fCite: a fractional citation tool to quantify an individual's scientific research output

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SHORT TITLE: **fCite: dividing impact by the number of authors**

ABSTRACT: Here, I present the *fCite* web service (fcite.org) a tool for the in-depth analysis of an individual's scientific research output. While multiple existing tools (e.g., Google Scholar, iCite, Microsoft Academic) focus on the total number of citations and the H-index, I propose the analysis of the research output by considering multiple metrics to provide greater insight into a scientist's multifaceted profile. The most distinguishing feature of *fCite* is its ability to calculate fractional scores for most of the metrics currently in use. Thanks to the division of citations (and RCR scores) by the number of authors, the tool provides a more detailed analysis of a scholar's portfolio. *fCite* is based on PUBMED data (~18 million publications), and the statistics are calculated with respect to ORCID data (~600,000 user profiles).

ABBREVIATIONS: RCR – Relative Citation Ratio; PMID – **P**ub**M**ed **Id**entifier; ORCID – **O**pen **R**esearcher & **C**ontributor **ID;** DORA - San Francisco **D**eclaration **o**n **R**esearch **A**ssessment; FLAE model - **f**irst-**l**ast-**a**uthor-**e**mphasis model; EC model – **e**qual **c**ontribution model; M-index – H-index divided by the number of years; fH-index – before H-index is calculated the citations are divided using FLAE model; fM-index – fH-index divided by the number of years; $FLAE_{RCR}$ – RCR score calculated using FLAE model; EC_{RCR} – RCR score calculated using EC model; $FLAE_{cit}$ – number of citations calculated using FLAE model; EC_{cit} – number of citations calculated using EC model; SJR - **S**CImago **J**ournal **R**ank indicator; HCR – **H**ighly **C**ited **R**esearchers list

KEY WORDS: bibliometrics, scientometrics, bibliometric analysis, quality of publications, bibliometrics tools, science impact, science policy, science evaluation, research assessment

INTRODUCTION

At present, the impact of the work of a scientist can be estimated by a number of bibliometric metrics, but there is a strong bias towards the number of articles written by an author, the total number of citations of those articles, the impact factors of the journals in which they appeared (1) and finally the H-index (2). In contrast to this approach, increasing number of people are opposed to a bibliometric, mechanical *modus operandi* and in favour of expert assessment (e.g., see the DORA declaration) (3). Although expert approach is a compelling idea, in real life a fair assessment of a scientific portfolio comprising multiple publications (for instance containing over 100 items) spread across multiple journals (e.g., in 2019 PUBMED alone indexed 48,601 journals) may not be possible in a reasonable amount of time. Even if the expert is familiar with the quality of the journal in which the publications appeared and, even if he/she has read the most important publications from the portfolio, he/she still needs to understand and judge the author's contribution to given work(s). With multiple-author papers this can be very difficult to achieve. Acknowledgment statements (if any) are usually very frugal, and it is often impossible to say which part of the work was done by which author. Moreover, if one also recognizes that publications are frequently interdisciplinary, the proper assessment of the influence of the average-sized portfolio is beyond the scope of a single person, and ultimately, it is very subjective. On the other hand, in many fields the order in the author list can be considered a rough approximation of the contribution, where the first author is the scientist who performed the most of the experiments (e.g., a PhD student), the middle authors are those who helped with multiple specialized parts of the work or/and the analysis of the data and the last/corresponding author is a principal investigator who conceived the project, obtained the funding and supervised all steps (frequently this does not exclude involvement in the experiments or the analysis). Such a model is termed the **f**irst-**l**ast-**a**uthor-**e**mphasis (FLAE) model (4), and depending on how much emphasis is placed on a particular author, the FLAE model can have multiple flavours (here we use three models named FLAE, FLEA2, and FLAE3; for details see the *Material and Methods*). However, given a sufficient number of items in the portfolio, they yield very similar results (5). In contrast, if the order of authors is random or alphabetical, we can always use the equal contribution (EC) model in which each author has the same weight (**Fig. 1**, Supplementary Fig. 1-4, Supplementary Tables 1-5). At this point, an open question is how to assess the influence of the publication. The most accessible (and frequently used) metric is the number of citations it has received over time. Usually, metrics such as total citation counts or the H-index are calculated using global scores (regardless of the number of authors, each author obtains all of the citations of the publication), but applying FLAE or EC models provides a straightforward way to quantify the author's contribution in a more precise manner. The division of the contribution is a highly demanding (and overlooked (6)) feature because the number of authors has increased steadily over time to exceed an average of six authors per research publication in 2015 (**Fig. 2**, Supplementary Table 6). The trend of having increasing numbers of authors is also clear when we analyse the mode of the number of authors in publications over the last 25 years (**Fig. 3**, Supplementary Table 7). Currently, publications with hundreds of authors are not rare, and some items can have more than several thousand authors. Concomitantly, shared first or last authorship has become a common practice, and it is not difficult to find publications with three or more shared first authors and few corresponding/last authors.

Rewarding all authors, regardless of their number, is an obvious shortcoming of current bibliometric tools and contradicts common sense. Consider a hypothetical situation in which you are a member of a grant or fellowship committee and have two applicants. Both of them published single publications in the same journal (for simplicity of the example), but the first publication has two authors (the applicant and his/her supervisor), while in the second case the applicant is the middle author of a consortium paper (such papers usually have few hundred authors). After a few years since the publication date, you see that the first publication has received a few dozen citations, while the second has a few hundred citations. Which candidate would you prefer? In the presented example, most experienced assessors would prefer the first candidate. If you were to do some back-of-the-envelope calculations, you would conclude that the first item has roughly an order of magnitude more citations per author than the second, and it is almost trivial to assess the contribution to the first publication; however, when there are a few hundred authors, it is literally impossible to say who did what, and most likely those hundreds of citations are self-citations or/and courtesy citations (for instance, the publication describes an important resource used by the whole field). The presented example is highly simplified, and usually there are more items in portfolios, which significantly complicates the analysis. Typically, portfolios will be more diverse in the number of items and journals in which they were published. The other well known drawback of the expert based evaluation system is it’s high cost (e.g, Research Excellence Framework in United Kingdom) (7). The *fCite* web service presented here should fill the gap between the (overly) simple bibliometric and expensive expert-based approaches, facilitating fairer assessment of scientific output.

MATERIALS AND METHODS

Data sets

The statistics in fCite are based on two data sets: (1) PUBMED data set – contains PUBMED publications (17,787,016 publications; 14,444,982 research and 3,342,034 non-research items) obtained via icite.od.nih.gov portal (Supplementary Data 1-2) and (2) ORCID (**O**pen **R**esearcher & **C**ontributor **ID**) data set – contains 5,380,983 user profiles (Supplementary Data 3).

Fractional contribution models of the authorship

Four, different models had been used to assess the author contribution:

- FLAE (**f**irst-**l**ast-**a**uthor-**e**mphasis) model is based on Tscharntke et al. 2007 definition with slight modifications (4). The contribution of individual authors can be described briefly as "the first author gets 100, the last 50, and all others 100/number of authors and then scores are normalized to 1". This type of the model gives the strongest weights to the first and the last author penalizing middle authorship (Supplementary Table 1).
- FLAE2 model is based on Corrêa Jr. et al. 2017 (5). This is empirical model based on the authorship contribution for the mega-journal PLoS ONE (~65,000 publications). On average this model is more benign for middle authors. As the data presented by Corrêa Jr. and co-authors are limited up to ten authors, for the longer author lists the contribution has been modeled by curve fitting with some noise using the initial matrix (with up to ten authors), and thresholds 0.06 for 30 authors and 0.07 for 100 authors (for more details see scipy.optimize.curve_fit documentation and http://www.fcite.org/FLAE2.txt) (Supplementary Table 2). Additionally, this model is asymmetric, i.e. middle author weights depends on the position, the closer to the first author, the better are weights for middle author (up to 10th author).
- FLEA3 model is a simple variation of FLAE model, but the contribution of individual authors is more equal. It can be shortly described as "the first author always get at least three times more than co-authors, and the last author at least two times more than other co-authors" (Supplementary Table 3).
- EC (equal contribution) model assumes that each author contributed equally to given work (Supplementary Table 4).

First three models assume that for a given field the order of the authors is not random and the first author was the one who contributed the most while the last is a senior author who conceived the project (frequently the corresponding author). Such assumption is true for many sub-fields of the biomedical sciences. Alternatively, in many other sub-fields the order of the authors can be alphabetical, ordered from the most significant to the least significant author or completely random or irregular. In such cases EC model should be used. For simplicity, all models assume that there is only one first and one last author which is not necessarily true as with strong pressure for the publishing in the top journals and having more and more authors per the work, nowadays many papers have multiple first and senior authors. All four models are metrics agnostics thus they can be used for the citations, RCR scores, or/and H-index.

Additional metrics used in *fCite*

In order to analyze the portfolio, the user is asked to provide all combination of author names and surnames, and the list of PMID (**P**ub**M**ed **ID**entifier) ids . As a result he/she obtains:

a) the size of the portfolio with the time span of the publishing period,

b) the number (and the percentage) of the single, the first, the last and the middle author papers,

c) H-index (2),

d) M-index (H-index divided by the number of years from the first publication),

e) fH-index and fM-index (the citations are divided according the author contribution to each paper using FLEA model),

f) the average number of the papers per year,

g) the total and fractional citation and RCR scores based on FLAE, FLAE2, FLAE3, EC models (Citations, total RCR, $FLAE_{RCR}$, $FLAE2_{RCR}$, $FLAE3_{RCR}$, EC_{RCR}, $FLAE_{cit}$, $FLAE2_{cit}$, $FLAE3_{cit}$, EC_{cit}, respectively),

h) the average number of the authors,

i) FLEA per year (RCR),

j) the average FLAE article score (RCR),

k) the average article impact per year (RCR),

l) the ratio between $FLAE_{RCR}$ and total RCR and the expected value,

m) sortable table for individual publications with PMID, year, title, authors, article-type, journal, and $FLAE_{RCR}$, $FLAE2_{RCR}$, $FLAE3_{RCR}$, EC_{RCR}, $FLAE_{cit}$, $FLAE2_{cit}$, $FLAE3_{cit}$, Ec_{cit}, Citations, total RCR scores.

