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Alphabetic order of authors in scientific publications: A bibliometric study using 27 scientific fields

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Abstract Paper authorship and author placement have significant consequences for accountability and assignment of credit.

Keywords bibliometrics · scientific authorship · authors order · scientific publication

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1 Introduction

Whenever there are two or more authors, the authorship order becomes a relevant aspect of scientific publications. This is becoming an increasingly pertinent issue, since diverse studies have shown a continuously increasing trend in the average number of authors per publication (Broad 1981; Grant 1989; Onwude et al. 1993; Persson et al. 2004; Greene 2007; Wuchty et al. 2007; Fernandes 2014; Henriksen 2016; Fernandes and Monteiro 2017). In some scientific fields, such as Medicine, authors seem to follow a relatively clear and known set of authorship rules that stipulate how to position their author names in publications (Baerlocher et al. 2007). Moreover, there have been some suggestions on how to solve authorship issues, such as recommended by Strange (2008). Despite of this, many authors still follow their own rules (thus ad hoc), although there are implicit rules that are often followed in practice and that are discussed in the next paragraphs.

Typically, the first author is considered the main author, the one that contributed the most to the intellectual effort or writing of the paper. As

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argued by Peidu (2019), the first author is clearly the one with the highest contribution or responsibility. When there are two or more co-authors that have contribute equally, it is becoming common to indicate several “equal first authors” (Hu 2009). For instance, this can be applied when several research teams collaborate. In such cases, the leaders of each team can assume the role of corresponding authors.

Another implicit rule is to set the order of the authors based on the descending contributions to the contents of the paper. This approach sounds fair but it implies that it is possible to measure the individual contributions, which often is not easy (e.g., long research project with a large team). Whenever this measurement is not possible or easy, the simplest solution is to use an alphabetical order by taking into consideration the surnames of the co-authors. This alternative may sound unfair, as co-authors may feel that their publication position order does not reflect their relative contribution. Additionally, only the first author of papers with more than three co-authors appears in the text bibliographic references when these are abbreviated as (first) “author et al.” There can also be hybrid solutions that use a mixture of contribution and alphabetical based orders. For example, choose the first and last authors and order the rest alphabetically.

It should be noted that there are some proposals to assign relative values to the co-authors of a scientific publication according to the relative positions of each one (Trueba and Guerrero 2004; Hagen 2014; Vavryčuk 2018; Bornmann and Osório 2019). For instance, the harmonic authorship credit method uses the following formula to distribute the one-unit point among the N co-authors of a scientific paper:

$$Credit\,(i) = \frac{1/i}{\sum_{j=1}^{N} 1/j}$$

where i and j denote the author position ($\in \{1, ..., N\}$) in the publication. This formula progressively assigns a higher value to the first co-authors and lower ones to the last ones. For example, when $N = 4$ the first author ($i = 1$) gets a credit of 0.48 points, the second author ($i = 2$) gets half of this score (0.24), the third author is credited with a 0.16 score and the last author receives just 0.12 points. Thus, the choice of the position of the authors is not irrelevant and can have a great impact in the researcher career and her/his institution. Clearly, these relative scoring formulas only make sense when researchers from a scientific community or field tend to adopt the descending contribution order.

In this paper, we present a bibliometric study that targets a total of 27 scientific fields, aiming to characterize what is the prevalence of an alphabetic ordering of co-authors in scientific articles. *** to be written ***.

The paper is organized as follows. Section 2 describes the state of the art. Then, the adopted research methodology is presented (Section 3). Next, the obtained results are presented and analyzed. Finally, conclusions are drawn in Section 5.

2 Related Work

The decision on the positions of the names of the authors of a scientific publication has a different importance within research fields. In some scientific areas, the first author in a multi-authored paper is considered to be the most important contributor. Thus, authors are not typically listed according to an alphabetical order. Other scientific disciplines consider that the order of the authors is not important, since it is assumed that all have contributed similarly. In such cases, authors are more commonly listed in an alphabetical order. Despite this reality, studies on the authors order across diverse disciplines are not abundant. We next describe the main results found in studies that address issues related to the authors order in different fields.

*** penso que se tem de melhorar a ordem de apresentação destes estudos, cronologica? por temática de conceito? ***

Peidu (2019) discusses several practices used to decide the authors order, namely:

1. by amount of contribution;
2. alphabetical order;
3. multiple first author or multiple last author;
4. by seniority or reverse seniority;
5. by raffling or lottery system; and
6. by negotiation or mutual understanding.

Waltman (2012) observed that in 2011, the authors of less than 4% of all publications intentionally chose to list their names alphabetically. Mathematics, economics (including finance), and high-energy physics were the fields where the use of alphabetical order in the authors list was more prevalent (Marušić et al. 2011; Waltman 2012). In particular, publications with a large number of authors, often known as kilo-papers, tend to adopt an alphabetical order.

Frandsen and Nicolaisen (2010) presented a study related to the credit assignment practices in the fields of economics, high-energy physics, and information science. They show that the practices of alphabetization of authorship are different among the three fields. A slight increase was found in the economics field during a 30-year period (1978–2007). In information science, a significant decrease was found to have occurred during the same 30-year period. High-energy physics, during the period 1990–2007, has witnessed a high and stable percentage of alphabetically ordered authors lines.

