The perception of scientific authorship across domains

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Abstract

We extend previous research by systematically investigating whether perceptions of scientific authorship vary between domains. Employing regulations for authorship of scientific journals as well as the Scientists Survey 2016 conducted by the German Centre for Higher Education Research and Science Studies (DZHW), we provide a comprehensive picture of perceptions of scientific authorship across domains from the perspective of the supply side (journals) as well as the demand side (researchers). We find considerable differences in the perception of authorship across disciplines on both sides. Hence, not only domain-specific "formal norms", but also domain-specific statements about ideals can be observed with regard to scientific authorship. The results have important implications: in order to avoid that researchers in disciplines with much narrower definitions of authorship are disadvantaged when compared to their colleagues from disciplines that rely on broader authorship definitions, domain-specific perceptions of authorship should be taken into account when allocating funding and jobs.

Keywords

Perception of scientific authorship; Co-Authorship; Publication ethics; Disciplinary cultures

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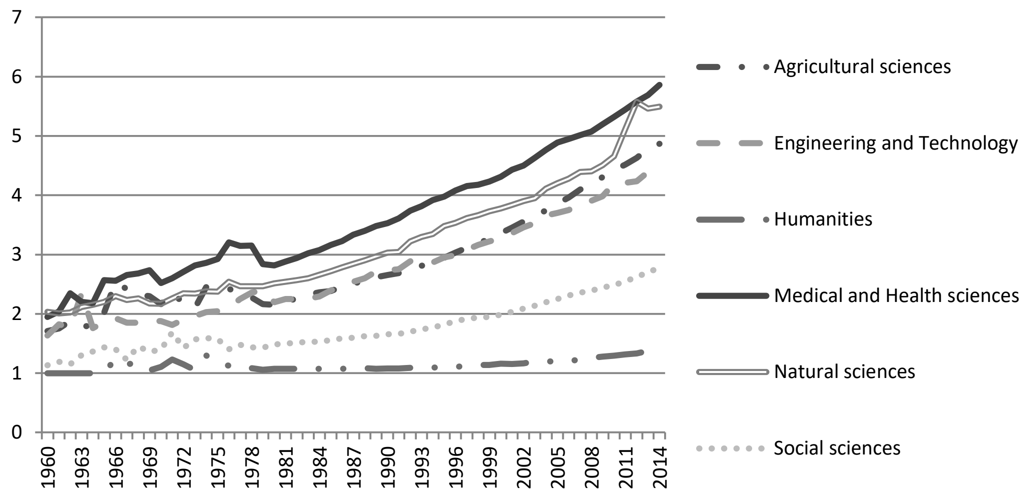
1 Introduction

In May 2015, the scientific paper with the largest ever number of co-authors was published: over 5,100 individuals were named as co-authors of an article on the measurement of the Higgs boson mass (Aad et al. 2015). Admittedly, this is an extreme case, but it illustrates a development that is not unique to research in Physics. The number of co-authors listed per publication is on the rise in almost all scientific domains (Cunningham and Dillon 1997; Glänzel 2002; Hudson 1996; Levsky et al. 2007; Sin 2011).
Indeed, this is not a new phenomenon. As de Solla Price (1989: 79) already stated, the exponential growth in science causes a steady move towards an infinity of co-authors per paper. Figure 1 illustrates this development. Over the period from 1960 to 2014, the average number of authors per publication has increased from 2.0 to 5.2, but the mean number of authors per publication differs across domains. For example, in the Natural Sciences, the average number of authors increased from 2.0 to 5.5. In other domains, such as the Social Sciences and Humanities, the average number of co-authors has only marginally increased and single-authored publications are still widespread (see also Glänzel 2002; Engels et al. 2012; Lissoni et al. 2013; Mayer 2016).[1]

Figure 1: Mean number of authors per publication 1960-2014 by domain



Calculation bases: All available publications in the Web of Science data base that were published between 1960 and 2014, document types article, letter, or review.

However, Figure 1 also illustrates something else: even though large differences in the rise of the number of co-authors per publication are visible across domains, the relative ordering of domains remains stable. For example, the mean number of authors per publication in the Medical and Health Sciences as well as the Natural Sciences has been notably higher across time when compared with Social Sciences or Humanities. This development raises the question what determines the ordering in the mean number of authors across domains. One potential explanation might be that not only scientific processes and practices, but also perceptions of authorship vary substantially between domains.
Most of the more general definitions of scientific authorship highlight that a *substantive* or *significant* contribution is a necessary condition to be considered as an author of a publication

[1] We build on previous studies that analyze the development of the number of co-authors by looking at the *mean* number of authors per paper. One might argue that the mean may be distorted by hyper-authorship publications occurring first and foremost in the Natural Sciences. Therefore, looking at the *median* instead might be the better choice. However, analyzing the median number of authors per paper lead to similar results.

(e.g., American Sociological Association 1999; Elsevier 2015). This coincides with the view of one of the most important research funding organization in Germany, the German Research Foundation (DFG), which states that only those researchers should be listed as authors of a scientific publication who *simultaneously* contributed substantively to the underlying study/studies, the collection, analysis, and interpretation of the data *as well as* the drafting of the manuscript (Deutsche Forschungsgemeinschaft 2013). The above-mentioned definitions of scientific authorship may convey the impression that authorship is clearly regulated, but it is in fact a frequently discussed topic in many disciplines (e.g., Flanagin et al. 1998; Levsky et al. 2007; Marušić et al. 2006; Smith 2012). Previous studies agree that it depends on the discipline whether or not specific tasks/activities are considered as sufficient to grant authorship (e.g., Jabbehdari and Walsh 2017). However, they fail to explore individual authorship perceptions *in detail* and *across all scientific domains,* especially concerning the notion what tasks are deemed sufficient to be named as an author. In other words, a *systematic* examination of the perceptions of authorship across scientific domains has remained undone. If domain-specific perceptions of authorship prevail, then authorship is unlikely to be attributed equally across different domains. This, in turn, may have severe consequences for the allocation of funding and the evaluation of researchers.

In the following, we systematically investigate whether different scientific domains indeed display different perceptions of authorship. We do so by, firstly, studying regulations for authorship of scientific journals and, secondly, analyzing the Scientists Survey 2016 conducted by the German Centre for Higher Education Research and Science Studies (DZHW). The Scientists Survey 2016 allows us to circumvent limitations previous studies have faced with regard to scientific authorship. Hence, we add to previous research by providing a more comprehensive picture of perceptions of authorship across domains from the perspective of the supply side (scientific journals) which act as formal norm-setters, as well as the demand side (researchers). As we are unable to study behavior on the demand side by analyzing author contributions to specific publications (e.g., who was included as an author, who was omitted), we focus on the attitudinal level, the internalized norms of scientists, because we are interested in the individuals' perceptions.

