ELEPHANT
IN THE LAB

OPINION

Factory science

Short title	Factory science
Long title	How many authors does it really need to write a paper?
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Motivation

As the major currency in the scientific reputation economy, the analysis of article publishing reveals different disciplinary cultures and working styles. In STEM fields (science, technology, engineering, and mathematics) scientists publish several short articles per year in collaboration with many colleagues around the world, while in the humanities an author might work alone or in a group of two, writing a book or a longer article.

In an attempt to understand scientific working styles better, we took a closer look on the number of authors per article in various disciplines (Table 1). We focused on the 20 highest performing authors in every subject area according to Scopus (see Schmidt et al. 2017a for the detailed methodology).

Summary of the results

In a series of short analyses, we analyzed coauthorship in 27 subdisciplines according to Scopus. For the most disciplines we analysed, the number of authors per article is increasing over time (2010 to 2016), although slightly. However, one subdiscipline – *Physics and Astronomy* – is outstanding. With a mean of 1,268 authors per paper and a maximum of 5,154 authors of one article (Schmidt et al. 2017b, original article, see also Table 1) this discipline features by far the most authors. The high number of authors is not a unique case in one paper (Figure 1) and the number of coauthors is still increasing by 58 per year (Table 1). In 2016, over 50% of the articles in *Physics and Astronomy* have more than 1,000 authors.

The average number of authors per article is much higher in *Physics and Astronomy*, but the maximum number of authors per articles in *Medicine* as well as *Biochemistry, Genetics, and Molecular Biology* is also above 1,000 (Table 1).

Meaning of Authorship – Good practice

We were wondering: What does authorship really mean if you share it with 1,200 other coauthors? Does it still reflect the complexity of scientific work and practice? Especially, if you consider that there are guidelines like the Vancouver Recommendations with the following four criteria on who is an author in medical journals:

> 1. *Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work*; AND
> 2. *Drafting the work or revising it critically for important intellectual content*; AND
> 3. *Final approval of the version to be published*; AND
> 4. *Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.*

This is in line with the Australian Code for the Responsible Conduct of Research. In addition, in their Code, the authors clearly state:

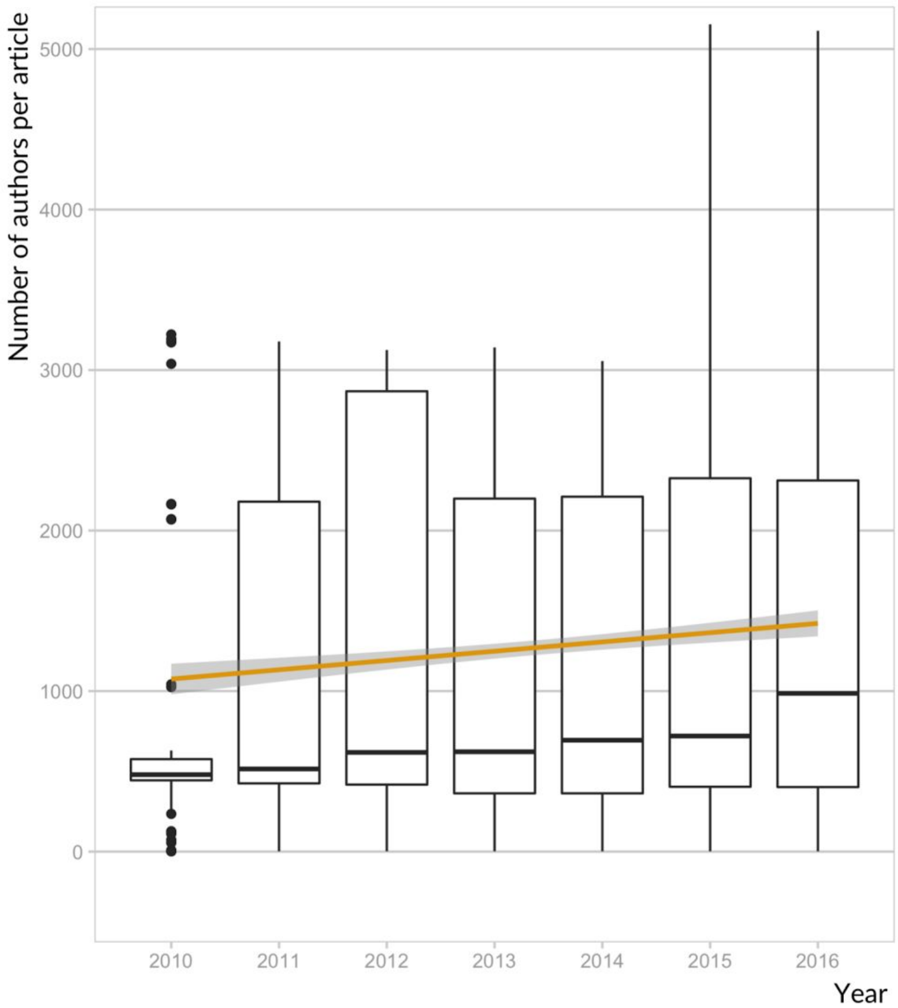
> *The right to authorship is not tied to position or profession and does not depend on whether the contribution was paid for or voluntary. It is not enough to have provided materials or routine technical support, or to have made the measurements on which the publication is based. Substantial intellectual involvement is required.*