Sauermann and Haeussler (2017) pointed out the probability of error when deducing contributions based on the position of the author. Their paper discusses the data related to articles published in the period 2007-2011 in PLOS ONE, a journal primarily focused in the biological and life sciences. This periodical requires all its articles to disclose the types of contributions made by each co-author, using predefined categories. Sauermann and Haeussler have conducted two studies, being the first one related to the author order and the respective contribution statements. They concluded that in some cases the author order was not always aligned with the respective contribution statements. In particular, the author order was considered a less reliable indicator of the authors' contributions when there was a high number of co-authors.

Maciejovsky et al. (2009) analysed 38,000 journal articles from the fields of economics, psychology, and marketing, and concluded that the three fields have different author ordering practices.

Peffers and Hui (2003) compared, in the field of information management systems, the percentages of papers with alphabetically ordered author lists in journals with high impact factors with the corresponding ones in journals with median or low impact factors. Their conclusion was that in median or low impact factor journals the alphabetical order of authorship tends to disappear.

Weber (2018) argued that alphabetical order gives an unfair advantage to researchers whose last name initials are at the beginning of the alphabet. Weber provided evidence that there was an alphabetical discrimination and that researchers often react to it, for example, by avoiding collaborations with other authors.

*** em que medida o nosso estudo é diferente dos anteriores ***

3 Methodology

This study aimed to perform a comprehensive coverage of scientific areas, as reflected in terms of journal articles. Thus, we selected all the 27 subject areas that are listed in SCImago website (`https://www.scimagojr.com/`), as consulted in May 2020 and shown in Table 1. SCImago is a publicly portal, backed by the Scopus scientific database and that is often used to rank the quality of journals (Falagas et al. 2008). It should be noted that in certain fields, such as Computer Science and Engineering, publications in conference proceedings are as prestigious as in journals (Glänzel et al. 2006; Lisée et al. 2008; Vardi 2009; Vrettas and Sanderson 2015). However, in order to adopt an uniform criterion for all scientific areas, this study only considers journal articles.

3.1 Research goal

The research approach we have used in our study is the Goal, Question, Metric (GQM) methodology (Basili 1992). Following the GQM goal template, the goal of this study is defined as to systematically identify issues related to multi-authored papers, namely which scientific fields adopt the alphabetical order to list the authors. To tackle this goal, the following research question (RQ) is taken into account:

RQ: How is the use of the alphabetical order of authors characterized for all scientific areas?

#	Subject area	#	Subject area
1	Agricultural & Biological Sciences	15	Health Professions
2	Arts & Humanities	16	Immunology & Microbiology
3	Biochemistry Genetics & Molecular Biology	17	Materials Science
4	Business, Management & Accounting	18	Mathematics
5	Chemical Engineering	19	Medicine
6	Chemistry	20	Multidisciplinary
7	Computer Science	21	Neuroscience
8	Decision Sciences	22	Nursing
9	Dentistry	23	Pharmacology, Toxicology & Pharmaceutics
10	Earth & Planetary Sciences	24	Physics & Astronomy
11	Economics, Econometrics & Finance	25	Psychology
12	Energy	26	Social Sciences
13	Engineering	27	Veterinary
14	Environmental Science		

Table 1 The 27 subject areas addressed in this study

3.2 Data related with scientific publications

To answer the RQ, we consider two different datasets, each related with different queries used to fetch the authors ordering data of journal articles. A semi-automated retrieval method was adopted to fetch the paper metadata, which involved a manual selection of the target journals per scientific area, executed via the known International Standard Serial Number (ISSN). Then, the metadata of the associated articles was collected using the Scopus engine, as downloaded in May 2020. Dataset 1 (DS1) is related with all papers that were published in a prestigious journal of a subject area, assuming the last known SCImago Journal Rank (SJR) index. Dataset 2 (DS2) contains the metadata of a minimum of 1,000 articles published in the one or more top journals of a given subject area. To further differentiate the datasets, the DS2 sample includes recent articles, published in the years of 2018, 2019 and 2020.

Table 2 shows the journals that were considered for DS1. In the majority of the cases, DS1 includes the first ranked journal, according to the SCImago Journal Ranking indicator. There are a few exceptions that occur when the top journal for a given subject area is listed in two or more subject areas. In these cases, we consider that the journal has a multidisciplinary coverage and thus it is excluded from DS1, since the aim is to select journals that are representative of a single subject area. Thus, in these cases, the journal was replaced by the highest ranked journal that is related with a single SCImago scientific area. Table 2 presents several known journals, such as Nature (established in 1869), Science (1880), and Quarterly Journal of Economics (1886). For each journal, the table also indicates the initial year considered in this study and the total number of articles for DS1. All the metadata related to the papers published in that year or afterwards were downloaded from the Scopus engine.

Tables 3 and 4 show the journals that were considered for DS2. All the selected journals are listed in SCImago in just one subject area. The adopted process for journal inclusion was iterative. We went through the list of SCImago