The article is structured as follows: We begin by discussing different functions of authorship and disciplinary differences in authorship practices, before we set out the research gap and formulate our assumptions. In the empirical part of the paper, we start by reviewing the different journals' author guidelines across various domains. Next, we investigate perceptions of authorship within the German scientific community using the Scientists Survey 2016. Thereby, we also quantify the probability of being a certain *type of researcher* adhering to specific perceptions of authorship depending on the domain. We close with a discussion about the implications of our study.

2 Theoretical Considerations, Current State of Research and Assumptions

2.1 Functions of Authorship

Traditionally, authorship fulfills three functions: First, authorship attributes *credit* because it expresses and signals the ideas and output the authors contributed to their field (Claxton 2005; Birnholtz 2006). Second, and related to the first purpose, authorship contributes to an individual's *reputation* (Birnholtz 2006; Johann and Neufeld 2016). Being an author of a publication adds to the symbolic capital of a scientist, i.e., it contributes to the social recognition by competing scientists in a specific field (Bourdieu 1975). Moreover, authorship is most certainly a necessary condition to acquire citations which Merton (1988) calls "pellets of peer recognition that aggregate into reputational wealth." The "scientific credit" (Biagioli

2003) and reputation gained by publications is a necessary precondition for authorship to be turned into real wealth, as publication and citation numbers are today widely used as criteria in tenure procedures, the award of fellowships, and the allocation of third-party funds and grants (Birnholtz 2006; Whitley 2000; Jabbehdari and Walsh 2017). Accordingly, scientific authorship is the primary academic currency (Kwok 2005; Bennett and Taylor 2003; Dance 2012). Third, authorship also ascribes an author's *responsibility* to a certain piece of work. Authors may be attributed credit for a particular manuscript or discovery, but they also have to take responsibility for the claims they make, the ethical integrity of their research and potential mistakes they make (Birnholtz 2006). This function is especially important in biomedical research as their results may have implications for public health (Biagioli 1998). When scientific papers are published by a single author, authorship commonly indicates that this author came up with the research idea, conducted the research, and wrote the manuscript. Accordingly, the author receives all credit and the reputation and is exclusively responsible for all potential errors (Biagioli 2003; Bently and Biron 2014). In the early twentieth century, academic publications were usually single-authored. Hence, it was relatively easy to determine who should be credited for the work as well as being held responsible for the results and potential mistakes.

However, as set out above, co-authorship is on the rise. The reasons for this development are manifold. As Lissoni et al. (2013) point out, (a) scientific work is increasingly specialized, which comes along with the necessity of larger teams of scientists to contribute their expertise, and (b) it is also increasingly important to share data and facilities, which generates multi-team research accompanied by multi-author publications (see also Katz and Martin 1997; Ponomariov and Boardman 2016; Teixeira da Silva and Dobranszki 2016; Jones et al. 2008). For example, large research groups in Physics may grant authorship for every publication from the lab to all scientists who at least worked on the group's experiments for one year and a certain amount of time, regardless of what they have eventually contributed to the publication (Biagioli 2003). In addition, phenomena such as ghost and gift authorship are increasingly observable (e.g., Wislar et al. 2011; Teixeira da Silva and Dobranszki 2016; Jabbehdari and Walsh 2017). This might be due to the development that publication records have become more and more important in relation to allocating funds, jobs and salary (e.g., Jiménez-Contreras et al. 2003; Liefner 2003; Birnholtz 2006). For example, researchers may be more inclined to gift authorship to successful colleagues because they may expect to increase their chances of publication in a top-journal. Recent developments in the Life Sciences[2] even indicate that Foucault's (1969) characterization of the author as a functional principle has some truth, as the understanding of authorship has seemed to move away from the author as a genial creator of text towards a person that merely gives meaning to text by their name (Logdberg 2011; The PLoS Medicine Editors 2009; Wager 2007a). It is therefore not surprising that studies on authorship criteria of academic journals imply that publications in Natural Sciences and Medicine often list at least one author that does not match the journals' authorship criteria (Hwang et al. 2003; Šupak-Smolčić et al. 2015; Wislar et al. 2011; Goodman 1994; Malički et al. 2012).

Whatever the reasons for the rise in co-authorship might be, it certainly has consequences for the core functions commonly associated with authorship. As Biagioli (2003) puts it, "scientific authorship is losing (or has already lost) its role as the containment vessel for credit and responsibility". In other words, the larger the number of co-authors per paper the more ambiguous it becomes who contributed how much, and to which parts of the publication, who should merit credit and earn reputation, and who is responsible for potential errors (Lissoni et al. 2013; Birnholtz 2006).

[2] For example, studies conducted by professional medical writing companies that recruit academics with a high reputation as alleged authors.

2.2 Disciplinary Differences

A large portion of the literature dealing with the functions of authorship either takes a sociological perspective and examines phenomena such as the meaning of reputation (Cronin 2005; Biagioli 2003; Riesenweber 2014) or it investigates how authorship is translated into credit and reputation, e.g., by focusing on how publications and their citations can be used to calculate measures such as the h-index (Walters 2015; Adler et al. 2009; Waltman 2015; Rahman et al. 2017). Current research on credit attribution and reputation of multi-author publications especially focuses on the conventions of researchers (a) who should be listed as author of particular publications and (b) how to create markers that indicate how much and to which parts they have contributed. Both strands of research emphasize domain-specific peculiarities.[3]

Regarding the latter, large parts of the scientific world have agreed to attribute meaning to the order of authors in publications to enable readers of papers to identify the authors who should be granted the most credit and thus establish a better reputation. However, how to practically implement this when the order of authors of multi-author publications is concerned differs from domain to domain and sometimes even within domains (see, also for the following, Tscharntke et al. 2007; Dance 2012; Igou and van Tilburg 2015; Teixeira da Silva and Dobránszki 2015): In the Social Sciences, for example, it is common practice to either list the authors in alphabetical order, indicating that all authors contributed equally, or to start with the author who made the largest contribution, followed by the author who did the second largest, and so forth, indicating a decline in the importance of each author's contribution. In other domains, primarily such domains where research is done in labs (e.g., Biomedical Sciences), it is more common that the first and the last author are granted most credit because, as Tscharntke et al. (2007) put it, the last author "is assumed to be the driving force, both intellectually and financially, behind the research." In Mathematics and Theoretical Computer Sciences, in turn, it is common to list authors alphabetically regardless of how much they contributed. Hence, for outsiders who do not know the domain-specific peculiarities it is hardly possible to know how much an individual co-author actually contributed.