Did all the authors in articles with several thousand authors contribute to the published work according to these guidelines? Of course not. If one divides the written words without acknowledgements and affiliations by the number of authors (ca. 1.1 words per author in the paper with 5,154 authors) it is questionable what a "substantial contributions" is. Authorship is merely a remnant from an analogue past and cannot depict the complexity of scientific collaboration today, at least in hyper-authored papers.

Factory science

Drawing from the sheer number of authors in *Physics and Astronomy* it can be supposed that scientific knowledge production is similar to the production in a factory. The actual work leading to a paper such as described is divided in so many small parts, that we can speak of a new form of division of labour in some disciplines of science – like in a factory where a lot of workers (researchers) contribute to a complex product (publication). In humanities disciplines one can speak of handicraftsmen, who do most of the steps leading to a final product on their own or with very few colleagues. Maybe also the understanding and meaning of the products may vary between these poles of scientific working models. While in one the article itself is actually the product, it is in some STEM disciplines just the (scientific) currency or sales channels.

The quantity of published articles (products) in the factory science subject area *Medicine* is outstanding: globally 20 authors coauthored 7,741 articles in seven years. The number of articles by the 'best performing' scientists are shown in Figure 2. With 651 articles in seven years and if we assume 250 working days per year, the uppermost author coauthored a paper every 3 working days. This is even outperformed in the subject area *Physics and Astronomy* with 993 articles coauthored by one author in seven years which means one article in less than 2 working days (Figure 3).



NUMBER OF AUTHORS PER ARTICLE
IN THE SUBJECT AREA PHYSICS AND ASTRONOMY

Increase of co-authors per year = 58
Number of articles = 2135

Figure 1: Boxplot of the number of authors per paper in the subject area *Physics and Astronomy* for the years 2010 to 2016 . The box denotes 25–75% of the values with the median (bold line) in it. The small circles are outliers. The yellow line shows a linear model of the mean number of authors per article with a confidence interval of 0.95 shown in light grey. Data source: Scopus. CC BY 4.0 Schmidt, Fecher, Kobsda.