#	journal	ISSN	initial year	number articles
1	Genome Biology	1474-760X	2000	4 689
2	Science	0036-8075	2004	37 946
3	Nature Reviews Genetics	1471-0056	2000	3 263
4	Journal of Labor Economics	0734-306X	1985	818
5	Nature Reviews Chemistry	2397-3358	2017	255
6	Chemical Reviews	1520-6890	1924	5 054
7	SoftwareX	2352-7110	2015	345
8	Journal of Operations Management	0272-6963	1980	1 336
9	Periodontology 2000	0906-6713	1993	1 013
10	Annual Review of Astronomy and Astrophysics	1545-4282	1990	466
11	Quarterly Journal of Economics	0033-5533	1886	4 437
12	Nature Energy	2058-7546	2016	806
13	Advanced Materials	0935-9648	1989	19 191
14	Energy and Environmental Science	1754-5692	2008	3 783
15	Vital and Health Statistics [Series 2]	0083-2057	1965	138
16	Nature Reviews Immunology	1474-1733	2001	3 283
17	Nature Reviews Materials	2058-8437	2016	404
18	Journal of the American Mathematical Society	1088-6834	1988	966
19	CA Cancer Journal for Clinicians	1542-4863	1950	2 190
20	Nature	1476-4687	1992	33 907
21	Nature Reviews Neuroscience	1471-0048	2000	3 425
22	World Psychiatry	2051-5545	2011	656
23	Nature Reviews Drug Discovery	1474-1776	2002	3 264
24	Reviews of Modern Physics	0034-6861	1929	3 326
25	Annual Review of Psychology	0066-4308	1950	1 222
26	Administrative Science Quarterly	0001-8392	1975	605
27	Annual Review of Animal Biosciences	2165-8110	2013	163

Table 2 Selected journals for DS1.

journals for a given subject area, ranked according to the SJR criterion, and searched for a journal that fits exclusively in that area. We then searched in Scopus for all papers published in the selected journal ISSN within the 2018 to 2020 year. If the returned number of papers was smaller than 1,000, then we selected the next highest ranked journal for the same subject area, until the more than 1,000 papers were reached. For instance, the last Scoups search query for the subject area #7, which covers three journals, was:

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PUBYEAR AFT 2017 AND (ISSN(1935-8237) OR ISSN(2352-7110) OR ISSN(2162-237X))
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This query searches the articles published after 2017 in the three journals with the indicated ISSNs. Whenever the number of articles by Scopus was higher than 2,000, only the metadata of the first 2,000 were considered. It should be noted that for the journals that have two ISSNs, as indicated in SCImago, the query includes both ISSNs, just to make sure that all articles of that journal were considered.

The entries in the files retrieved from Scopus and related with the papers metadata were “cleaned” using a code written in the Python language. Firstly, only the list of authors for each paper was considered and thus the other fields were discarded. Then, data errors, inconsistencies, lack of data, wrong spellings, etc. were eliminated/corrected. Only the 26 letters in the

#	journal	ISSN
1	Trends in Ecology and Evolution	0169-5347
	Ecology Letters	1461-023X
	Annual Review of Entomology	0066-4170
	Studies in Mycology	0166-0616
	Ecological Monographs	0012-9615
2	Nous	1468-0068
	The Philosophical Review	0031-8108
	Ethics	1539-297X
	Nous-Supplement: Philosophical Issues	1533-6077
	British Journal for the Philosophy of Science	1464-3537
	Philosophy and Phenomenological Research	0031-8205
	Philosophical Quarterly	0031-8094
	Mind	0026-4423
	Philosophical Studies	0031-8116
3	Nature Reviews Molecular Cell Biology	1471-0072
	Cell	0092-8674
4	Academy of Management Annals	1941-6520
	Academy of Management Journal	0001-4273
	Academy of Management Review	0363-7425
	Strategic Management Journal	1097-0266
	Organization Science	1526-5455
	Journal of Business Venturing	0883-9026
	Journal of Retailing	0022-4359
5	Catalysis Science and Technology	2044-4761
6	Chemical Reviews	1520-6890
	Chemical Society Reviews	0306-0012
7	Foundations and Trends in Machine Learning	1935-8237
	SoftwareX	2352-7110
	IEEE Transactions on Neural Networks and Learning Systems	2162-237X
8	OR Spektrum	0171-6468
	Annals of Operations Research	0254-5330
9	Periodontology 2000	0906-6713
	Journal of Clinical Periodontology	1600-051X
	Clinical Oral Implants Research	1600-0501
	International Endodontic Journal	1365-2591
10	Reviews of Geophysics	8755-1209
	Annual Review of Marine Science	1941-0611
	Nature Geoscience	1752-0908
	Earth System Science Data	1866-3516
	Bulletin of the American Meteorological Society	1520-0477
11	Quarterly Journal of Economics	0033-5533
	Journal of Political Economy	0022-3808
	Econometrica	0012-9682
	Review of Economic Studies	0034-6527
	American Economic Journal: Macroeconomics	1945-7707
	American Economic Review	0002-8282
	American Economic Journal: Applied Economics	1945-7790
	Journal of Economic Literature	0022-0515
12	Joule	2542-4351
	Renewable and Sustainable Energy Reviews	1364-0321
13	IEEE Communications Surveys and Tutorials	1553-877X
	Automatica	0005-1098
14	Global Change Biology	1365-2486

Table 3 Selected journals for DS2.