Regarding the former conventions, drawing on contribution statements requested by some journals, Larivière et al. (2016) reveal that - with the exception of medicine where a division of labor is relatively common - being involved in writing the main text is the task that is usually associated with authorship. However, previous studies show that authorship seems to be anything but an unequivocally defined concept, as it may rather reflect various activities or functions of the research and writing process. These range from substantive contributions to the manuscript to technical contributions, laboratory work, the provision and coding of data or materials, to project conceptualization or fundraising (e.g., Laudel 2002; Haeussler and Sauermann 2013). Accordingly, Haeussler and Sauermann (2013) state that "authorship can be granted for a wide range of contributions, including those that are not conceptual in nature" and that it "may also reflect social mechanisms that are relatively independent of actual contributions." Moreover, a study by Jabbehdari and Walsh (2017) relying on a survey conducted with the relevant corresponding authors in ten different disciplines shows that including people who only made specialized contributions (i.e., guest authorship) as well as excluding people who significantly worked on the project (i.e., ghost authorship) as authors is common practice. Jabbehdari and Walsh (2017) conclude that authorship is a trade-off of individual characteristics and the collaboration structures through negotiation.

[3] Please note that co-authorship practices may not only vary between domains, but also between publication types (e.g., articles, book chapters) within the same domain, even though to a smaller degree.

2.3 Research Gap and Approach

In sum, past research indicates that authorship practices vary across disciplines (e.g., Teixeira da Silva 2011; Teixeira da Silva and Dobranszki 2016; Jabbehdari and Walsh 2017). This is no surprise, as scientific fields act as social contexts shaping researchers' attitudes and holding a specific set of conventions established *inter alia* by major organizations in the field (Whitley 2000; Becher 1994). However, research so far suffers from data limitations. Previous studies on the supply side, i.e., journals and their authorship guidelines, have been predominantly conducted in a single specific field, mostly (bio)medicine (Bošnjak and Marušić 2012; Wager 2007b; Marušić et al. 2011). Prior research on the demand side, i.e., researchers, suffer from limited survey data from individual domains (e.g., Haeussler and Sauermann 2013), base their conclusions on the analyses of contribution statements or surveys among corresponding authors (Hwang et al. 2003; Larivière et al. 2016), or rely on bibliometric data consisting of article metadata, e.g., the number of co-authors, the order of authors' names, or the authors' affiliations only (e.g., Igou and van Tilburg 2015; Leydesdorff et al. 2014; Waltman 2012; West et al. 2013). A systematic examination of researchers' internalized authorship norms is still pending (see also Jabbehdari and Walsh, 2017). It is thus necessary to explore individual authorship perceptions in more detail.

We contribute to previous research by providing a more comprehensive picture of perceptions of authorship across domains from the perspective of the supply side as well as the demand side. This is crucial in order to fully understand the domain-specific authorship practices and their repercussions. In particular, we aim to answer two core research questions: (1) Do various domains differ with regard to perceptions of authorship on both sides, as previous findings suggest? (2) Are differences across domains on the level of journal criteria reflected in scholars' authorship perceptions on the individual level? We expect to find domain-specific peculiarities of authorship as a result of the domain-specific cultures. For example, researchers in the Natural Sciences and Engineering and Technology may be more likely to have a broader understanding of authorship than those in the Social Sciences and Humanities, because in the former domains strict labor division is more common than in the latter. Journals are supposed to consider such domain-specific peculiarities in their guidelines. Moreover, journals act as formal norm-setters and researchers follow the guidelines established by such norms.

In order to answer our research questions, we systematically examine the authorship guidelines of leading journals in the various domains. Next, we explore researchers' authorship perceptions across different domains. Thereby, we build on previous studies on and theoretical considerations about authorship and distinguish ten activities or functions that may be crucial for being listed as an author (e.g., Laudel 2002; Böhmer et al. 2011; Haeussler and Sauermann 2013). Our classification of domains is based on the Field of Science and Technology (FOS) classification system specified by the OECD, which groups the different subject fields into six major domains: Agricultural Sciences, Engineering and Technology, Humanities, Medical and Health Sciences, Natural Sciences, and Social Sciences.[4]

In the following section we set out our data and approach in more detail.

[4] The FOS provides 42 minor fields such as Psychology and Medical Engineering within the major fields. However, we will only use the major field classification in this study as case numbers are too low for using the more detailed minor field classification.

3 Data and Method

3.1 The Supply Side (Journals)

Nowadays, researchers disseminate their scientific output first and foremost by publication in academic journals. Hence, it may be the normative regulations for authorship in (leading) journals that determine how researchers think about authorship, rather than the rules provided by relevant research funders. High-impact-factor journals act as a reference point and provide orientation for lower-tier journals from the domain. For instance, we already know that high impact journals are more likely to have ethics policies than other journals (Resnik et al. 2009). For every domain, we randomly selected 10 out of 100 journals with the highest Journal Impact Factor[5] (JIF) as recorded by the Web of Science[6] in 2014 (see Table OA1 in the online supplementary material)[7]. We collected the authorship guidelines of each journal as available on their web pages. In order to code the authorship guidelines, we developed a coding scheme on the bases of theoretical considerations and previous studies distinguishing between ten activities or functions that are deemed as crucial for being listed as author by journal editors. For reasons of comparability, these activities or functions correspond with the activities or functions we will focus on below, when investigating the perceptions of authorship within the German scientific community. We differentiate between explicit and implicit statements, where the former refers to the activity or function that is directly addressed (e.g., "We recommend that authorship be based on the following criteria…") and the latter to vague definitions without further specification of tasks (e.g.,: "Authors whose names appear on the article have contributed sufficiently to the scientific work"). With regard to the implicit activities or functions, we assume that they comprise all possible types of contributions. The coding of each activity/function is dichotomous, the number of mentions within the particular authorship guidelines was not considered. Cases where specific activities or functions are explicitly named as exclusion criterion are coded separately. To assess inter-coder reliability, coding was conducted by two coders separately. The agreement for the coding of the journal guidelines can be considered as sufficient (Holsti intercoder reliability coefficient = 0.70). Any diverging classifications were re-assessed by the second author.

3.2 The demand side (researchers)

The demand-side analyses are based on the DZHW-Scientists Survey 2016. This survey was conducted from March to May 2016. The population was all professors and mid-level researchers at German universities. The sampling followed a two-stage cluster design with a 40 per cent proportionate stratified random sample at the first stage (59 out of 152 universities) and a sample of the respective research staff's email addresses compiled from the universities' web sites at the second stage. In total, 55,694 researchers were invited to participate in the survey, and 4,844 questionnaires were completed. This translates into a response rate of approximately 10% (Neufeld and Johann 2018a, 2018b). One quarter of all

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[5] Journals with a high impact factor often publish reviews that get on average more citations than research articles (Mayuru and Mabe 2000). In addition, the classification of disciplines often groups minor fields together that have different publication patterns – this explains why five Social Science journals are from the field of Psychology. However, this overview is intended to be non-exhaustive and should serve illustrative purposes by using major journals.

[6] We use the following Web of Science databases for the analyses: *Science Citation Index Expanded*, *Social Sciences Citation Index*, and *Arts & Humanities Citation Index*.