Initial data cleaning

In order to analyze the authorship patterns, the PUBMED data set (over 17 million of publications) had been mapped into ORCID portfolios (over 5 million of users). The ORCID data set provided author name and surname with the list of publications. First, an empty records (the profiles without public data) had been discarded (4,217,452 out of 5,380,983 records). Next, the portfolios with at least one publication with the DOI, PMID or PMC identifiers had been filtered. This gave 1,154,443 portfolios (with 19,516,285 non-unique articles in total). As 19,097,891 (97,85%) of items had only DOI identifier, additional step was required (namely mapping DOI to PMID identifiers). The whole PUBMED records (27,414,004 publications) had been search for DOI using summary XML files and *eutils* tool provided by the National Institutes of Health (NIH). As a result 599,468 (7,813,971 articles) of non-empty portfolios with at least one PMID had been obtained.

Example record from ORCID (csv format)

```
ORCID,surname,name,list_of_PMIDS
0000-0002-2518-5940,Liebovitz,David,23550982||23646091||19468082||22034582||19267397||17219478||
19647184||28527507||17219519
```

Example record from PUBMED (json format)


```
{
    "pmid": 23456789,
    "doi": "10.1002/cncr.27976",
    "authors": "Arun Sharma, Stephen M Schwartz, Eduardo M\u00e9ndez",
    "citation_count": 26,
    "citations_per_year": 4.333333,
    "expected_citations_per_year": 2.538138,
    "field_citation_rate": 4.872565,
    "is_research_article": true,
    "journal": "Cancer",
    "nih_percentile": 69.700000,
    "relative_citation_ratio": 1.707288,
    "title": "Hospital volume is associated with survival but not multimodality therapy in Medicare patients with advanced head and neck cancer.",
    "year": 2013
}
```


fCite uses following fields: authors, citation_count, relative_citation_ratio, is_research_article, year and pmid.

Data analysis

One of the first steps of the analysis was to clean the name and surname provided by the ORCID database. The data in ORCID are in the UNICODE (UTF-8) format which means that they can contain any Non-English letters. Thus, at this step all surnames and names had been translated to equivalents of English letters (e.g., Kozłowski Łukasz to Kozlowski Lukasz, 吴锋 to Wu Feng). Then, given the list of PMIDs in the portfolio, all publication records from PUBMED had been retrieved. In order to identify the author position on the authorship list, Levenshtein and Jaro–Winkler distances had been applied in the following way. First, a set of possible surname and name combinations had been prepared (name surname, surname name, n surname, name initial surname, etc. for instance given John Smith, the set contained john smith, smith john, j smith, john x smith, etc.). This step was required as the order of the name, surname, initials and the letter size are frequently different in the databases or/and particular publication records. Next, for each author in the individual authorship list the Jaro–Winkler distance is calculated. The author which has the highest Jaro-Winkler distance is used (the similarity threshold of 0.7 is used to filter out non-important hits). From now on, for each publication in the portfolio, the position of the author is available and can be used to divide the publications into the sole, first, last and middle author ones. Having positions of the authors allow to use fractional models (FLAE, FLAE2, FLAE3 and EC) to calculate fractional scores for the citations and RCR metrics.

ORCID data had been also used to quantify the significance of obtained scores. For instance, it is not enough to say that $FLAE_{RCR}$ (or any other score) is equal to 10. Obviously, the bigger the number the better, but it is useful to compare it to some reference. For this purpose we calculated the percentiles for the score in respect to all ORCID portfolios (the value below which a given percentage of observations in a group of observations falls).

Note that the percentiles presented by *fCite* are calculated separately for each individual metrics including division into research and non-research item portfolios (**Table 1**). Additionally, as the distribution of bibliometric metrics is practically never normal (Gaussian), the percentiles are presented with additional precision (this allow to distinguish similar portfolios, especially top ones).

RESULTS

The primary result of the work presented here is, a web service (fcite.org), where an author's contribution can be calculated using fractional models in addition to the plethora of statistics related to a given portfolio (**Fig. 4**). The *fCite* service operates using a list of PMID and/or ORCID ids accompanied by all combinations of the names and surnames of a given author. The analysis can be performed for all items (research articles and non-research items such as editorials, reviews, and others) or separately only for the research items. The *fCite* service relies on citations and so-called RCR (**r**elative **c**itation **r**atio) scores that come from the iCite web service and are calculated based on the PUBMED database (8). As of October 2019, *fCite* comprises over 17 million publications and counting (the *fCite* database grows by ~100,000 items each month). The reference for the scores comes from the analysis of ORCID data (572,910 profiles with 7,008,012 unique publications in total). The ORCID profiles provide the names of the authors, together with the lists of co-authored publications. Thus, by using string metrics such as Levenshtein and Jaro–Winkler distances (9), it is possible to identify an author's position in the list of the authors for each publication. This provides the unique opportunity to study authorship patterns depending on whether the person is the first, middle, last or single author. These data provide a solid foundation for the assessment of the author's position importance with respect to portfolio size and time. As shown in **Fig. 5** (and Supplementary Tables 8-9), at the beginning of a scientist's career (with small portfolios with fewer than 10 items), a substantial number of first author papers are expected. As the researcher progresses (and the number of publications increases), the last author publications begin to take the place of the first author publications. Surprisingly, the middle and single authored fractions are roughly stable regardless of portfolio size (where single author papers are extremely rare, and middle author papers constitute over half of the items). Moreover, calculating the main scores provided by *fCite* (e.g., $FLAE_{RCR}$, $FLAE2_{RCR}$, $FLAE_{Cit}$, $FLAE2_{Cit}$, EC_{RCR}, EC_{Cit}) for the ORCID users provides solid ground for the assessment of the importance of the obtained numbers (so-called percentiles) (**Table 1**).

DISCUSSION

Over the past fifty years, bibliometrics have become an inherent part of the assessment of scientific progress. Such measures, with all of their pros and cons, will be used regardless of whether we support this approach. This development began with the impact factors defined by Eugene Garfield in the 1950s and peaked with the creation of the H-index in 2005. Despite their multiple shortcomings, bibliometrics can offer an instantaneous and relatively fair assessment of science impact. As many scholars have noted previously, one cannot focus on a single number because it cannot embrace the complexity of a researcher's work (see also Goodhart's adage). Therefore, it is not proper to focus, for instance, only on the total number of citations or the H-index (which is itself highly correlated with the total number of citations (10)). As those two metrics have been frequently used by funding bodies (consciously/openly or not), researchers have optimized their behaviour, which has led to citation cartels (11), salami slicing (12), and continual increases in the number of authors per publication and the self-citation rate (13). A so-called "publish-or-perish" culture has emerged. The purported quality of a work is inherited directly from impact factors of the journal immediately after publication. The number of authors of papers is irrelevant because all of them receive full credit. Even if someone were to state that the first or the last/ corresponding authors are more important, the community has already found easy "fix" by adding multiple first and last authors. This may sound pessimistic, but some fields have already adapted to this new reality very well. Therefore, no one is surprised when a high-energy physics paper has a few thousand authors. Similar approaches are emerging in other fields. In medicine, which already has one of the highest number of authors per publication, many believe that the data provider should be listed as an author of all subsequent publications even without making any other contribution (14). Recently, there is a growing trend towards establishing consortia or groups containing multiple labs/consortia. While this has the advantage of making collaborations that can have synergistic effects, it also has disadvantages. Usually, such initiatives are based on multi-million-dollar grants, and as the results appear, the whole group (usually a few hundred authors) is assigned as the authors of almost every paper produced by the consortium. The *fCite* proposed here stymies such malicious behaviour by simply dividing the citations (or RCRs) by the number of authors while taking into account an author's number and position. Obviously, the FLAE models used here are far from perfect, and they cannot replace an experienced assessor who reads publications and is familiar with all the insights of his/her own field, but they are a good starting point and certainly a better solution than using the total number of citations or H-index.

All of this being said, one should be aware of the multiple limitations of *fCite*. First, as *fCite* is based on PUBMED, it is not appropriate for many fields that are not well represented in that database (for instance, computer science or social sciences). Second, *fCite* currently does not filter out self-citations (under development). Moreover, the author has this far been unable to tag and fix all consortium/group papers. Frequently, such items' authorship appears as "John Smith, Jan Kowalski, SOME Group", where the first two are leaders, and the SOME group consists of a hundred or more people whose names appear in the supplementary material. FLAE models will count such cases as papers with three authors (likely to have hundreds of citations designating only those three authors and elevating the scores for the first two). Finally, the last shortcoming of *fCite* is that it accords all citations the same weight, which is a massive simplification. This aspect of bibliometrics is well studied and can be considered from many angles. First, not all citations are equal, as a citation can be positive or negative (where the subsequent authors disagree with the original hypothesis). Then, even if the citation is positive, it may have different meanings depending on the section of the article where it is made (the introduction, the methods or the discussion). Moreover, some citations are more important because they are cornerstones for subsequent research, while others are simply review mentions used briefly in the introduction. The other aspect related to citations is that frequently the most important citations are missing due to journal restrictions (for instance, the entire method section, pivotal for any research, is placed in the supplementary material, which has its own reference list and is not listed in most databases). Many such cases can be handled by semantic methods (15), but this approach remains in its infancy. Other characteristics that are frequently used (but not implemented in *fCite*) are the importance of the journal from which the citation comes (e.g., SJR indicators developed by SCImago (16)). Nevertheless, *fCite* is the first, large-scale method that takes into account the number of authors and their positions (only one-time analyses of specific journals, fields, or nations have been done in the past (17) (18)). Additionally, *fCite* uses RCR scores that are taken from iCite (based on PUBMED). Note that these scores differ from citations in many aspects. First, RCR is intended to capture field relevance (it is normalized with respect to the field's citation levels). Next, in contrast to citations, which are only additive metrics, RCRs can decrease over time. This aspect, while it has been criticized by some (19), is a very useful and demanded feature of bibliometric metrics (that is also missing in the H-index), as RCR can decline when the work begins to be outdated. The other feature of RCR that should not be overlooked is that this metric gives more weight to newer articles (for instance, ten citations for ten-year-old and two-year-old articles will result in dramatically different RCR scores).