#	journal	ISSN
15	Journal of Physiotherapy	1836-9553
	Physical Therapy	0031-9023
	Physiotherapy Research International	1358-2267
	Musculoskeletal Science and Practice	2468-7812
	Journal of Chiropractic Medicine	1556-3715
16	Annual Review of Microbiology	0066-4227
	Annual Review of Virology	2327-0578
	mBio	2161-2129
17	Progress in Materials Science	0079-6425
	Annual Review of Materials Research	1531-7331
	Acta Materialia	1359-6454
18	Journal of the American Mathematical Society	1088-6834
	Inventiones Mathematicae	0020-9910
	Publications Mathématiques	0073-8301
	Duke Mathematical Journal	0012-7094
	Communications on Pure and Applied Mathematics	0010-3640
	Acta Numerica	0962-4929
	Annales Scientifiques de l'Ecole Normale Superieure	0012-9593
	Acta Mathematica	0001-5962
	Geometric and Functional Analysis	1420-8970
	Annales de l'Institut Henri Poincare	0294-1449
	Memoirs of the American Mathematical Society	0065-9266
19	CA - A Cancer Journal for Clinicians	1542-4863
	New England Journal of Medicine	0028-4793
20	Nature	1476-4687
21	Nature Reviews Neuroscience	1471-0048
	Nature Neuroscience	1097-6256
	Neuron	0896-6273
22	Clinical and Translational Immunology	2050-0068
	International Journal of Nursing Studies	0020-7489
	NursingPlus Open	2352-9008
	Journal of Nursing Scholarship	1547-5069
	Journal of Nursing Management	0966-0429
23	Annual Review of Pharmacology and Toxicology	1545-4304
	Trends in Pharmacological Sciences	0165-6147
	Advanced Drug Delivery Reviews	0169-409X
	International Journal of Pharmaceutical Investigation	2230-9713
	British Journal of Pharmacology	0007-1188
24	Reviews of Modern Physics	0034-6861
	Advances in Physics	1460-6976
	Nature Physics	1745-2473
	Physics Reports	0370-1573
25	Annual Review of Psychology	0066-4308
	Personality and Social Psychology Review	1088-8683
	Psychological Inquiry	1532-7965
	Psychological Science in the Public Interest & Supplement	1529-1006
	Journal of Applied Psychology	0021-9010
	Perspectives on Psychological Science	1745-6916
	Psychological Review	0033-295X
	Educational Psychologist	1532-6985
	Psychological Science	0956-7976
26	National Vital Statistics Reports	1551-8922
	American Journal of Political Science	0092-5853
	Quarterly Journal of Political Science	1554-0634
	American Political Science Review	1537-5943
	Political Analysis	1047-1987
	American Sociological Review	0003-1224
	Review of Educational Research	0034-6543
	Journal of Politics	1468-2508
27	Veterinary and Comparative Oncology	1476-5829
	Veterinary Research	0928-4249
	Journal of Veterinary Emergency and Critical Care	1479-3261
	Veterinary Pathology	1544-2217

Table 4 Selected journals for DS2 (cont.).

Latin/Roman alphabet (A to Z) were considered. Diacritics were removed, thus many non-Latin letters, such as â, ã, á, à, ä, ă, æ, ç, č, ğ, ł, ń, ø, ș, ț, ż, were replaced by the most similar Latin letter.

3.3 Ordering indicators

In this study, we adopt two main alphabetic author order indicators:

1. the measurement of fully ordered author papers; and
2. a degree of alphabetic ordering, measured using the Inversion criterion.

These indicators are detailed in the next paragraphs.

Regarding the first indicator, we have implemented a Python program to analyze, for each paper, how many authors it contains and if the list of authors is either ordered or not ordered. The detection of an alphabetically ordered author sequence may fail in a few cases. One reason for this possibility lies in the fact that small words with only lowercase letters (e.g., da, de, del, den, der, di, do, dos, du, la, le, te, ten, ter, thi, van, van, von), that usually precede surnames, are ignored in our study. If however the preceding small word has an initial capital letter, it is considered to be part of the surname. This may differ from the rules followed by the authors. The Python program considers "Almeida A., De Barbosa B., Carvalho C." to be disordered, but "Almeida A., de Barbosa B., Carvalho C." to be ordered. The surname of the second author is "De Barbosa" in the former case and "Barbosa" in the latter. Another reason is the use of non-Latin letters that can affect the analysis whether a list of authors is ordered. For example, the Danish/Norwegian alphabet includes three letters (æ, ø, å) that are considered to be the last ones (i.e.,they appear after z). However, when they are transformed into Latin letters (to ae, oe, aa) the ordering analysis is likely to change. For example, the list of authors "Bratbak G., Tsagaraki T.M., Øvreås L." is ordered according to the danish/norwegian alphabet, but when latinised ("Bratbak G., Tsagaraki T.M., Oevreaas L.") it becomes disordered. Nevertheless, the number of papers where such situations occur is residual and does not affect the overall results presented in this manuscript.

It is important to notice that there are lines of authors that are accidentally in alphabetical order, i.e., the authors are ordered, but that was not the criterion used to place them in the authors list. If, for example, 2-author papers are considered, around 50% of them would be ordered. With six co-authors, there are $6! = 720$ different combinations to place them and only one is alphabetically ordered. Thus, the probability to find an alphabetical-ordered six-author line (that was not specifically arranged in alphabetical order) is smaller than 0.0014%. For higher number of authors ($N \gg$), this value is obviously smaller. To cope with this issue, we define a baseline for the first indicator, which is defined as $1/N!$. In this work, the baseline is compared with the Percentage of Fully Ordered (PFO) articles, defined as:

$$\mathrm{PFO}(D) = \frac{\mathrm{FO}(D)}{\#D} \tag{1}$$

author list	FO	DAO
<A,B,C,D,E>	1	100%
<A,B,C,E,D>	0	90%
<B,A,C,E,D>	0	80%
<B,D,A,C,E>	0	70%
<B,E,A,C,D>	0	60%
<B,E,A,D,C>	0	50%
<B,E,D,A,C>	0	40%
<E,B,D,A,C>	0	30%
<E,D,B,A,C>	0	20%
<E,D,C,A,B>	0	10%
<E,D,C,B,A>	0	0%

Table 5 Examples of FO and DAO values for 5-author lists.