[7] Journals can be assigned to more than one discipline by the Web of Science. In case a journal was picked for more than one discipline, we randomly assigned it to one of the disciplines and selected a new journal from the set. This was the case for "Advanced Energy Materials" which classifies as an interdisciplinary journal for the Natural Sciences as well as Engineering and Technology.

participating scientists were from the Natural Sciences, about 21% each from the Medical and Health Sciences and the Social Sciences, and 17% of respondents work in Engineering and Technology. Only 9% belong to the Humanities and just 6% specialized in Agricultural Sciences.

Researchers' perceptions of authorship were measured using a battery of ten questions inquiring which activities or functions are deemed sufficient for a person to be named as an author of a publication to which they have contributed (see Table 1). The ten variables were coded 1 if the respondents declared the activity/function to be sufficient, otherwise they were coded 0.

Our goal is to identify latent perceptions of authorship. We thus ran Latent Class Analysis (LCA) in order to identify various *types of researchers* adhering specific perceptions of authorship instead of investigating the variables separately.[8]

In order to disentangle whether researchers' perceptions of authorship are a result of domain-specific peculiarities, we first present some bivariate statistics. As researchers in the different domains vary in their demographic and socio-economic characteristics (She Figures 2012 2013; West et al. 2013) and because differences in authorship perceptions may be ascribed to such factors (Haeussler and Sauermann 2013), we further estimate multinomial logistic regressions with our typology of researchers as the dependent variable. In total, we present two models: Model 1 is our baseline model, which only includes our control variables, researchers' age, gender, and academic position. In Model 2, we add the researchers' domain. We report the marginal effects computed following the "observed-value-approach" (Hanmer and Kalkan 2013).

4 Results

4.1 The Supply Side (Journals)

The results for the journal guidelines are presented in Figure 2. With regard to the authorship criteria, we find little variation between the 60 journals considered for analysis (The full list of journals is presented in Table OA1 in the online supplementary material). Eight journals do not provide any definition of authorship; many of these journals are those in the Humanities and Social Sciences (three each). In the Agricultural and the Natural Sciences, respectively, one journal did not list any authorship criteria (Agronomy for Sustainable Development and Living Reviews in Solar Physics).

Almost one third of all journals (22) refer to the criteria by a major society or committee in their field, such as the American Psychological Association or the International Committee of Medical Journal Editors (ICMJE). This approach seems to be most common in the Medical and Health Science (seven out of ten journals refer to the ICMJE guidelines). Furthermore, 18 journals refer to general publisher guidelines. For example, this is the case for 13 out of 16 Elsevier journals.

Most authorship definitions begin with a vague statement such as "An 'author' is generally considered to be someone who has made substantive intellectual contributions to a published study" (Veterinary Research) and then proceed by specifying particular tasks that are sufficient to be considered a substantial contribution. Furthermore, the guidelines often list tasks that do *not* qualify for authorship: "acquisition of funding alone, collection of data alone, or general supervision of the research group alone does not constitute authorship" (ICMJE). Some guidelines remain unspecific for the tasks that qualify as "significant scientific contributions." However, they state at least exclusion criteria (Langmuir). The

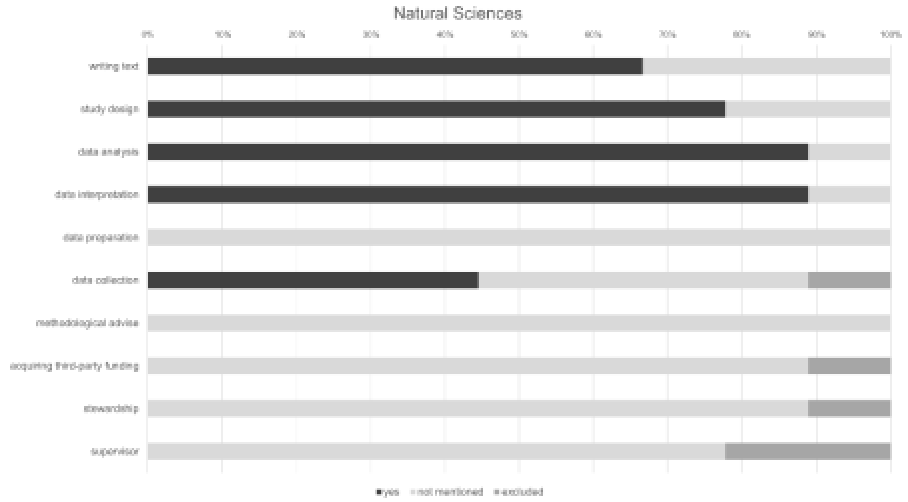
[8] We used Mplus 6 to run LCA (Muthén and Muthén 1998-2010).

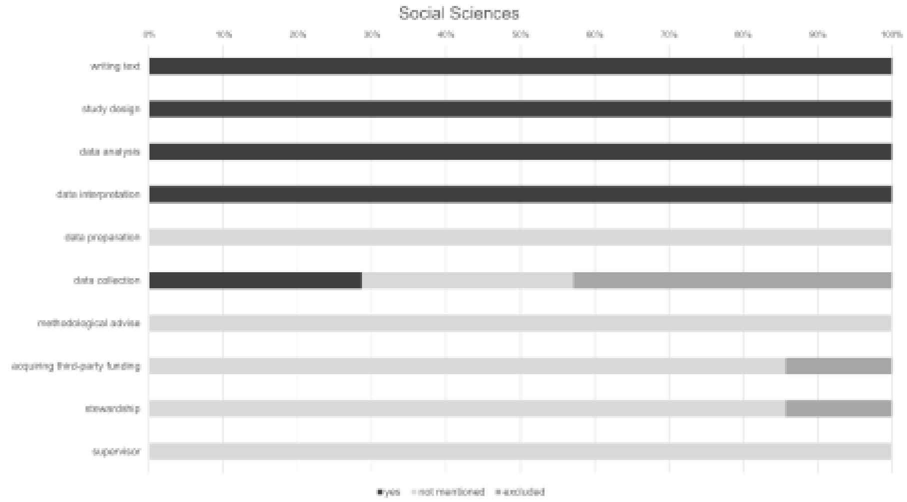
Elsevier General Guidelines already take account of current developments, especially in the Medical and Health Sciences, and refer to “medical writing” as an activity that only qualifies for recognition in the acknowledgements. Two journals (*Journal of Materials Chemistry* and *Advanced Energy Materials*) offer the possibility of contribution statements to declare responsibilities, one journal (*Ecology Letters*) already requires disclosure statements of authorship that are printed at the end of the article.

In the 60 journals, we identified four criteria that do not qualify for authorship and are neither mentioned nor specifically excluded: methodological advice, acquisition of funding, stewardship, and supervision.