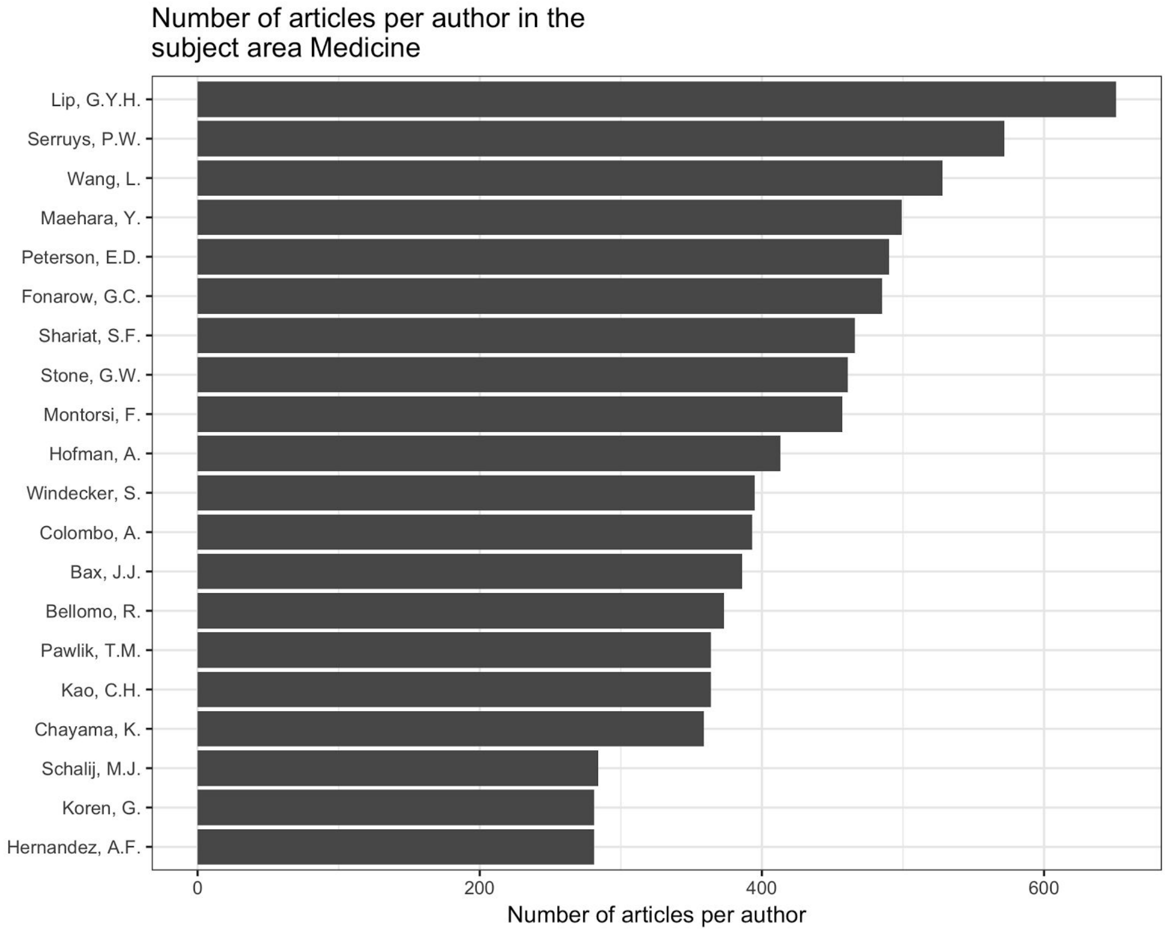


Figure 2: Number of articles per author for the 20 highest performing authors in the subject area *Medicine* for the years 2010 to 2016. Data source: Scopus. CC BY 4.0 Schmidt, Fecher, Kobsda.

As our first search was restricted (see Schmidt et al. 2017a for the detailed methodology), we took a second look on the top 20: on average, the authors listed in Figure 2 (co)authored 1,287 documents (within Scopus) in their ongoing careers with a mean of 46,612 citations per author. Unfortunately, two authors were not in the analysis of citations as the numbers were too big to display according to Scopus, likely because these numbers where >100,000. In *Physics and Astronomy* they (Figure 3) published 1,176 documents on average with a mean of 36,054 citations (again, excluding one author for the same reason).

A last, small and very simplified calculation and then we are done: if you divide the mean number of documents by the mean duration of the ongoing science foremen careers you get 59.5 articles per year in *Physics and Astronomy* and 43.5 in *Medicine*. And now, go back to work, lazybones.