A highly illustrative example is an analysis of top researchers in comparison to the scores provided by Google Scholar and other sources. Supplementary Table 10 reports a selection of statistics for some successful scientists (many of whom are listed in the Highly Cited Researchers (HCR) list created by Clarivate Analytics). It is clear that the H-index or total citation counts can often be misleading, and more comprehensive analysis using multiple bibliometric metrics can help. For instance, while HCR is most likely filtered against easy-to-spot cases such as Scientists B and D, it still frequently includes cases such as Scientists A and F. On the other hand, due its limitations (having >15 so-called "Highly Cited Papers"), some outstanding scientists are overlooked (e.g., Scientist C). Therefore, *fCite* can be a very useful tool for deep profiling of even very similar portfolios (with respect to the H-index or total citation count) with surprising discriminatory power (e.g., compare Scientists M and N).

In summary, *fCite* (available free of charge at fcite.org) is a bibliometric tool that provides versatile metrics that can take into account the number of authors and their position on the authorship list. Hopefully, it will facilitate unbiased comparisons of researchers' importance when they are competing for limited funding and, consequently, enhance scientific development.

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AUTHOR CONTRIBUTIONS

L.P.K. conceived the project, acquired and analysed the data, developed the web service, and prepared the manuscript.

DATA AND MATERIALS AVAILABILITY

The *fCite* web service (fcite.org) is available free of charge. All the data needed to evaluate the conclusions in the paper are presented in the Supplementary Materials and at the *fCite* web site. The raw data come from NIH (iCite) and ORCID databases and are available as stated in the Supplementary Materials.

Figure 1. Fractional models used in *fCite* (FLAE, FLAE2, FLAE3, EC). The weights for the first, middle and last author up to ten authors. For numerical data see Supplementary Tables 1-3, respectively.

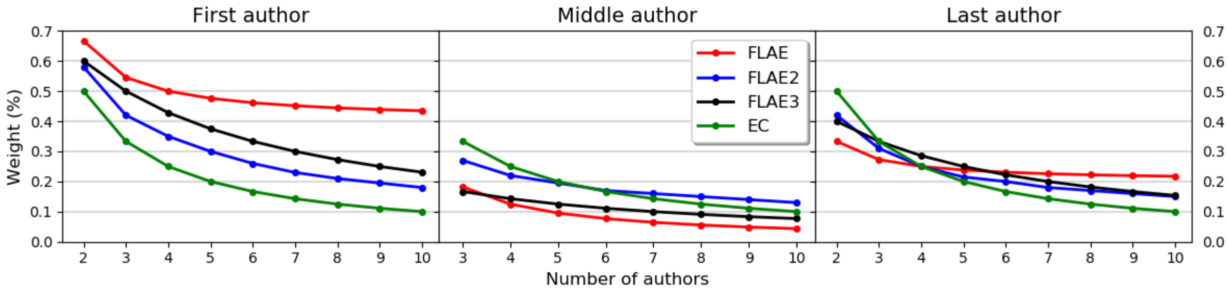


Figure 2. The increase in the average number of authors over time (whole PUBMED, 17 million items). For the numerical data, see Supplementary Table 6.

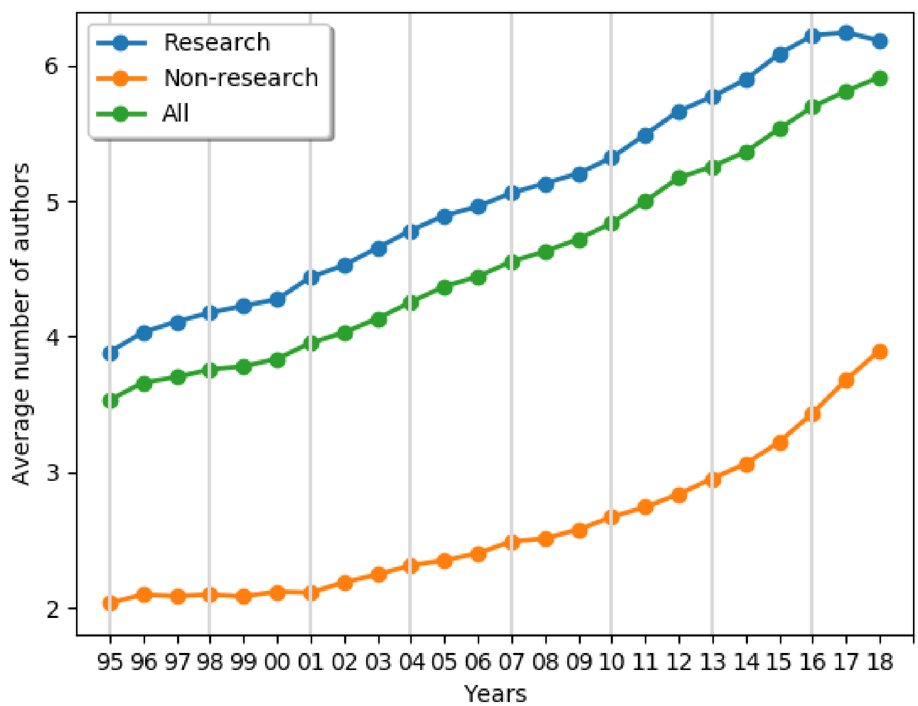


Figure 3. Number of authors over time with respect to research and non-research items (the years 1995-2018; 17,651,086 PUBMED publications). For the numerical data see Supplementary Table 7. Animated version of the the figure is available at: *http://www.fcite.org/stats.html#Authors_over_years*

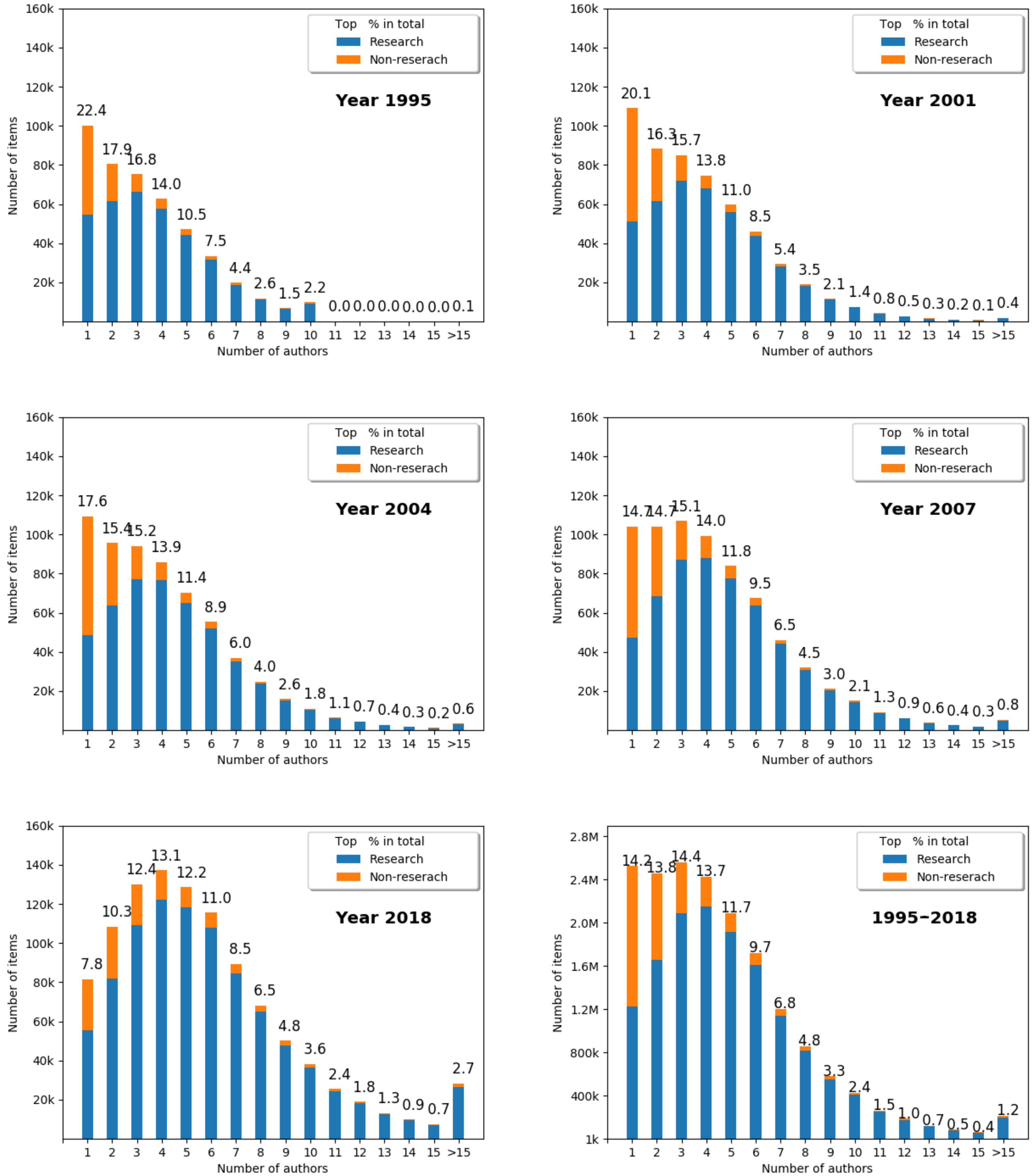


Figure 4. Example output from *fCite*. Given the list of PMIDs (16 items in this case) and all combinations of the name, the user obtains a detailed analysis of the researcher's contribution (for a brief user manual for *fCite*, see the "Help" section). On the top left, you have the number of articles and the time span within they were published. Next, in the top-right panel, you have some statistics about single, first, last and middle authorship alongside the H-index, M-index and their fractional analogues. In the centre, you have the scores for the fractional models based on RCR ($FLAE_{RCR}$, $FLAE2_{RCR}$, $FLAE3_{RCR}$, EC_{RCR}, $FLAE_{RCR}$ and total RCR). Then, using those values, you obtain scores such as the average number of the authors in the publication, $FLAE_{RCR}$ per year, average article $FLAE_{RCR,}$ the article impact per year, and the ratio of $FLAE_{RCR}$/RCR alongside the expected ratio based on the number of authors in the portfolio. The next line is a simple repetition of the scores but here based on raw citations. Note that the main scores are accompanied by the percentiles (based on ORCID portfolios) to facilitate the assessment of the importance of the scores. Finally, you have a sortable table with individual publications and their scores.