Where D is dataset with a total of $\#D$ author lists and FO(D) denotes the number of fully ordered lists in D. The dataset D is defined according to an analysis criterion. For example, it can include all papers from DS1 and that have only N = 4 authors. The D members are author sequence lists $l =< a_1, a_2, ..., a_N >$, where a_i denotes the i-th author of the paper. A list is fully ordered if the alphabetic condition $a_i < a_j$ is true when $i < j$.

In the field of Computer Science, the efficiency of sorting algorithms has been well studied. Thus, there are several methods that were proposed to measure the sorting degree (more precisely, its inverse, i.e., the degree of disorder), such as the eleven metrics proposed by (Estivill-Castro and Wood 1992). The most common metric is the number of inversions that exist in a list or sequence. Let Inv(l) denote the number of inversions in list $l =< a_1, a_2, ..., a_N >$, where (i, j) is an inversion if $i < j$ and $a_i > a_j$. The maximum number of inversions in a list with N elements is thus $\frac{\mathrm{N}\times(\mathrm{N}-1)}{2}$, which occurs for the inversely ordered list. For example, the lists <A, B, C, Z, D> and <Z, A, B, C, D> have one and four inversions, respectively. The pair (Z,D) is the only inversion in the first list. There are 4 inversions in the second list, the pairs (Z,A), (Z,B), (Z,C), and (Z,D). In this paper, we adapt the inversion metric to measure the degree of alphabetic ordering (DAO) of a list l, within the $[0, 1]$ range, by using:

$$\mathrm{DAO}(l) = 1 - \frac{\mathrm{Inv}(l) \times 2}{\mathrm{N} \times (\mathrm{N} - 1)} \quad (2)$$

A DAO value of zero indicates a fully inverted ordered list. The higher the value, the more ordered is the list. When DAO(l) = 100%, it corresponds to the fully ordered list (measured by FO). As an example, Table 5 shows several DAO(l) values for 5-author papers. In this paper, we performing the distinct ordering analyses, by considering a dataset with several lists ($D = \{l_1, l_2, ..., l_{\#D}\}$). In such cases, we measure the overall DAO(D) value as the average of all DAO(l) values.

The DAO measure has some interesting properties. Firstly, it provides a numeric score that is more informative than the binary fully ordered measurement (as shown in Table 5). For example, it can provide a high order value (e.g., 90%) for the papers that are almost ordered or that are actually ordered but that are not correctly detected by our Python program (e.g., usage of the Danish alphabetic ordering). Secondly, for any fixed number of paper authors (N), a random list of authors (r) will tend to produce a DAO(r) = 50%, which is the baseline value considered for the DAO indicator.

4 Results

Using code written in Python, for each dataset (DS1 and DS1) we computed the PFO and DAO indicators. Since we wanted to check if the usage of an alphabetic ordering changes when a paper has more authors, the indicator overall percentages were computed for different number of authors, namely from N = 2 to N = 9, also including a special value of N > 9, which denotes all papers with more than 9 authors.

Tables 6 and 7 present the fully ordered (PFO) results for DS1 and DS2. Similarly, Tables 8 and 9 show the degree of alphabetic ordering (DAO) values for the two datasets (DS1 and DS2). The first row of the tables present the baseline values. We have highlighted any PFO or DAO overall values that were 10 percentage points higher than the baseline (signaled by using a **boldface** font). For each subject area, we also track the maximum number of authors (column **max.**).

We first analyze the maximum number of authors (column max), which clearly shows subject area differences. Some scientific areas have a smaller maximum number of authors, such as: Mathematics (5 for DS1, 6 for DS2); and Business, Management & Accounting (5 for DS1 and 8 for DS2). Other scientific subjects have a much higher number of authors, including Arts & Humanities (2932 for DS1), Multidisciplinary (2422 for DS1) and Medicine (506 for DS2). Figure 4 shows two histograms of the numbers of paper authors ($N \in \{2, ..., max\}$) for the Economics (#11, left plot) and Environmental Science (#14, right graph) areas. The figure reveals two distinct patterns for the typical number of authors that appear in each area. Economics papers tend to have just two authors, while most Environmental Science articles have four authors.

Regarding the alphabetic ordering, there is an overall consistency in the obtained results for both datasets (DS1 and DS2) and indicators (PFO and DAO). For instance, highlighted results (when compared with baseline values) tend to appear in similar cases for all ordering results (Tables 6, 7, 8 and 8). Moreover, Table 10 presents several Pearson correlations that were computed when varying the number of paper authors from N =2 to N =5 (range that appears in all 27 scientific subjects). The correlations show a very positive alignment between the two ordering indicators (PFO and DAO, with just one 0.8 correlation and several values above 0.90. Also, there is a positive relationship in the alphabetic ordering measurements obtained for both datasets (DS1 and DS1), with the correlations ranging from 0.63 to 0.81. Turning to the comparison among the different scientific areas, there are a few areas that