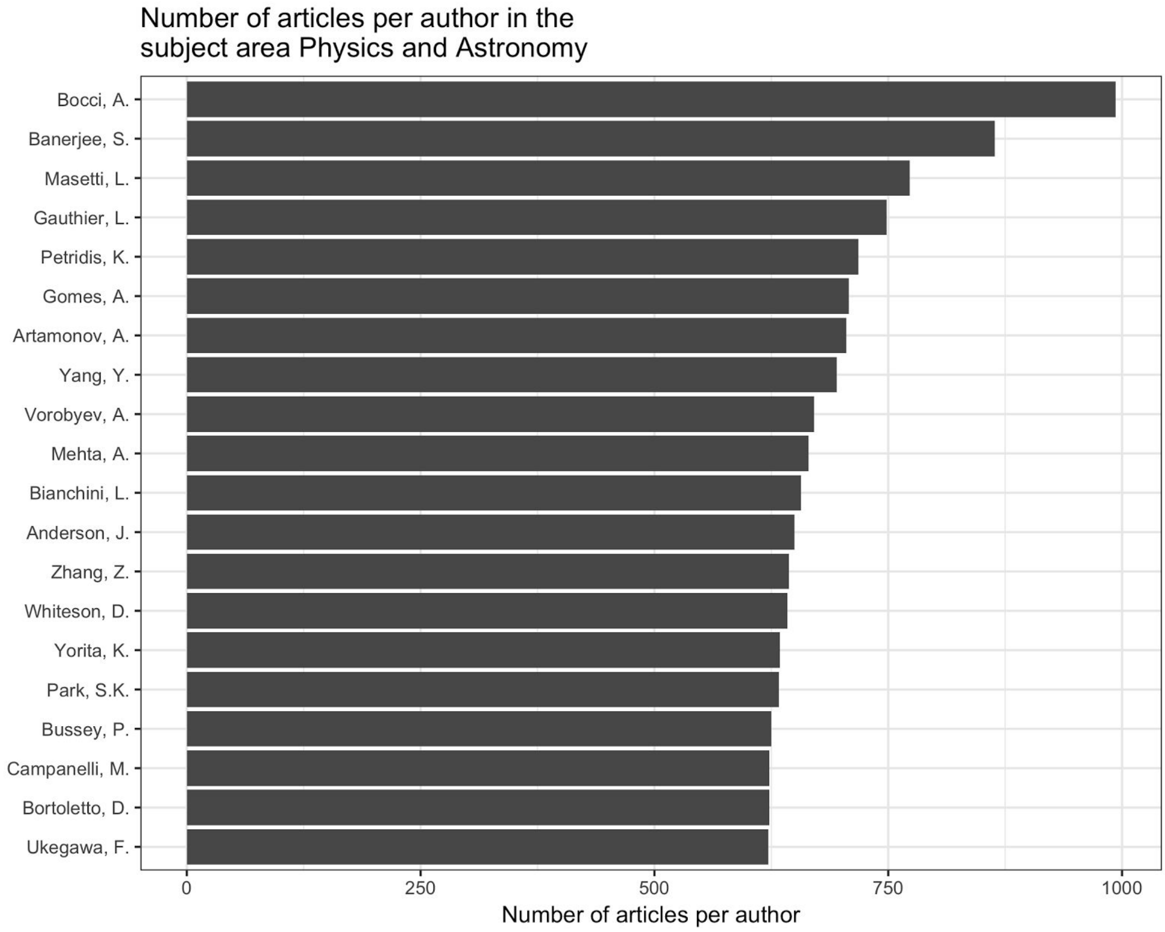


Figure 3: Number of articles per author for the 20 highest performing authors in the subject area *Physics and Astronomy* for the years 2010 to 2016. Data source: Scopus. CC BY 4.0 Schmidt, Fecher, Kobsda.

Table 1: Summary of bibliometrics for the 20 highest performing authors in the years 2010 to 2016 for each of 27 subject areas according to Scopus.

Subject Area	**Increase in number of coauthors per year**	**Mean coauthors per article**	**Maximal coauthors per article**	**Mean number of citations per article**	**Maximal number of citations per article**	***n***
Agricultural and Biological Sciences	0.2	5.2	111	8.9	479	2710
Arts and Humanities	0.0	2.1	8	6.6	40	749
Biochemistry, Genetics, and Molecular Biology	-2.1	16.7	1269	33.4	1774	818
Business, Management, and Accounting	0.1	2.6	8	10.5	138	999
Chemical Engineering	0.3	2.6	15	5.9	112	1303
Chemistry	0.1	5.5	16	13.0	562	3142

Computer Science	0.1	4.0	21	11.4	199	1558
Decision Sciences	0.0	3.1	13	7.1	35	192
Dentistry	0.0	5.5	25	13.6	183	1536
Earth and Planetary Sciences	0.3	8.7	468	23.4	1375	2818
Economics, Econometrics, and Finance	0.1	2.8	9	8.4	188	1077
Energy	0.3	3.6	11	19.7	496	1683
Engineering	0.3	2.8	34	9.8	480	3828
Environmental Sciences	0.1	5.9	49	17.5	624	1759
Health Professions	0.1	3.7	16	7.0	140	808
Immunology and Microbiology	0.4	9.7	83	34.4	2938	968
Materials Science	0.2	4.1	13	15.1	490	1318
Mathematics	0.1	2.9	9	8.2	357	3657
Medicine	0.4	11.0	1193	30.7	2861	7741
Multidisciplinary	-0.1	3.3	58	14.5	348	1111
Neuroscience	0.5	8.0	342	38.8	924	1122
Nursing	0.3	3.7	61	7.5	126	1282
Pharmacology, Toxicology, and Pharmaceutics	0.1	5.5	47	16.8	526	1165
Physics and Astronomy	57.8	1268.2	5154	27.4	3323	2135
Psychology	0.0	4.1	61	14.4	300	954
Social Sciences	0.1	2.7	14	9.7	485	1050
Veterinary Science	0.2	6.0	22	6.6	98	1404

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