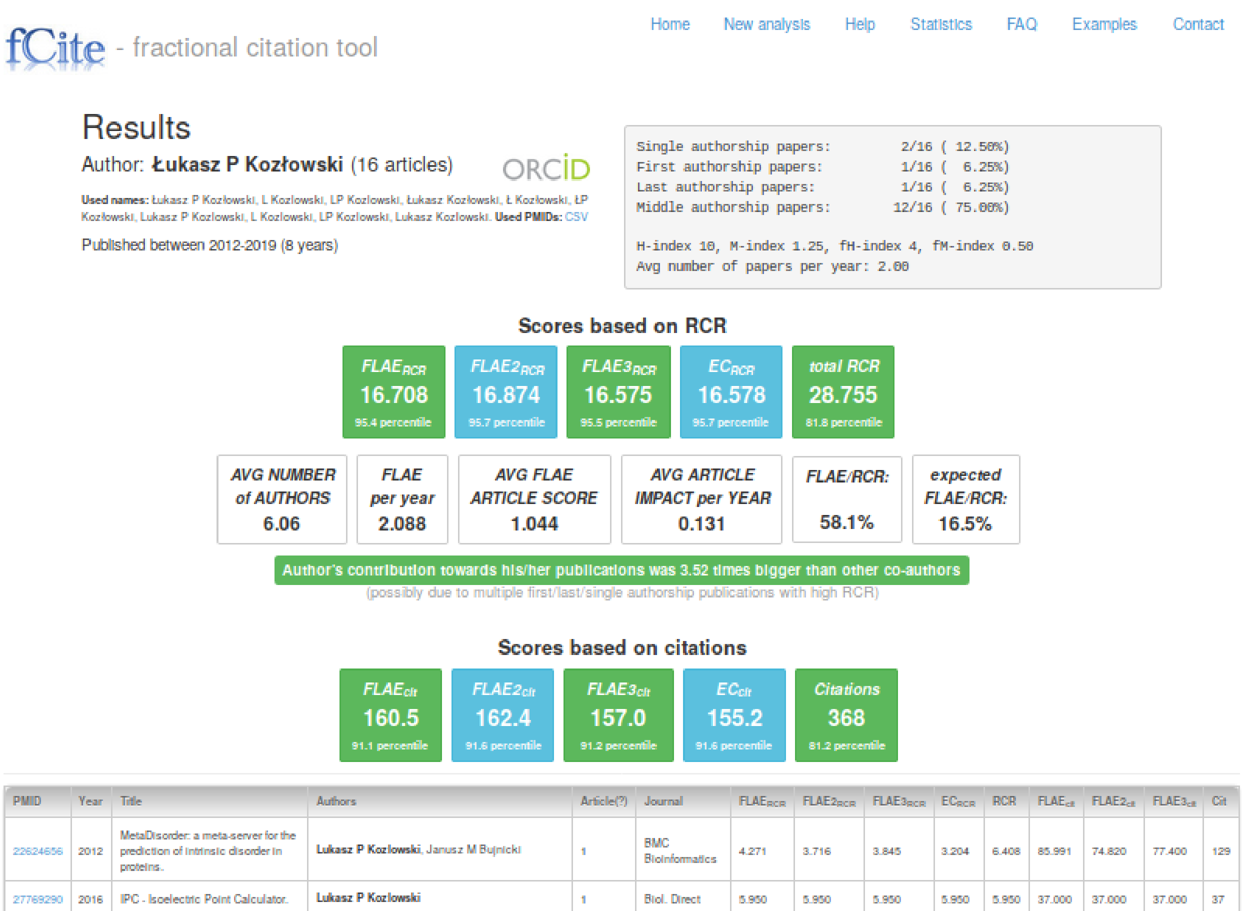
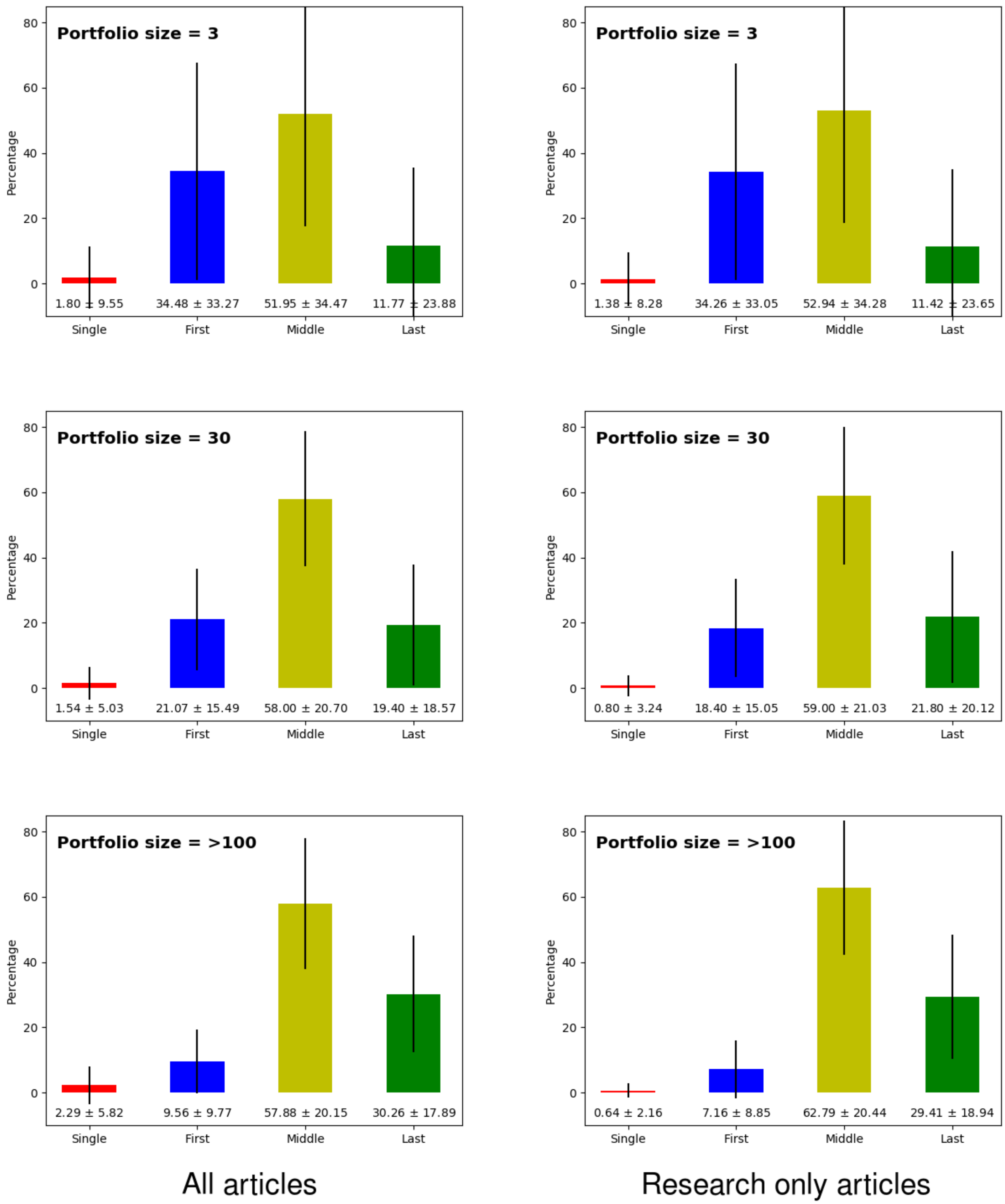


Figure 5. Percentage of single, first, middle and last authorship papers with respect to the size of the portfolio. For the numerical data, see Supplementary Tables 8-9. Animated version of the the figure is available at: http://fcite.org/stats.html#bar_plot