		N-authors									
#	**subject**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**>9**	**max.**
-	baseline	50	17	4	1	0	0	0	0	0	-
1	Agricult. & Biolog. Sc.	52	17	3	1	1	1	1	1	0	386
2	Arts & Humanities	51	22	7	3	2	1	1	1	1	2 932
3	Bioch., Genet. & Molec.	53	16	7	10	**11**	**14**	**20**	**20**	0	144
4	Busin., Manag. & Acc.	**91**	**86**	**83**	**75**	-	-	-	-	-	5
5	Chemical Eng.	50	24	9	0	**14**	0	0	0	0	24
6	Chemistry	55	24	9	7	3	1	2	0	3	32
7	Computer Science	49	14	6	4	6	10	13	0	0	19
8	Decision Sciences	58	24	13	6	0	0	-	-	-	7
9	Dentistry	51	21	4	0	0	0	0	0	0	16
10	Earth & Planet. Sc.	55	**31**	**20**	**33**	-	-	-	-	-	5
11	Economics	**89**	**87**	**88**	**85**	**60**	0	0	-	-	8
12	Energy	55	25	**18**	6	6	0	0	0	0	59
13	Engineering	53	18	6	2	1	0	1	0	0	32
14	Environmental Science	51	19	3	1	0	0	0	0	0	45
15	Health Professions	56	9	**20**	0	0	0	0	0	0	18
16	Immun. & Microbiology	48	19	6	5	0	0	0	0	**10**	90
17	Materials Science	42	12	7	0	0	0	0	-	0	15
18	Mathematics	**98**	**96**	**89**	**86**	-	-	-	-	-	5
19	Medicine	50	15	6	0	0	0	4	0	0	42
20	Multidisciplinary	51	20	8	3	1	1	0	0	0	2 422
21	Neuroscience	50	19	9	2	5	0	0	0	0	42
22	Nursing	46	23	4	0	0	0	0	0	0	101
23	Pharmacy	59	19	6	6	2	3	0	0	3	65
24	Physics & Astronomy	**70**	**49**	**35**	**32**	**26**	6	**24**	**31**	**15**	48
25	Psychology	57	**27**	**17**	0	0	-	-	-	-	6
26	Social Sciences	**60**	20	**22**	**11**	0	-	-	-	-	6
27	Veterinary	53	19	8	0	0	0	0	-	-	8

Table 6 Percentage of fully ordered articles per number of authors for DS1 (values 10 percentage points higher than the baseline are in **boldface**).

present a consistent alphabetic pattern. In particular, we have identified two main patterns:

- **strong alphabetic degree**:
  - DS1 and DS2 – **Economics** (#11) and **Mathematics** (#18);
  - DS1 – **Business, Management & Accounting** (#4);
- **moderate alphabetic degree**:
  - DS1 and DS2 – **Social Sciences** (#26)
  - DS1 – **Physics & Astronomy** (#24), **Biochemistry Genetics & Molecular Biology** (#3, e.g., $N \in \{7, 8, 9, > 9\}$) and **Earth & Planetary Sciences** (#10, e.g., $N \in \{3, 4, 5\}$));
  - DS2 – **Arts & Humanities** (#2, e.g., $N \in \{2, 3, 4\}$).

The *DAO* differences for DS1 and D2 can be visualized in Figure 4, which includes the eight subject areas previously listed has having an interesting alphabetic ordering degree pattern. Figure 4 allows to visually confirm that the strong alphabetic ordering areas (#11 and #18) maintain the same level of indicator values for DS1 (top graph) and DS2 (bottom plot). The obtained ordering results are aligned with the ones made by Waltman (2012), which

		N-authors									
#	**Subject**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**>9**	**max.**
-	Baseline	50	17	4	1	0	0	0	0	0	-
1	Agricult. & Biolog. Sc.	51	20	5	2	1	0	0	0	0	73
2	Arts & Humanities	43	**67**	0	0	-	-	0	-	0	46
3	Bioch., Genet. & Molec.	47	19	9	0	0	0	0	0	0	72
4	Busin., Manag. & Acc.	**62**	**31**	12	2	**20**	0	0	-	-	8
5	Chemical Eng.	44	19	5	1	0	0	0	1	1	15
6	Chemistry	52	19	7	1	2	0	0	0	0	25
7	Computer Science	52	20	5	1	1	3	0	0	0	24
8	Decision Sciences	58	**39**	**24**	**14**	**11**	0	**50**	-	-	8
9	Dentistry	53	17	6	1	0	0	0	0	0	42
10	Earth & Planet. Sc.	49	18	6	1	2	0	0	0	0	501
11	Economics	**98**	**93**	**88**	**85**	**50**	**100**	-	-	-	7
12	Energy	55	20	6	5	0	0	3	0	1	32
13	Engineering	53	22	6	3	0	0	0	0	0	11
14	Environmental Science	51	17	3	1	0	0	0	2	1	104
15	Health Professions	51	20	3	1	0	0	0	0	0	21
16	Immun. & Microbiology	46	17	3	1	0	0	0	0	0	104
17	Materials Science	52	12	5	1	0	0	0	0	0	20
18	Mathematics	**97**	**94**	**96**	**100**	**75**	-	-	-	-	6
19	Medicine	49	19	3	0	0	0	5	0	0	506
20	Multidisciplinary	54	19	10	2	2	0	4	3	0	559
21	Neuroscience	53	15	4	0	0	1	0	0	0	95
22	Nursing	53	16	5	1	0	0	0	0	0	25
23	Pharmacy	55	17	3	0	0	0	0	0	0	30
24	Physics & Astronomy	**67**	**48**	**24**	6	8	2	4	3	1	99
25	Psychology	52	15	5	2	2	0	0	0	0	124
26	Social Sciences	**81**	**55**	**42**	**21**	0	**20**	0	0	-	9
27	Veterinary	40	23	3	2	0	0	0	0	0	22

Table 7 Percentage of fully ordered articles per number of authors for DS2 (values 10 percentage points higher than the baseline are in **boldface**).

highlighted an alphabetic author degree usage in the fields of Economics, Mathematics and Physics. Finally, it should be noted that in some cases, there is a slight alphabetic ordering increase for papers that have a larger number of authors. For example, the average DAO values rise from $N = 9$ to $N > 9$ for several subject areas. This occurs in six areas (#2, #3, #6, #9, #10 and #13) for DS1 (Table 8) and five areas (#1, #9, #10, #14 and #25) for DS2 (Table 9).