Nevertheless, we identify domain-specific differences: The authorship criteria of the majority of the journals in the Humanities and Social Sciences are rather homogenous. In these domains, the consensus seems to be that writing text, designing studies, analyzing and interpreting data are the specific tasks required for crediting authorship. Furthermore, the Humanities and Social Sciences have the highest share of missing definitions. Hence, the perception that researchers have a consensus about the definition of authorship might still prevail and suggest that no formal definition by the scientific journals is required. The authorship criteria of journals in the Natural Sciences as well as the Agricultural Sciences, Engineering and Technology are more diverse. In these domains, contribution statements are sometimes used to declare responsibilities of individual authors. Other publishers such as the Nature Publishing Group, made it obligatory to use contribution statements that precisely name which function each author fulfilled (Nature 2009). Journals in the Medical and Health Sciences appear to have the most precisely defined criteria and are seen to be most exclusive, compared to the other domains. These journals very specifically lay out which tasks qualify and/or do not qualify for authorship to the highest degree across domains.

Figure 2: Major journals' authorship criteria by domain





Note: Only journals with explicit authorship guidelines were included in the analysis for the reported results.

4.2 The Demand Side (Researchers)

Turning to the demand side, we first present the results of the LCA. We opted for the five classes solution because the BIC criterion as well as various statistical tests (Vuong-Lo-Mendell-Rubin Likelihood Ratio Test as well as Lo-Mendell-Rubin Adjusted LRT Test) indicate that the five-classes solution was best. Moreover, the average latent class probabilities for the most likely latent class membership by latent class is throughout > 0.75 indicating that the five-classes solution differentiate, as required, distinctly between the five classes (see Geiser 2011 for a discussion on how to adjudicate between solutions, see Table A1 and A2 in the Appendix for fit statistics).

The resulting types of researchers are described in Table 1. The first group of researchers ("*Writing-Oriented Researchers*": 15%) holds the view that people should only be named as an author of a publication if they were involved in writing the text. For the second group of researchers ("*Narrow Definition-Oriented Researchers*": 29%) assigning authorship is also appropriate if people are involved in designing the studies on which the manuscript is based or in analyzing or interpreting the data, respectively. These first two groups are closest to the DFG's definition of authorship (see also Böhmer et al. 2011). However, the views of the remaining three groups of researchers do not correspond with the DFG's definition of authorship. Roughly 33% of the German researchers ("*Data Collection-Oriented Researchers*") felt that not only writing the text, designing the studies on which the text is based, or analyzing and interpreting the data is sufficient to be named as author, but that it is also appropriate to be a co-author, if a person had prepared and collected data or material that the analyses are based on. For the fourth group of researchers ("*Stewardship-Oriented Researchers*": 5%) co-authorship should also be granted if people were supervising one of the co-authors' doctorate or were in a management position, even though they did not contribute to the content or practice. Finally, around 18% of the researchers ("*Catch-Alls*") indicated that it is valid to become a co-author, if a person contributed anything – regardless of what this contribution looked like in detail.

Table 1: Types of researchers holding different perceptions of authorship

	Writing-Oriented Researchers	*Narrow Definition-Oriented Researchers*	*Data Collection-Oriented Researchers*	*Stewardship -Oriented Researchers*	*Catch Alls*	Total
The person was exclusively involved in writing the text	0.95	0.93	0.88	0.94	0.92	0.92
The person was exclusively involved in designing the studies on which the text is based	0.25	0.79	0.88	0.71	0.94	0.76
The person was exclusively involved in preparing the data	0.01	0.06	1.00	0.00	0.88	0.51
The person was exclusively involved in analyzing the data	0.13	0.79	1.00	0.33	0.98	0.77
The person was exclusively involved in acquiring third-party funding	0.00	0.18	0.20	0.22	0.63	0.24
The person was exclusively involved in interpreting the data	0.13	0.84	0.84	0.57	0.80	0.71
The person was exclusively involved in advising on the application of particular methodology	0.00	0.04	0.09	0.17	0.21	0.09
The person was exclusively involved in collecting data or material	0.01	0.19	0.53	0.17	0.72	0.37
The person was exclusively in a management position (without making any content-related or practical contribution)	0.04	0.04	0.08	0.91	0.69	0.21
The person was exclusively supervisor of one of the co-authors' doctorate	0.12	0.21	0.14	0.99	0.96	0.35
Group size in percent	*15.30*	*28.67*	*33.18*	*4.98*	*17.87*	*100.00*

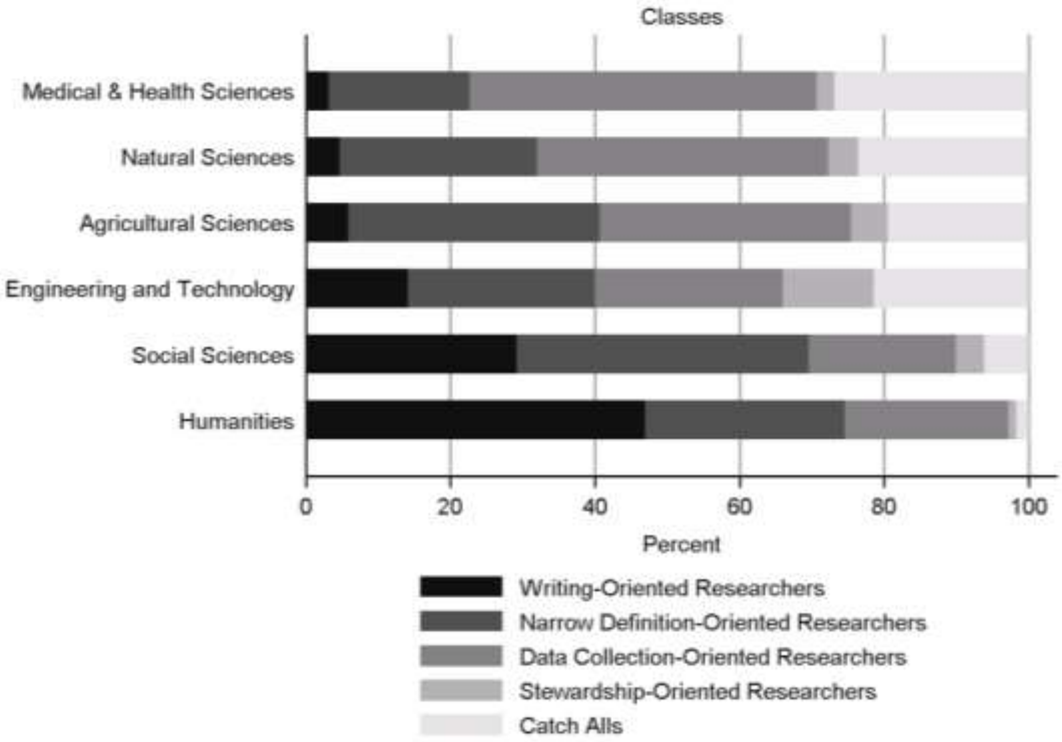
Wording: "Authorship and acknowledgements are dealt with differently depending on the discipline and the institution. Which of the activities or functions listed below is sufficient in itself for a person to be named as co-author of a publication to which they have contributed, and which result in being named in the acknowledgements?"