	RCR									
	FLAE		FLAE2		FLAE3		EC		Total RCR	
	All	Research	All	Research	All	Research	All	Research	All	Research
25.0 %	0.241	0.222	0.265	0.247	0.259	0.241	0.253	0.236	1.470	1.398
50.0 %	0.993	0.893	0.958	0.859	0.965	0.867	0.909	0.811	5.363	4.950
60.0 %	1.628	1.436	1.541	1.353	1.560	1.374	1.462	1.277	8.809	8.035
70.0 %	2.679	2.320	2.519	2.248	2.556	2.205	2.398	2.048	14.683	13.194
75.0 %	3.475	2.984	3.263	2.776	3.315	2.825	3.118	2.634	19.203	17.145
80.0 %	4.598	3.895	4.320	3.632	4.382	3.715	4.140	3.468	25.707	22.808
85.0 %	6.318	5.247	5.922	4.892	6.009	4.982	5.713	4.694	35.766	31.348
90.0 %	9.238	7.535	8.724	7.056	9.628	7.177	8.452	6.811	53.620	46.317
92.5 %	11.733	9.417	11.126	8.868	11.297	9.041	10.827	8.625	69.633	59.395
95.0 %	15.923	12.570	15.207	11.857	15.475	12.092	14.964	11.614	97.613	81.829
96.0 %	18.662	14.551	17.894	13.810	18.163	14.101	17.628	16.149	116.382	96.418
97.0 %	22.703	17.411	21.716	16.642	22.175	16.959	21.549	18.530	142.459	117.749
98.0 %	29.433	22.257	28.435	21.334	28.951	21.776	28.227	21.270	190.610	150.524
99.0 %	44.580	33.573	43.294	32.277	44.129	33.007	43.448	32.275	303.261	232.081
99.5 %	68.146	51.340	66.220	49.257	67.798	50.669	66.144	49.132	474.222	349.833
99.6 %	79.580	60.028	77.070	57.461	78.620	59.118	77.186	57.563	556.720	396.323
99.7 %	99.570	77.268	95.486	75.146	97.869	76.975	96.026	75.933	704.544	459.216
99.8 %	150.133	177.843	144.683	169.492	149.153	175.890	145.143	169.598	1087.509	575.450
99.9 %	1359.852	1208.689	953.556	823.147	1120.820	995.152	798.151	639.006	5202.912	3998.950

	Citations									
	All					Research				
	FLAE	FLAE2	FLAE3	EC	Total	FLAE	FLAE2	FLAE3	EC	Total
25.0 %	1.3	1.4	1.3	1.3	7.0	1.2	1.3	1.3	1.2	7.0
50.0 %	7.5	7.5	7.5	7.2	42.7	7.0	7.0	6.9	6.6	40.4
60.0 %	14.7	14.5	14.5	13.9	83.4	13.4	13.1	13.2	12.5	77.7
70.0 %	29.0	28.0	28.2	26.8	163.7	25.8	24.9	25.0	23.7	150.4
75.0 %	41.2	39.5	39.8	37.8	232.7	36.4	34.7	35.0	33.0	211.8
80.0 %	59.5	56.8	57.2	54.3	336.6	51.9	49.2	50.0	46.9	304.4
85.0 %	88.9	84.5	85.4	81.2	506.0	76.1	76.0	72.8	68.7	452.2
90.0 %	158.0	135.3	137.0	130.6	816.8	119.2	112.3	113.7	107.8	717.9
92.5 %	191.6	181.0	183.8	175.0	1105.1	157.0	147.4	150.1	142.0	961.8
95.0 %	273.9	259.6	263.6	252.8	1613.5	221.1	207.3	211.1	201.1	1378.5
96.0 %	326.3	310.8	314.8	303.8	1965.3	261.2	245.2	250.2	238.4	1655.7
97.0 %	406.8	388.3	394.7	380.4	2487.6	317.7	300.0	305.8	294.5	2079.5
98.0 %	542.3	517.8	527.1	511.9	3401.0	414.5	394.2	402.3	386.6	2786.9
99.0 %	850.0	819.8	833.5	808.0	5622.9	629.3	599.5	612.8	597.7	4472.3
99.5 %	1301.2	1252.8	1278.0	1254.5	9546.5	956.2	902.7	927.3	902.8	7013.1
99.6 %	1488.8	1442.5	1478.3	1440.8	11446.9	1098.8	1053.0	1081.6	1053.0	8093.1
99.7 %	1798.4	1752.0	1780.5	1746.7	14926.8	1335.5	1275.7	1316.7	1276.2	9739.7
99.8 %	2398.1	2329.2	2390.5	2337.4	25862.2	1820.2	1757.4	1787.8	1779.6	12812.4
99.9 %	24012.0	20191.8	21141.2	20336.2	88650.7	21915.9	15234.5	18257.1	13323.2	85374.5

TABLE 1. Percentile scores based on ORCID profiles in 2018 for the key metrics used in *fCite* with respect to RCR and citations (a selection of the thresholds is presented; all data were bootstrapped 1000 times; and for complete list with the supporting values, see the files at http://www.fcite.org/percentiles_2018/). parts For the ratio and spread between fractional metrics (e.g., FLEA) and total RCR (Total Citations), see Supplementary Figures 1-2.

Supplementary Materials for

fCite: a fractional citation tool to quantify an individual's scientific research output

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This PDF file includes:

Supplementary Text

Captions for Supplementary Data 1-3

Supplementary Figsures 1-4

Supplementary Tables 1-10

Supplementary Text

Motivation

The number of the authors steadily increase over last 25 years (Supplementary Table 5). Moreover, when we divide the publications into research items (describing the original works) and non-research (e.g., the reviews, the editorials, etc.) we clearly can see that on average research publication require more authors. Given the fact that currently the publications with dozens or even hundreds of authors are common, it is desirable to modify the bibliometric metrics (e.g., citations, H-index) to seize the number of the authors for individual paper.

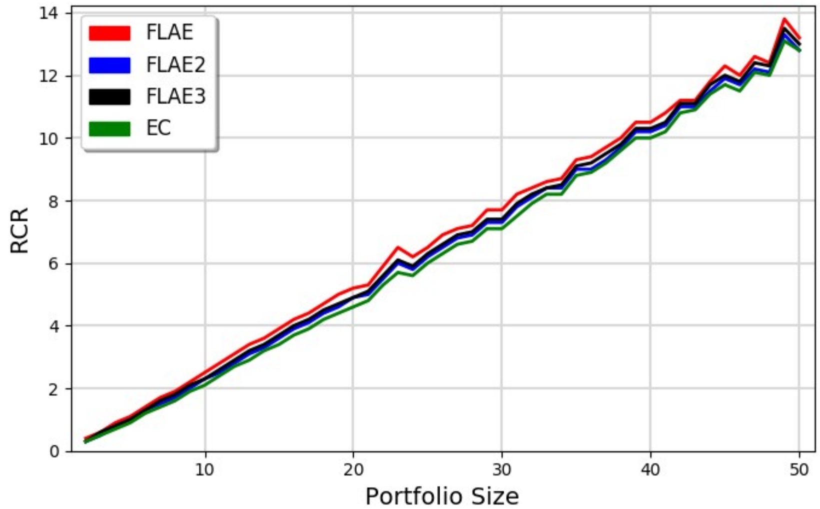
The patterns of authorship versus portfolio size

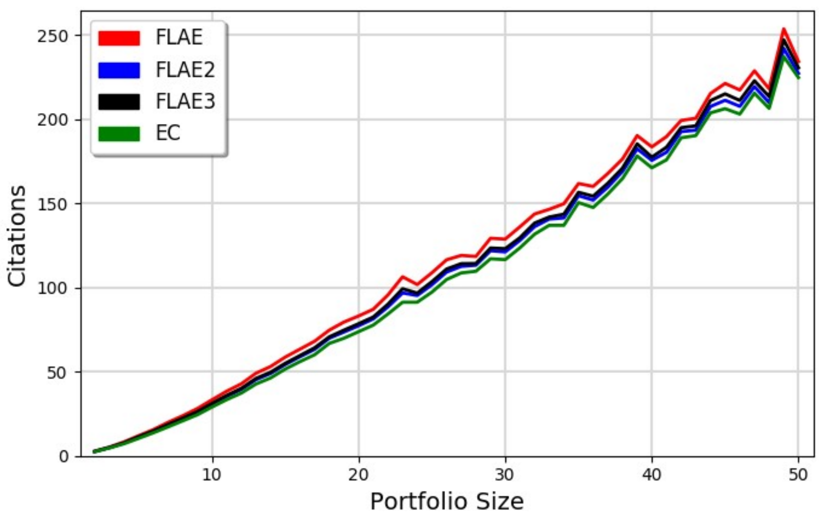
The ratio between fractional and total metric declines as the size of portfolio increase (Supplementary Fig. 1). Regardless of the main metric used (RCR or citation) the trend is stable and the data show that small portfolios have more first author publications. When the portfolio size increases more last author items appear. Depending the fractional model used, the small portfolios have 20-25% of contribution of the author falling below 18% for bigger portfolios. Here, it is interesting to point that regardless of fractional model (FLAE vs FLAE2 vs FLAE3 vs EC) the portfolios with around 40-60 items score virtually identical (which means that for mature scientist with multiple publications is not important which fractional model will be used). One should also take into account the spread of the scores which is huge for small size portfolios and decreases over the number of items, but it is always very significant and comprise at least roughly 20% (Supplementary Fig. 2).