5 Conclusions

COMPLETAR

Author contributions

J. M. Fernandes performed the conceptualization, methodology, software, investigation, resources, formal analysis, writing – original draft, writing - review

		N-authors										
#	**Subject**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**>9**	**max.**	**N_***
-	Baseline	50	50	50	50	50	50	50	50	50	-	-
1	Agricult. & Biolog. Sc.	52	49	48	49	50	50	53	51	57	386	40 (62%,50)
2	Arts & Humanities	51	52	51	52	51	52	50	51	**71**	2 932	21 (62%,1309)
3	Bioch., Genet. & Molec.	53	48	53	56	48	**63**	**70**	**62**	**68**	144	
4	Busin., Manag. & Acc.	**91**	**92**	**95**	**92**	-	-	-	-	-	5	
5	Chemical Eng.	50	52	43	48	51	**67**	57	51	40	24	
6	Chemistry	55	54	53	53	50	50	55	56	**61**	32	
7	Computer Science	49	50	46	57	51	**60**	56	57	50	19	
8	Decision Sciences	58	55	54	49	**63**	**90**	-	-	-	7	
9	Dentistry	51	53	51	54	52	52	52	51	42	16	
10	Earth & Planet. Sc.	55	**63**	**67**	**80**	-	-	-	-	-	5	
11	Economics	**89**	**94**	**95**	**91**	**89**	**90**	32	-	-	8	
12	Energy	55	51	**61**	50	54	47	45	50	51	59	
13	Engineering	53	51	51	50	50	49	50	50	47	32	
14	Environmental Science	51	49	48	49	50	49	49	48	54	45	
15	Health Professions	56	33	56	46	50	33	**70**	**61**	40	18	
16	Immun. & Microbiology	48	53	50	56	**62**	46	57	**78**	58	90	
17	Materials Science	42	46	50	49	46	49	42	0	41	15	
18	Mathematics	**98**	**97**	**96**	**94**	-	-	-	-	-	5	
19	Medicine	50	46	52	51	53	50	55	52	**63**	42	
20	Multidisciplinary	51	52	52	51	51	51	50	50	**65**	2 422	31 (60%,948)
21	Neuroscience	50	49	48	53	52	**62**	54	**71**	**69**	42	
22	Nursing	46	54	58	56	51	56	57	48	57	101	
23	Pharmacy	59	53	54	53	55	**61**	55	**60**	**72**	65	17 (76%,32)
24	Physics & Astronomy	**70**	**70**	**68**	**73**	**71**	**65**	**68**	**81**	**74**	48	
25	Psychology	57	55	54	54	58	-	-	-	-	6	
26	Social Sciences	**60**	50	**65**	**72**	**70**	-	-	-	-	6	
27	Veterinary	53	53	57	45	55	**70**	**63**	-	-	8	

Table 8 Ordered degree mean percentage per number of authors for DS1 (values 10 percentage points higher than the baseline are in **boldface**).

and editing. P. Cortez contributed with methodology, validation, formal analysis, writing – review and editing and visualization.

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		N-authors										
#	Subject	2	3	4	5	6	7	8	9	>9	max.	N*
-	Baseline	50	50	50	50	50	50	50	50	50	-	-
1	Agricult. & Biolog. Sc.	51	54	53	55	53	55	53	**62**	**72**	73	11 (69%,113)
2	Arts & Humanities	**76**	**67**	**94**	40	-	-	54	-	45	46	
3	Bioch., Genet. & Molec.	47	52	49	47	46	51	47	49	50	72	
4	Busin., Manag. & Acc.	**62**	58	55	49	**64**	54	**62**	-	-	8	
5	Chemical Eng.	44	55	50	49	50	51	51	51	41	15	
6	Chemistry	52	52	50	49	51	48	50	50	51	25	
7	Computer Science	52	52	47	50	54	52	51	58	52	24	
8	Decision Sciences	58	**64**	**61**	57	56	53	**61**	-	-	8	
9	Dentistry	53	48	50	46	50	51	51	53	**68**	42	10 (59%,83)
10	Earth & Planet. Sc.	49	48	51	52	54	55	55	54	**73**	501	10 (63%,370)
11	Economics	**98**	**96**	**96**	**93**	**90**	**100**	-	-	-	7	
12	Energy	55	53	52	51	51	51	50	51	51	32	
13	Engineering	53	51	51	51	50	51	50	49	30	11	
14	Environmental Science	51	50	50	48	50	53	52	55	**69**	104	10 (62%,265)
15	Health Professions	51	56	50	50	52	53	50	52	55	21	
16	Immun. & Microbiology	46	49	50	49	51	50	48	47	48	38	
17	Materials Science	52	47	50	51	50	50	49	50	46	20	
18	Mathematics	**97**	**97**	**98**	**100**	**97**	-	-	-	-	6	
19	Medicine	49	50	50	53	55	54	51	52	53	506	
20	Multidisciplinary	54	52	53	57	54	51	54	51	58	559	58 (67%,16)
21	Neuroscience	53	51	50	47	49	52	50	48	54	95	
22	Nursing	53	49	49	50	49	49	54	53	51	25	
23	Pharmacy	55	51	50	49	51	53	50	50	49	30	
24	Physics & Astronomy	**67**	**70**	**64**	53	55	52	49	55	56	99	
25	Psychology	52	51	48	52	49	52	51	42	**60**	124	
26	Social Sciences	**81**	**72**	**73**	58	33	**76**	25	51	-	9	
27	Veterinary	40	49	47	47	49	52	53	52	50	22	