Note: All variables are coded as 1 if the respondents' declared the activity/function as sufficient for being named as a co-author, and coded as 0 otherwise. Mean values are reported. *N*=1.908.

Figure 3 illustrates that the distribution of class membership varies considerably across domains. In the Medical and Health Sciences, almost 23% belong to one of the first two classes including researchers whose perceptions are closest to DFG standards: around 3% are *Writing-Oriented Researchers*, another 19% *Narrow Definition-Oriented Researchers*. In contrast, most of the Medical and Health Scientists either belong to the *Data Collection-Oriented Researchers*, comprising researchers who deemed preparing and collecting the data or material sufficient to be listed as a co-author, or to the *Catch-Alls*, incorporating researchers who believe that it is valid to be a co-author, if a person contributed anything at all.

We observe a similar pattern in the Natural Sciences. Most of the Natural Scientists belong to the *Data Collection-Oriented Researchers*, whereas the share of researchers in the Natural Sciences belonging to the *Writing-Oriented Researchers* or the *Narrow Definition-Oriented Researchers* is comparatively small. However, the number of researchers in the first two classes is still larger than that in the Medical and Health Sciences.

Figure 3: Distribution of authorship perceptions by domain



Most Agricultural Scientists are grouped in the *Narrow Definition-Oriented Researchers* or the *Data Collection-Oriented Researchers*: Each of the two classes comprises around 35% of the respective researchers. The number of Agricultural Scientists who belong to the *Writing-Oriented Researchers*, describing researchers who hold the view that people should only be named as author of a publication if they were involved in writing the text, is yet relatively small.

In Engineering and Technology, a different picture is painted. Compared to the Medical and Health Sciences, the Natural Sciences, and the Agricultural Sciences, the share of people belonging to the *Writing-Oriented Researchers* is relatively large (14%). Moreover, a relatively large percentage of scientists in Engineering and Technology (13%) belong to the *Stewardship-Oriented Researchers*, indicating researchers who assign authorship as appropriate if people were simply supervisor of one of the authors' doctorate or in a management position without making any content-related or practical contribution.

With regard to their authorship perceptions, researchers in the Social Sciences and Humanities differ considerably from their colleagues in the other domains. All together around 70% belong to the *Writing-Oriented Researchers* or the *Narrow Definition-Oriented Researchers*. Moreover, only a very small proportion – approximately 6% in the Social Sciences and 2% in the Humanities – are assigned to the *Catch-Alls*.

The results of the multivariate analysis are presented in Table 2. The multivariate analyses further support the bivariate results. The model fit statistics indicate that the domain contributes considerably to the model fit. For example, in the baseline model (Model 1) Cragg and Uhler's R-squared is 0.08. When including the domain (Model 2) Cragg and Uhler's R-squared increases to 0.26. Turning to the average marginal effects, researchers in Engineering and Technology, the Social Sciences, and the Humanities reveal a statistically significant higher probability to belong to the *Writing-Oriented Researchers* and the *Narrow Definition-Oriented Researchers,* but display a statistically significant lower probability to belong to the

Data Collection-Oriented Researchers in comparison to the Medical and Health Sciences. Moreover, researchers in Engineering and Technology are also more likely to belong to the *Stewardship-Oriented Researchers* and researchers in the Social Sciences and Humanities less likely to belong to the *Catch-Alls*. Compared to the Medical and Health Scientists, Natural Scientists reveal a statistically significant higher probability to belong to the *Narrow Definition-Oriented Researchers*. Finally, a statistically significant positive effect on the affiliation with the *Narrow Definition-Oriented Researchers* and a statistical significant negative effect on the affiliation with the *Data Collection-Oriented Researchers* can be identified for Agricultural Scientists.

Table 2: Average marginal effects on the affiliation with types of researchers

	Model 1 (Baseline)					**Model 2 (Full Model)**				
	Writing-Oriented Researchers	*Narrow Definition-Oriented Researchers*	*Data Collection-Oriented Researchers*	*Steward-ship-Oriented Researchers*	*Catch Alls*	*Writing-Oriented Researchers*	*Narrow Definition-Oriented Researchers*	*Data Collection-Oriented Researchers*	*Steward-ship-Oriented Researchers*	*Catch Alls*
Post-Doc (Ref.: Pre-Doc)	-0.08**	-0.05	0.06	-0.01	0.08*	-0.02	-0.03	0.01	0.00	0.03
	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)
Post-Doc with career aspiration Prof (Ref.: Pre-Doc)	0.01	0.04	0.03	-0.05*	-0.03	0.01	0.03	0.02	-0.03	-0.03
	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)
Prof (Ref.: Pre-Doc)	-0.05	-0.05	0.20**	-0.06**	-0.03	-0.01	-0.05	0.17**	-0.05*	-0.06
	(0.05)	(0.06)	(0.06)	(0.02)	(0.05)	(0.04)	(0.06)	(0.06)	(0.02)	(0.05)
Female (Ref.: Male)	0.06**	-0.01	-0.02	-0.02	-0.01	0.02	-0.02	-0.01	-0.00	0.02
	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.02)
Age	0.00**	0.00*	-0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Natural Sciences (Ref.: Medical & Health Sciences)						0.01	0.09**	-0.05	0.00	-0.06
						(0.02)	(0.03)	(0.04)	(0.02)	(0.04)
Agricultural Sciences (Ref.: Medical & Health Sciences)						0.04	0.18**	-0.17**	0.03	-0.08
						(0.03)	(0.06)	(0.06)	(0.03)	(0.05)
Engineering and Technology (Ref.: Medical & Health Sciences)						0.10***	0.07*	-0.19***	0.09***	-0.07
						(0.03)	(0.04)	(0.04)	(0.02)	(0.04)
Social Sciences (Ref.: Medical & Health Sciences)						0.25***	0.21***	-0.26***	0.01	-0.22***
						(0.03)	(0.04)	(0.04)	(0.02)	(0.03)
Humanities (Ref.: Medical & Health Sciences)						0.40***	0.10*	-0.22***	-0.01	-0.26***
						(0.05)	(0.05)	(0.05)	(0.02)	(0.03)
LL	-2073.144					-1921.278				
Cragg & Uhler's R^2	0.077					0.264				
N	1430					1430				

Note: Delta-method standard errors in parentheses. * p<.05, ** p<.01, *** p<.001

5 Discussion

Academia seems to lack universal agreement about what kind of a contribution ought to define authorship of a publication. We found several differences in the perception of authorship across domains on the supply (journals) and considerable differences on the demand side (researchers). Hence, not only domain-specific “formal norms” (Haeussler and Sauermann 2013), but also domain-specific statements about ideals can be observed with regard to scientific authorship.