Supplementary Data 1. PUBMED data set containing publications with PMID numbers from 7 million to 19 million (json format). http://www.fcite.org/icite_1218_7M-19M.tar.gz or http://dx.doi.org/10.18150/repod.3945420

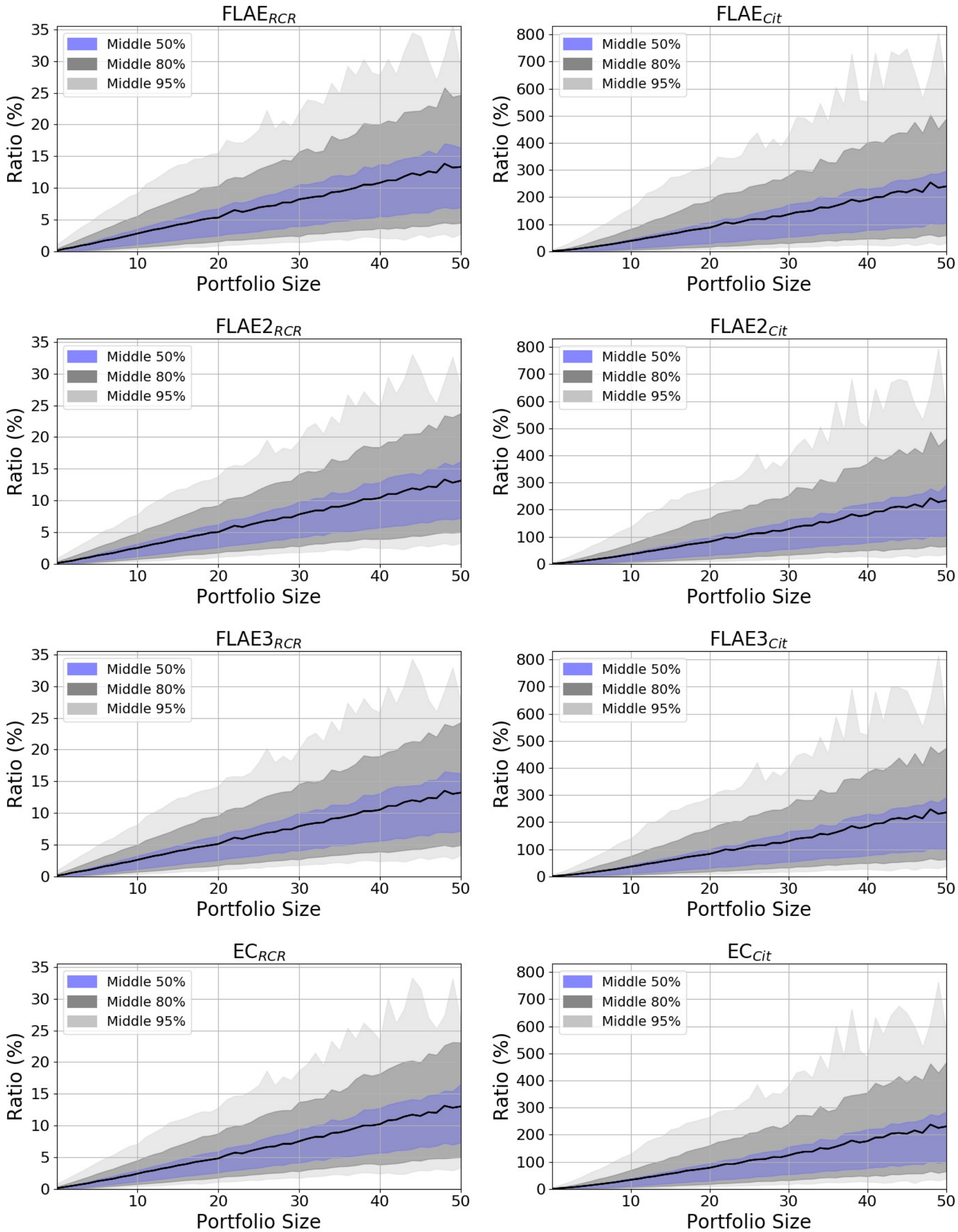
Supplementary Data 2. PUBMED data set containing publications with PMID numbers from 20 million to 32 million (json format). http://www.fcite.org/icite_1218_20M-32M.tar.gz or http://dx.doi.org/10.18150/repod.2195699

Supplementary Data 3. ORCID Public Data File (xml format). https://figshare.com/articles/ORCID_Public_Data_File_2018/7234028

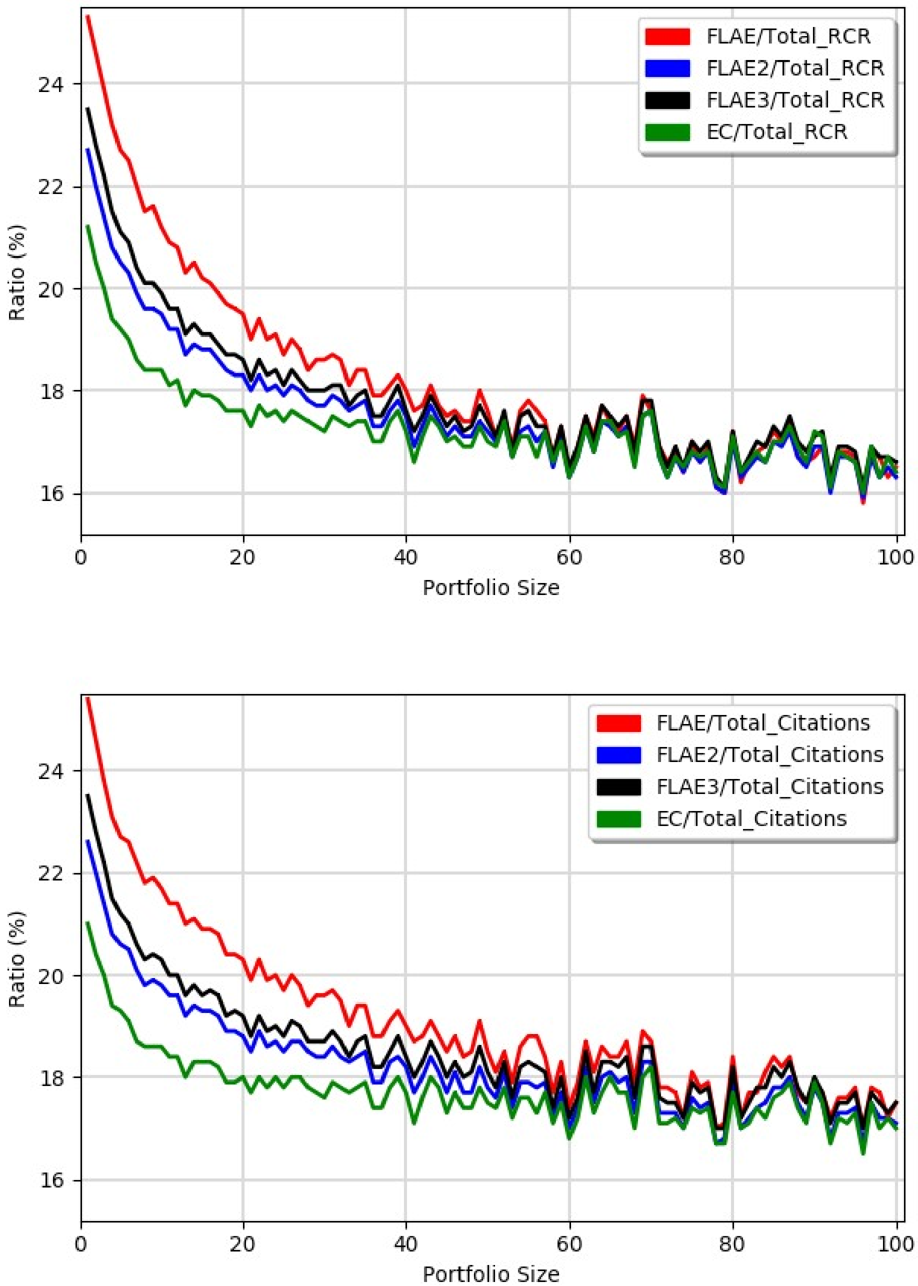

FLAE
FLAE2
FLAE3
EC
RCR
Portfolio Size
0
2
4
6
8
10
12
14
10
20
30
40
50


FLAE
FLAE2
FLAE3
EC
Citations
Portfolio Size
0
50
100
150
200
250
10
20
30
40
50

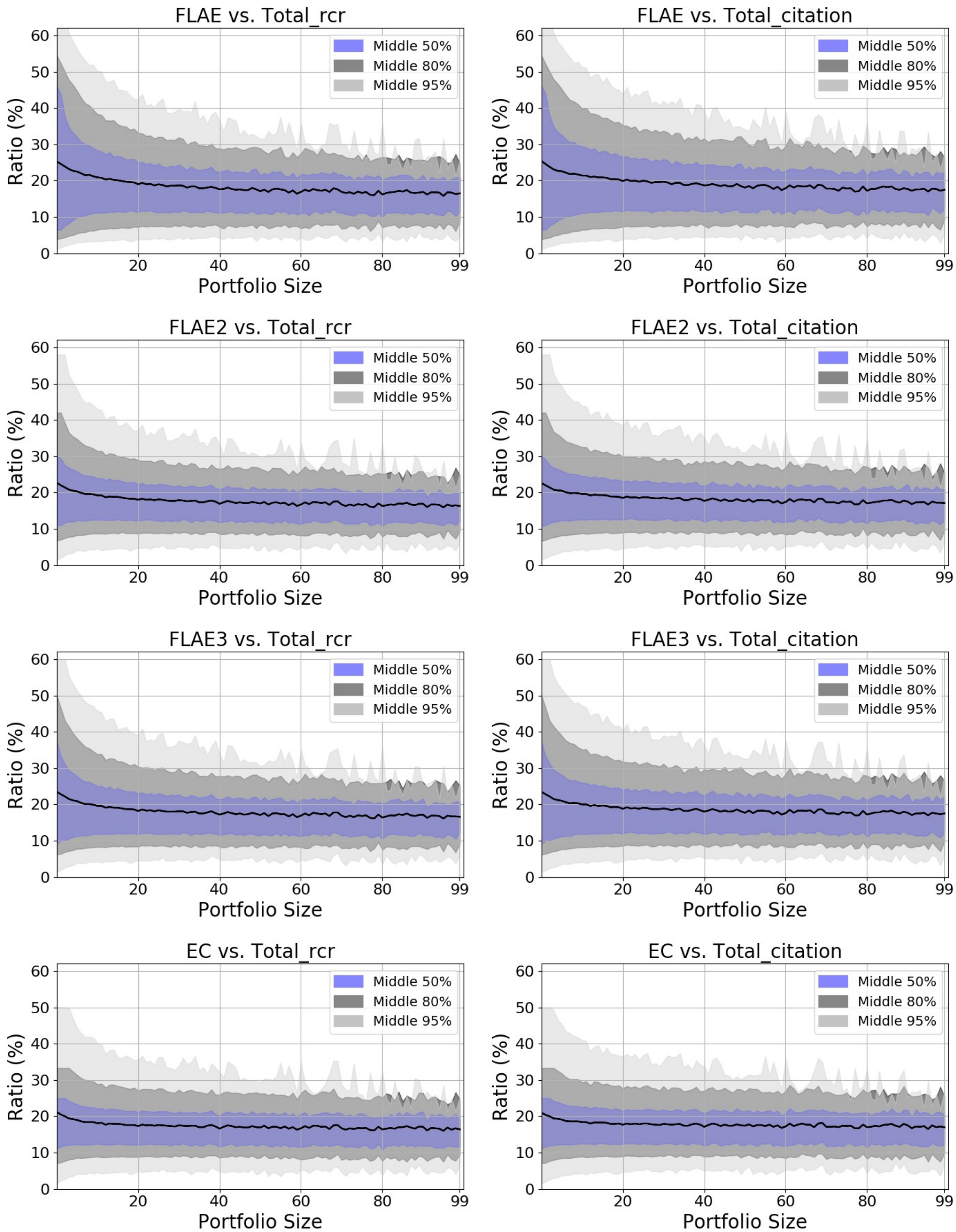
Supplementary Figure 1. Fractional metrics ($FLAE_{RCR}$, $FLAE_{Cit}$, $FLAE2_{RCR}$, $FLAE2_{Cit}$, $FLAE3_{RCR}$, $FLAE3_{Cit}$, EC_{RCR}, EC_{Cit}) in respect to the portfolio size (only the 394,189 ORCID portfolios with 2-50 items are presented).