Table 9 Ordered degree mean percentage per number of authors for DS2 (values 10 percentage points higher than the baseline are in **boldface**).

		N-authors			
Variable 1	Variable 2	2	3	4	5
PFO (DS1)	PFO (DS2)	0.81	0.74	0.81	0.79
DAO (DS1)	DAO (DS2)	0.76	0.73	0.63	0.67
PFO (DS1)	DAO (DS1)	1.00	0.98	0.97	0.94
PFO (DS2)	DAO (DS2)	0.90	0.97	0.80	0.97

Table 10 Person correlation values for the ordering indicators.

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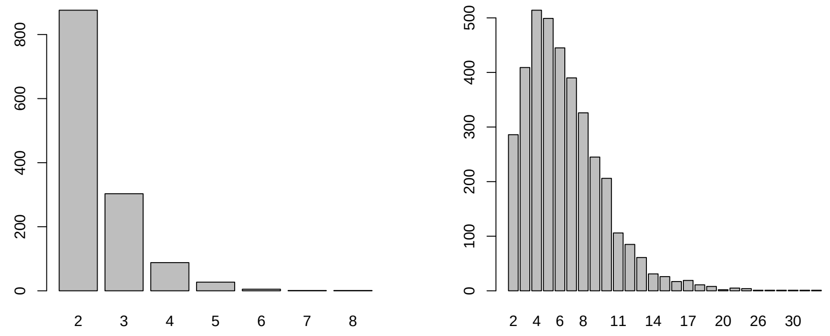

Fig. 1 Histograms of the number of authors (x-axis presents N; $y-$axis shows the number of papers) for two example scientific areas (Economices – left graph; Environmental Science – right graph).

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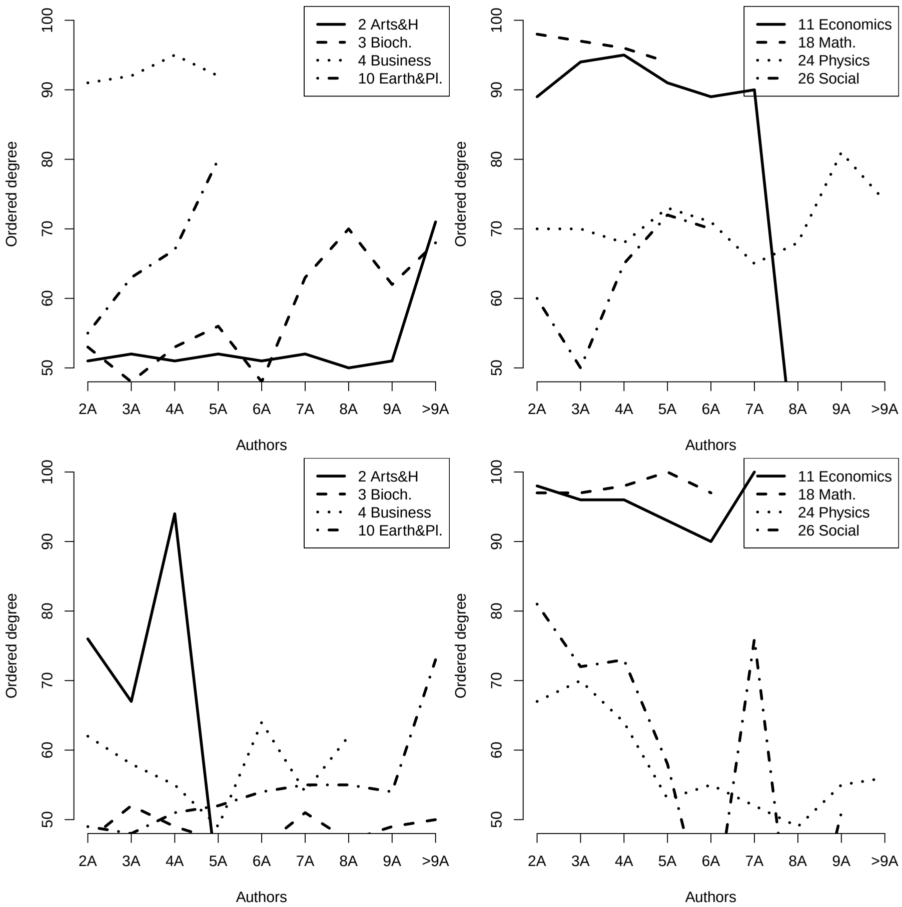

Fig. 2 Ordered degree by number of authors for selected scientific areas (DS1 – top graphs; DS2 – bottom graphs).

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