On the supply side, journals in the Natural Sciences, the Medical and Health Sciences, and Engineering and Technology convey a broader understanding of authorship than journals in the Social Sciences and Humanities. We found the most specific definitions of authorship with several exclusive criteria in the Medical and Health Sciences, where discussions of authorship practices – including, sometimes, alleged malpractice - are quite common (Logdberg 2011; The PLoS Medicine Editors 2009; Wager 2007a). We only rarely identified rather comprehensive definitions of authorship that are supplemented by explicit statements about the potential co-authors’ contributions in order to emphasize each individual’s responsibility. Hence, most journal guidelines do not reflect the on-going debate on “fixing” authorship by introducing a contributor-ship model that requests authors to explicitly declare how far they contributed to a manuscript (e.g., Clement 2014; Smith 2012; Taylor and Thorisson 2012). However, regarding journals’ authorship criteria, we also identified notable variation within the domains, expect for the Medical and Health Sciences, where the guideline by the ICMJE prevails.

A similar picture is painted for the demand side: A large number of the researchers in the Natural Sciences, the Agricultural Sciences, and Engineering and Technology exhibit a broader understanding of authorship that encompasses tasks like collecting or preparing the data. Similarly, a large proportion of researchers in the Medical and Health Science share a perception of authorship that contradicts the restrictions set by most medical journals relying on the ICMJE criteria. In turn, researchers’ perceptions are closest to the German Research Foundation’s (DFG) standard in the Social Sciences and Humanities.

However, our research also has some limitations. Due to sample size constraints, we had to employ a classification of domains that divides the scientific world into six major domains. Such a classification does not account for potential subdomain-specific differences, which we suspect exist as well, since some subdomains have their own specific production patterns, academic journals, and scientific values (Gläser 2006). We would thus recommend that future research validates our findings by employing a more differentiated classification of disciplines if possible. A further limitation concerns the sampling procedure we used in order to select journals. For every domain, we randomly selected 10 out of 100 journals *with the highest Journal Impact Factor*. However, top journals within different domains are often owned by the same publisher. Accordingly, we may overestimate the homogeneity of the perception of authorship within domains on the supply side compared to studies that employ sampling procedures that also account for lower-ranked journals.

In sum, we find domain-specific peculiarities of authorship on both sides. Differences across domains on the level of the journal criteria are at least partly reflected in the researchers’ authorship perceptions on the individual level. In other words, in domains with more comprehensive journal guidelines, scholars tend to hold broader views of authorship. Hence, the results lend empirical support for our hypotheses. The considerable differences may be explained by disciplinary cultures that are linked to specific scientific methods and practices. In the “hard sciences,” the production of text is often the last and also a relatively small part of a long sequence of research steps. The writing of the manuscript also merely consists of a report of the conducted studies/experiments. In turn, the writing process is more important in the Social Sciences and, in particular, in the Humanities. Researchers in these fields spend a lot of time preparing texts.

Our findings show that researchers' perceptions about what tasks are seen as sufficient for authorship vary enormously by domain. Whereas in the Humanities traditional authorship perceptions still prevail, we find large shares of researchers that perceive supervision and management/managerial tasks as sufficient for granting authorship in the Natural Sciences. Accordingly, in the Natural Sciences it has become more difficult to determine who should acquire credit and reputation for a publication and who takes responsibility for its results, at least when compared to the Humanities. Some journals have reacted to this development by either requesting that one co-author accepts responsibility for the contributions of the whole group (Nature Publishing Group) or that all co-authors provide contribution statements (e.g. Ecology Letters).

Which policy implications do these findings have? As Kuther (2008) states, "publications are the currency of academia and the major indicator of research productivity" (see also Dance 2012; Bennett and Taylor 2003). If authorship is attributed for very different tasks, interdisciplinary comparisons of publication measures such as the h-index become meaningless. Moreover, if (a) substantial differences as a consequence of domain-specific authorship conventions and perceptions in the scientific productivity remain to exist between domains (Lee and Bozeman 2005) and (b) the raw number of publications is used as a critical criterion for the allocation of funding (e.g., Auranen and Nieminen 2010), funds may be inadequately distributed across domains. Consequently, researchers of domains with much narrower definitions of authorship may be disadvantaged when compared to their colleagues from domains that rely on broader authorship definitions. One possible way to adjust for such a bias would be a fixed definition of authorship that applies to all disciplines. However, some researchers have already voiced concerns that this is hardly applicable in practice: "The inherently community-specific nature of scientific authorship is not a problem but a predicament. We cannot come up with a unified notion of scientific authorship" (Biagioli 2003: 274). Another and probably more promising attempt would be to consistently draw on the fractional counting method that has been applied in bibliometric analyses since the 1950s (Havemann 2009). Here, every publication with *k* authors is only attributed with *1/k* to each author. This approach is already used for the Leiden Ranking (CWTS Leiden Ranking 2016). Finally, field-normalization – which has already been employed for comparative analyses of the number of citations (Waltman 2015; Waltman and van Eck 2015) – would help to provide a measure of comparability for researchers' performances across disciplines.

There is and probably will never be a consensus about a single definition of authorship transferable to all academic disciplines. Occasionally, hyper-authorship papers with several thousands of authors can make sense in certain situations (Biagioli 2003; Birnholtz 2006). Therefore, it could be appropriate to completely switch to the contributorship model where every author has to indicate what they have contributed to the manuscript (Clement 2014; Taylor and Thorisson 2012). The contributorship model also seems promising with regard to providing solutions for common mal practices, such as guest and gift authorship (Lissoni et al. 2013), without having to rely on fixed-notions of authorship.

Appendix

Table A1: LCA fit statistics

Number of classes	Vuong-Lo-Mendell-Rubin Likelihood Ratio Test for 4 (H0) vs. 5 classes (p value)	Lo-Mendell-Rubin Adjusted LRT Test (p value)	AIC	BIC	Adj. BIC
2	0.0000	0.0000	18866.598	18983.228	18916.511
3	0.0000	0.0000	18511.774	18689.496	18587.832
4	0.0172	0.0179	18363.835	18602.649	18466.038
5	0.0173	0.0181	18262.432	18562.338	18390.780
6	0.0842	0.0866	18206.803	18567.801	18361.295

Table A2: Average Latent Class Probabilities for Most Likely Latent Class Membership (Row) by Latent Class (Column)

	Writing-Oriented Researchers	*Narrow Definition-Oriented Researchers*	*Data Collection-Oriented Researchers*	*Stewardship-Oriented Researchers*	*Catch Alls*
Writing-Oriented Researchers	0.870	0.104	0.000	0.025	0.000
Narrow Definition-Oriented Researchers	0.079	0.858	0.008	0.024	0.031
Data Collection-Oriented Researchers	0.001	0.160	0.754	0.000	0.085
Stewardship-Oriented Researchers	0.026	0.085	0.000	0.805	0.085
Catch Alls	0.000	0.030	0.114	0.024	0.832

Online-Appendix (online supplementary material)