Supplementary Figure 2. The spread of the fractional metrics ($FLAE_{RCR}$, $FLAE_{Cit}$, $FLAE2_{RCR}$, $FLAE2_{Cit}$, $FLAE3_{RCR}$, $FLAE3_{Cit}$, EC_{RCR}, EC_{Cit}) in respect to the portfolio size. For the animated plots see fcite.org/stats.html



Supplementary Figure 3. The ratio between the fractional metrics (FLAE, FLAE2, FLAE3, EC) vs. total metrics (RCR or Citations) in respect to the portfolio size.



Supplementary Figure 4. The spread of the ratio between the fractional metrics (FLAE, FLAE2, FLAE3, EC) vs. total metrics (RCR or Citations) in respect to the portfolio size. For the animated plots see htt://www.fcite.org/stats.html

SUPPLEMENTARY TABLE 1. The confusion matrix for up to ten authors for FLAE model. A model with strong emphasis of the first and the last author. For the more details see: http://www.fcite.org/FLAE.txt

No.	Weights for individual authors
1	1.0000
2	0.6667, 0.3333
3	0.5455, 0.1818, 0.2727
4	0.5000, 0.1250, 0.1250, 0.2500
5	0.4762, 0.0952, 0.0952, 0.0952, 0.2381
6	0.4615, 0.0769, 0.0769, 0.0769, 0.0769, 0.2308
7	0.4516, 0.0645, 0.0645, 0.0645, 0.0645, 0.0645, 0.2258
8	0.4444, 0.0556, 0.0556, 0.0556, 0.0556, 0.0556, 0.0556, 0.2222
9	0.4390, 0.0488, 0.0488, 0.0488, 0.0488, 0.0488, 0.0488, 0.0488, 0.2195
10	0.4348, 0.0435, 0.0435, 0.0435, 0.0435, 0.0435, 0.0435, 0.0435, 0.0435, 0.2174

SUPPLEMENTARY TABLE 2. The confusion matrix for up to ten authors for FLAE2 model (based on (5)). A model with moderate emphasis of the first and the last author. For the more details see: http://www.fcite.org/FLAE2.txt

No.	Weights for individual authors
1	1.0000
2	0.5800, 0.4200
3	0.4200, 0.2700, 0.3100
4	0.3500, 0.2200, 0.1800, 0.2500
5	0.3000, 0.1950, 0.1450, 0.1450, 0.2150
6	0.2600, 0.1700, 0.1300, 0.1200, 0.1200, 0.2000
7	0.2300, 0.1600, 0.1200, 0.1100, 0.1000, 0.1000, 0.1800
8	0.2100, 0.1500, 0.1100, 0.0950, 0.0900, 0.0900, 0.0850, 0.1700
9	0.1950, 0.1400, 0.1000, 0.0850, 0.0820, 0.0810, 0.0790, 0.0780, 0.1600
10	0.1800, 0.1300, 0.0900, 0.0820, 0.0780, 0.0750, 0.0730, 0.0720, 0.0700, 0.150

SUPPLEMENTARY TABLE 3. The confusion matrix for up to ten authors for FLAE3 model. For the more details see: http://www.fcite.org/FLAE3.txt

No.	Weights for individual authors
1	1.0
2	0.6000, 0.4000
3	0.5000, 0.1667, 0.3333
4	0.4286, 0.1429, 0.1429, 0.2857
5	0.3750, 0.1250, 0.1250, 0.1250, 0.2500
6	0.3333, 0.1111, 0.1111, 0.1111, 0.1111, 0.2222
7	0.3000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.2000
8	0.2727, 0.0909, 0.0909, 0.0909, 0.0909, 0.0909, 0.0909, 0.1818
9	0.2500, 0.0833, 0.0833, 0.0833, 0.0833, 0.0833, 0.0833, 0.0833, 0.1667
10	0.2308, 0.0769, 0.0769, 0.0769, 0.0769, 0.0769, 0.0769, 0.0769, 0.0769, 0.1538

SUPPLEMENTARY TABLE 4. The confusion matrix for up to ten authors for EC model (equal contribution of all authors). For the more details see: http://www.fcite.org/EC.txt

No.	Weights for individual authors
1	1.0000
2	0.5000, 0.5000
3	0.3333, 0.3333, 0.3333
4	0.2500, 0.2500, 0.2500, 0.2500
5	0.2000, 0.2000, 0.2000, 0.2000, 0.2000
6	0.1667, 0.1667, 0.1667, 0.1667, 0.1667, 0.1667
7	0.1429, 0.1429, 0.1429, 0.1429, 0.1429, 0.1429, 0.1429
8	0.1250, 0.1250, 0.1250, 0.1250, 0.1250, 0.1250, 0.1250, 0.1250
9	0.1111, 0.1111, 0.1111, 0.1111, 0.1111, 0.1111, 0.1111, 0.1111, 0.1111
10	0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000

SUPPLEMENTARY TABLE 5. The correlations between fractional models and total scores. The lower triangular portion of the matrices (green) correspond to 394,189 ORCID portfolios with 2-50 items and the upper triangular portion of the matrices correspond to all ORCID portfolios with at least single item (600,755 portfolios).

	RCR						Citations				
	FLAE	FLAE2	FLAE3	EC	Total		FLAE	FLAE2	FLAE3	EC	Total
FLAE		0.9852	0.9929	0.9652	0.7592	**FLAE**		0.9874	0.9937	0.9708	0.7883
FLAE2	0.9700		0.9977	0.9951	0.7802	**FLAE2**	0.9741		0.9980	0.9959	0.8051
FLAE3	0.9884	0.9937		0.9876	0.7724	**FLAE3**	0.9896	0.9945		0.9898	0.7985
EC	0.9237	0.9879	0.9675		0.7837	**EC**	0.9363	0.9901	0.9730		0.8073
Total	0.5762	0.6166	0.6012	0.6264		**Total**	0.6466	0.6850	0.6703	0.6937	

SUPPLEMENTARY TABLE 6. The average number of the authors (PUBMED 17,787,016 publications in 1995-2018).

Year	Research	Non-research	Research Avg	Not-research Avg	Total Avg
1995	363007	85576	3.8849	2.0349	3.5320
1996	370198	87896	4.0317	2.0976	3.6606
1997	363577	92127	4.1102	2.0864	3.7011
1998	378481	95424	4.1766	2.0980	3.7581
1999	390468	102615	4.2272	2.0834	3.7811
2000	421771	107840	4.2740	2.1196	3.8353
2001	429734	113286	4.4378	2.1117	3.9525
2002	439721	118445	4.5258	2.1878	4.0297
2003	457320	126100	4.6535	2.2453	4.1330
2004	487038	132345	4.7827	2.3123	4.2549
2005	521093	134582	4.8916	2.3505	4.3700
2006	545681	138391	4.9606	2.4008	4.4427
2007	569964	139565	5.0582	2.4892	4.5529
2008	606463	143759	5.1299	2.5105	4.6280
2009	638608	144718	5.2028	2.5767	4.7176
2010	672589	149643	5.3194	2.6699	4.8372
2011	718523	156326	5.4893	2.7427	4.9985
2012	775637	163479	5.6627	2.8384	5.1710
2013	811789	181971	5.7698	2.9523	5.2539
2014	845090	195823	5.8954	3.0620	5.3624
2015	878182	209943	6.0838	3.2217	5.5316
2016	896432	209084	6.2214	3.4351	5.6945
2017	935012	189792	6.2433	3.6815	5.8111
2018	927277	123246	6.1820	3.8971	5.9139
Total	14444982	3342034	5.2915	2.6970	4.8040

SUPPLEMENTARY TABLE 7. The number of the authors over the years with the respect to the research and non-research items (years 1995-2018).

Author number	All	Not research	Research	Non research fr	Fr from all
1	2524210	1297946	1226264	51.4	14.2
2	2456770	800840	1655930	32.6	13.8
3	2562334	477521	2084813	18.6	14.4
4	2429355	280806	2148549	11.6	13.7
5	2089498	171352	1918146	8.2	11.7
6	1719482	111165	1608317	6.5	9.7
7	1203690	65535	1138155	5.4	6.8
8	858575	41505	817070	4.8	4.8
9	580374	25882	554492	4.5	3.3
10	425535	18655	406880	4.4	2.4
11	264146	11718	252428	4.4	1.5
12	186533	8447	178086	4.5	1.0
13	122871	6002	116869	4.9	0.7
14	8663	4482	82211	5.2	0.5
15	6279	3421	59373	5.4	0.4
>15	212771	16699	196072	7.8	1.2

SUPPLEMENTARY TABLE 8. Percentage of single-, first-, middle- and last-authorship papers in respect to the size of portfolio for all articles (both research and non-research items). As the number of available portfolios decreases as the size of portfolio increases the data has been bootstrapped 10,000 times (especially crucial for the portfolios with >50 items, where there is less than 1,000 of portfolios passing the threshold).

