position and inventorship. 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, 2010), and that the two sectors may further "converge", especially in the life sciences (Murray, 2010; Vallas and Kleinman, 2008).

Tables 4-6 about here

DISCUSSION AND CONCLUSION

An increasing number of studies provide anecdotal evidence of misconnects between substantive contributions and authorship. Similar observations have been made in the context of patenting. 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 compare the drivers of authorship on papers and of inventorship on patents. Second, our survey-based study allows us to directly measure various dimensions of project contributions and to separate such contributions from scientists' social status. 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 status allow us to examine not only the main effects of these two sets of factors, but also potential interaction effects, i.e., whether a given level of project contribution has different effects on attribution depending on a scientist's social status.

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 – our proxy for status in the scientific community - 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. Even though 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 likely to make conceptual contributions; however, it may additionally reflect that co-inventorship by supervisors facilitates the internal processes required for filing a patent application or that supervisors make other types of contributions that are not captured in our data. Third, we find interactions between project contribution and social status; more specifically, contributions in the form of laboratory work are more likely to be rewarded with authorship when made by accomplished scientists.

Taken together, our results suggest that authorship on publications reflects a heterogeneous set of factors including conceptual contributions but also other types of 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, they provide further evidence that inventorship and especially authorship may reflect different types of substantive contributions as well as social factors. 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 in interpreting and evaluating patent and publication output. Our results may be particularly important for social scientists. 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.[5] Thus, it is conceivable that the decrease in "true" performance in later stages of a

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[5] Interestingly, 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

scientist's life cycle is even larger than estimated using publications as measure of scientific productivity (cf. Levin and Stephan, 1991). 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 "guest authorship" and "ghost authorship", 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 our discussion of "guest" and "ghost" authorship used the existing authorship and inventorship guidelines as the standard against which practices were compared, this approach does not reflect the view that current guidelines are perfect and deviations from these guidelines are unethical. Rather, the goal of our empirical analysis was to examine the drivers of authorship and inventorship and to assess how well scientists' practices are aligned with the formal standards. While some of our results could be interpreted as reflecting undesirable deviations from explicit standards, they could also be interpreted as evidence that the current 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. Birnholtz (2006) suggests that such ambiguities lead to the use of alternative mechanisms such as word-of-mouth recommendations, the ability to "get noticed", or judgments based on how scientists present themselves in informal seminars and talks. This

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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.

system has its own limitations, however, including potential team disputes about who presents research results and lower visibility of persons who conduct excellent research but prefer to stay in the background. Moreover, such a system seems inefficient as research becomes more and more multidisciplinary and international.

A promising approach towards improving the current system is the idea of contributorship, which is the outcome of discussions within the biomedical community and has been laid out by Rennie et al. (1997). These authors propose to use the term “contributor” rather than “author”, where a contributor is a person who “has added usefully to the work” (Rennie et al., 1997, p. 583). 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 also provide information about individuals’ responsibility for particular tasks (Biagioli, 2003), which may help in fighting scientific misconduct and fraud (Deichmann and Muller-Hill, 1998; Lacetera and Zirulia, forthcoming). While some journals such as Nature and the Proceedings of the National Academy of Sciences have moved in the direction suggested by Rennie et al. (1997), many journals – especially outside of the biomedical sciences – still rely on traditional attribution practices.

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Figures

Figure 1: Summary of predictions

	Authorship on Paper	**Inventorship on Patent**
Substantive contributions		
Conceptual	++	++
Technical	+	0
Data and materials	+	0
Social Factors		
Hierarchical position	+	+
Status in the scientific community	+	0
Interaction effects		
Hierarchical position x Contributions	+	+
Status in community x Contributions	+	0

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 for publication	3.58	1.04	1	5
Reputation for 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: 2,191 observations; (d) indicates binary variable.

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 Teamsize	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**

Note: ** indicates $p<0.01$, * indicates $p<0.05$.

Table 3: Authorship and inventorship (bivariate probit)

	1		2		3		4	
VARIABLES	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 x Conception/idea							0.005	-0.059
							(0.039)	(0.033)
Sci. accomplish x Laboratory work							0.127**	-0.002
							(0.042)	(0.035)
Sci. accomplish x Material/data							0.059	-0.074
							(0.049)	(0.044)
Hierarchical position x Conception/idea							0.016	0.034
							(0.041)	(0.033)
Hierarchical position x Laboratory work							0.105**	-0.062
							(0.041)	(0.035)
Hierarchical position x 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 teamsize	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	2,191		2,191		2,191		2,191	
chi2	199.8		187.7		280.9		196.3	
ll	-813.7		-815.9		-760.1		-737.0	

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

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

	1		2		3	
VARIABLES	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 teamsize	-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	1,355		1,355		1,355	
chi2	51.17		91.12		97.51	
ll	-321		-294.4		-290.4	

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

Table 5: Project contributions (ordered probit)

	1	2	3
VARIABLES	Conception/idea	Laboratory work	Data/material
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	2,191	2,191	2,191
chi2	136.6	273.4	72.57
ll	-3048	-3300	-2688

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

	Industrial scientists						**Academic Scientists**					
	1		2		3		4		5		6	
VARIABLES	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 teamsize	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	1,032		1,032		1,032		1,159		1,159		1,159	
chi2	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, ** indicates p<0.01, * indicates p<0.05