Table OA1: Major journals' authorship criteria by discipline

	Journal	Origin of authorship criteria	Writing the text	Study design	Data analysis	Data inter-pretation	Data preparation	Data collection	Advise on methods	Third-party funding	Manage-ment position	Super-visor
Agricultural Sciences	Veterinary Research	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Journal Of Sensory Studies	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Journal Of Food Composition And Analysis	PG - Elsevier		y_e	y_i	y_e		y_e				
	Agricultural And Forest Meteorology	PG - Elsevier		y_e	y_i	y_e		y_e				
	Food Control	PG - Elsevier		y_e	y_i	y_e		y_e				
	Agronomy For Sustainable Development		*no explicit definition of authorship found*									
	Journal Of Agronomy And Crop Science	Own definition	y_e	y_e	y_e	y_e		y_e		n		
	Canadian Journal Of Fisheries And Aquatic Sciences	PG - RCS	y_e	y_e	y_e	y_e		y_e				
	Forest Ecology And Management	PG - Elsevier		y_e	y_i	y_e		y_e				
	Food And Bioproducts Processing	PG - Elsevier		y_e	y_i	y_e		y_e				
Engineering and Technology	Journal Of Materials Chemistry	RCS	y_e	y_e	y_e	y_i		y_e				
	Langmuir	ACS	y_i	y_i	y_i	y_i	y_i	y_i	y_i	y_i	n	n
	Progress In Materials Science	PG - Elsevier		y_e	y_i	y_e		y_e				
	Bioinformatics	Own definition	y_e	y_e	y_e	y_e		y_e				
	Proceedings Of The Ieee	IEEE	y_e	y_e	y_e	y_e						
	Genome Biology	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Translational Research	PG - Elsevier		y_e	y_i	y_e		y_e				

	Water Research	PG - Elsevier		y_e	y_i	y_e		y_e				
	Ieee Transactions On Smart Grid	IEEE	y_e	y_e	y_e	y_e						
	Advanced Energy Materials	PG - Wiley	y_e	y_e	y_e			y_e				
Humanities	Journal Of Cultural Heritage	PG - Elsevier		y_e	y_i	y_e		y_e				
	Assessing Writing	PG - Elsevier		y_e	y_i	y_e		y_e				
	International Journal Of Language & Communication Disorders	ICMJE	y_e	y_e	ye	y_e		n		n		n
	Psychology Of Religion And Spirituality	APA	y_e	y_e	ye	y_e		n				
	Journal Of Philosophy		*no explicit definition of authorship found*									
	American Antiquity		*no explicit definition of authorship found*									
	Journal Of Archaeological Research	COPE based on ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Journal Of Island & Coastal Archaeology	PG - Taylor & francis	y_e	y_e	y_e	y_e		y_e				
	American Journal Of Speech-Language Pathology	ICMJE	y_e	y_e	y_e	y_e		y_e				
	Language Variation And Change		*no explicit definition of authorship found*									
Medical and Health Sciences	Pharmacology & Therapeutics	PG - Elsevier		y_e	y_i	y_e		y_e				
	Biochimica Et Biophysica Acta-Reviews On Cancer	Own definition	y_e	y_e	y_e	y_e		y_e				
	Science Translational Medicine	ICMJE	y_e	y_e	y_e	y_e		n	n	n	n	n
	MMWR Recommendations And Reports	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Immunological Reviews	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	MMWR Surveillance Summaries	ICMJE	y_e	y_e	y_e	y_e		n		n		n
	Human Reproduction Update	ICMJE	y_e	y_e	y_e	y_e		n	n	n	n	n
	Annals Of Surgery	ICMJE (own definition but similar)	y_e	y_e	y_e	y_e		n	n			n

	American Journal Of Respiratory And Critical Care Medicine	ICMJE	y_e	y_e	y_e	y_e						
	Journal Of Pathology	ICMJE	y_e	y_e	y_e	y_e		n	n	n	n	n
Natural Sciences	Fems Microbiology Reviews	COPE	y_e	y_e	y_e	y_e						
	Ecology Letters	COPE	y_i	y_i	y_i	y_i		n		n		n
	Journal Of Photochemistry And Photobiology C-Photochemistry Reviews	PG - Elsevier		y_e	y_i	y_e		y_e				
	Ieee Transactions On Fuzzy Systems	IEEE	y_e	y_e	y_e	y_e						
	Progress In Polymer Science	PG - Elsevier		y_e	y_i	y_e		y_e				
	Light-Science & Applications	Own definition	y_e	y_e	y_i	y_e		y_e				
	Nucleic Acids Research	Own definition	y_e	y_e	y_e	y_e						
	Accounts Of Chemical Research	ACS									n	n
	Living Reviews In Solar Physics		*no explicit definition of authorship found*									
	Bulletin Of The American Meteorological Society	AGU and ACS	y_i		ye	ye		y_e				
	Fems Microbiology Reviews	COPE										
Social Sciences	Journal Of Personality And Social Psychology	APA	y_e	y_e	y_e	y_e		n				
	Political Analysis		*no explicit definition of authorship found*									
	Journal Of Business Venturing	PG - Elsevier	y_e	y_e	y_e	y_e						
	Journal Of Educational Psychology	APA	y_e	y_e	y_e	y_e		n				
	American Journal Of Sociology		*no explicit definition of authorship found*									
	Psychological Science In The Public Interest	ICMJE	y_e	y_e	y_e	y_e		y_e		n	n	
	Journal Of Applied Psychology	APA	y_e	y_e	y_e	y_e		n				
	Econometrica		*no explicit definition of authorship found*									

Social Cognitive And Affective Neuroscience	PG - Oxford University Press	y_e	y_e	y_e	y_e		
Journal Of Peasant Studies	PG - Taylor & Francis	y_e	y_e	y_e	y_e		y_e

Abbreviations: ACS – American Chemical Society, APA – American Psychological Association, COPE – Committee on Publication Ethics, ICMJE – International Committee of Medical Journal Editors, IEEE – Institute of Electrical and Electronics Engineers, PG – Publisher Guidelines, RSC – Royal Society of Chemistry,

Used categories: n= exclusion criterion; y_i=implicit statement; y_e= explicit statement; =not mentioned. As of: November 2017

Table OA2: Summary statistics for variables in Table 2

	N	Min.	Max.	Mean	Std.dev.
Post-Doc	1430	0	1	0.18	0.39
Post-Doc with career aspiration Prof.	1430	0	1	0.15	0.35
Prof .	1430	0	1	0.25	0.43
Female	1430	0	1	0.38	0.49
Age	1430	22	76	37.78	10.26
Natural Sciences	1430	0	1	0.25	0.43
Agricultural Sciences	1430	0	1	0.06	0.24
Engineering and Technology	1430	0	1	0.19	0.39
Social Sciences	1430	0	1	0.22	0.42
Humanities	1430	0	1	0.09	0.29

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