Portfolio size	Single	First	Middle	Last	No. portfolios
3	1.805 ± 9.548	34.475 ± 33.269	51.954 ± 34.474	11.766 ± 23.878	45339
4	1.600 ± 8.346	33.820 ± 30.054	53.406 ± 31.352	11.174 ± 21.729	33626
5	1.555 ± 7.716	33.299 ± 27.893	54.422 ± 29.307	10.723 ± 20.373	26515
6	1.544 ± 7.499	32.813 ± 26.068	55.360 ± 27.398	10.283 ± 19.009	21897
7	1.383 ± 6.594	32.119 ± 24.739	56.157 ± 26.255	10.341 ± 18.240	18389
8	1.383 ± 6.394	31.464 ± 23.650	56.643 ± 25.286	10.510 ± 17.947	16033
9	1.458 ± 6.596	31.213 ± 22.931	56.310 ± 24.484	11.019 ± 17.963	13892
10	1.496 ± 6.582	30.254 ± 22.022	56.988 ± 24.254	11.262 ± 17.676	12545
11	1.348 ± 5.868	29.824 ± 21.263	57.296 ± 23.429	11.533 ± 17.464	10674
12	1.494 ± 6.325	29.308 ± 20.851	57.367 ± 23.050	11.831 ± 17.220	9653
13	1.319 ± 5.260	28.420 ± 20.173	58.037 ± 22.475	12.223 ± 17.384	8761
14	1.497 ± 5.700	28.102 ± 19.678	57.624 ± 22.541	12.777 ± 17.546	7963
15	1.518 ± 5.847	27.034 ± 19.400	57.899 ± 22.441	13.549 ± 17.865	7303
16	1.419 ± 5.177	26.517 ± 18.750	57.879 ± 21.824	14.186 ± 18.134	6690
17	1.515 ± 6.038	26.133 ± 18.512	58.186 ± 21.764	14.166 ± 17.848	6093
18	1.548 ± 5.985	25.533 ± 17.812	58.381 ± 21.498	14.538 ± 17.850	5589
19	1.413 ± 5.369	25.220 ± 17.959	57.909 ± 21.742	15.459 ± 18.196	5231
20	1.499 ± 5.189	24.730 ± 17.712	57.797 ± 21.450	15.974 ± 18.465	4914
21	1.495 ± 5.488	23.655 ± 17.131	58.381 ± 21.386	16.470 ± 18.295	4513
22	1.618 ± 5.738	23.215 ± 16.769	57.678 ± 20.800	17.489 ± 18.605	4226
23	1.395 ± 4.673	22.913 ± 16.182	58.659 ± 20.672	17.033 ± 18.196	3835
24	1.509 ± 5.018	22.809 ± 16.454	58.410 ± 20.849	17.272 ± 18.156	3591
25	1.587 ± 5.574	21.824 ± 15.937	57.868 ± 20.929	18.722 ± 19.077	3515
26	1.683 ± 5.586	21.637 ± 15.999	57.910 ± 21.264	18.770 ± 18.792	3117
27	1.526 ± 4.826	21.493 ± 15.934	57.873 ± 21.028	19.109 ± 19.375	3009
28	1.753 ± 5.803	20.772 ± 15.170	58.115 ± 20.745	19.361 ± 18.690	2677
29	1.591 ± 5.079	21.462 ± 15.548	57.553 ± 20.608	19.394 ± 18.521	2635
30	1.536 ± 5.026	21.069 ± 15.493	57.997 ± 20.703	19.399 ± 18.568	2471
31	1.619 ± 5.047	20.566 ± 15.645	57.736 ± 20.884	20.079 ± 18.652	2309
32	1.429 ± 4.202	19.410 ± 14.861	58.121 ± 20.370	21.040 ± 18.852	2140
33	1.633 ± 5.016	19.326 ± 14.633	58.249 ± 20.202	20.792 ± 18.749	2137
34	1.694 ± 4.735	19.348 ± 14.385	57.530 ± 20.097	21.429 ± 18.645	1907
35	1.712 ± 5.219	19.479 ± 15.002	57.346 ± 20.390	21.463 ± 18.872	1810
36	1.586 ± 4.191	18.528 ± 13.804	57.546 ± 20.385	22.340 ± 18.958	1700
37	1.617 ± 4.168	18.454 ± 14.539	56.617 ± 20.446	23.312 ± 19.643	1729
38	1.646 ± 4.668	17.855 ± 13.562	56.644 ± 19.811	23.855 ± 19.271	1543
39	1.743 ± 4.525	17.784 ± 14.104	55.639 ± 20.514	24.834 ± 19.230	1489
40	1.640 ± 5.088	18.365 ± 14.100	57.916 ± 19.948	22.080 ± 18.400	1461
41	1.559 ± 4.733	17.680 ± 13.569	57.068 ± 20.432	23.693 ± 18.949	1305
42	1.660 ± 4.586	17.175 ± 13.710	57.428 ± 21.059	23.736 ± 19.635	1367
43	1.666 ± 3.887	17.124 ± 13.465	56.138 ± 20.564	25.072 ± 19.799	1186
44	1.939 ± 6.258	16.137 ± 12.661	57.008 ± 20.561	24.916 ± 19.268	1172
45	1.639 ± 3.895	16.645 ± 12.841	57.957 ± 19.972	23.759 ± 18.791	1137
46	1.503 ± 3.613	16.686 ± 12.620	57.234 ± 20.118	24.577 ± 19.090	1082
47	1.547 ± 4.454	16.028 ± 13.354	57.871 ± 20.025	24.553 ± 19.081	1071
48	1.608 ± 4.321	16.422 ± 13.348	56.813 ± 20.267	25.157 ± 19.618	995
49	1.961 ± 4.995	17.026 ± 14.054	54.989 ± 20.002	26.023 ± 19.448	872
50	1.960 ± 5.016	15.880 ± 13.182	57.866 ± 21.060	24.294 ± 18.893	844
51	2.191 ± 6.857	15.464 ± 12.934	57.460 ± 19.505	24.885 ± 18.349	833
52	2.015 ± 5.349	14.681 ± 12.171	57.543 ± 20.084	25.760 ± 18.946	790
53	1.815 ± 5.731	14.966 ± 12.815	57.212 ± 19.556	26.007 ± 18.938	773
54	1.971 ± 5.910	15.394 ± 13.198	56.118 ± 20.057	26.516 ± 19.112	714
55	1.963 ± 5.130	15.330 ± 12.747	55.771 ± 20.303	26.936 ± 19.267	702
56	1.928 ± 4.848	16.255 ± 14.003	54.931 ± 20.663	26.887 ± 19.520	689
57	1.888 ± 4.978	14.467 ± 12.267	56.794 ± 19.314	26.851 ± 18.204	665
58	1.715 ± 5.420	12.023 ± 11.994	63.210 ± 22.986	23.053 ± 20.018	743
59	2.002 ± 4.978	14.772 ± 12.344	56.207 ± 20.338	27.020 ± 19.037	625
60	2.016 ± 5.181	13.658 ± 11.762	56.921 ± 19.855	27.406 ± 19.277	596
61	1.997 ± 5.474	14.290 ± 12.254	56.668 ± 20.230	27.046 ± 19.160	564
62	2.181 ± 5.761	13.878 ± 12.306	55.356 ± 20.023	28.585 ± 19.948	593
63	2.035 ± 5.975	13.834 ± 12.589	57.733 ± 19.533	26.397 ± 18.374	513
64	1.942 ± 5.172	14.811 ± 12.808	55.491 ± 20.259	27.756 ± 19.157	484
65	2.125 ± 5.615	13.566 ± 11.884	54.029 ± 20.029	30.280 ± 19.507	477
66	1.819 ± 3.345	13.863 ± 12.170	56.334 ± 19.336	27.984 ± 18.813	480
67	1.987 ± 4.412	14.851 ± 11.950	54.995 ± 19.528	28.168 ± 19.029	464
68	1.614 ± 3.076	13.586 ± 11.572	55.001 ± 19.257	29.798 ± 18.689	441
69	2.627 ± 7.300	13.604 ± 11.599	54.233 ± 20.245	29.536 ± 19.593	443
70	2.094 ± 4.409	13.313 ± 10.981	54.384 ± 19.327	30.209 ± 18.306	446
71	2.130 ± 5.856	13.517 ± 11.445	56.087 ± 20.005	28.267 ± 18.747	420
72	1.970 ± 4.943	13.006 ± 12.200	56.742 ± 20.123	28.282 ± 18.629	378
73	1.964 ± 5.752	13.368 ± 12.086	56.824 ± 19.408	27.845 ± 19.094	386
74	1.913 ± 4.216	13.206 ± 11.864	57.473 ± 19.135	27.407 ± 18.432	364
75	2.716 ± 9.263	12.496 ± 11.310	56.160 ± 21.150	28.627 ± 18.943	389
76	1.756 ± 3.237	12.001 ± 9.543	56.824 ± 18.841	29.420 ± 18.866	342
77	1.584 ± 3.346	13.373 ± 12.150	56.318 ± 19.939	28.725 ± 18.627	321
78	1.775 ± 4.549	10.771 ± 10.555	57.105 ± 20.530	30.350 ± 19.457	332
79	1.963 ± 3.918	12.348 ± 10.690	59.079 ± 19.993	26.609 ± 17.985	298
80	2.255 ± 6.448	12.759 ± 10.706	55.678 ± 19.228	29.308 ± 18.376	303
81	2.154 ± 4.787	11.919 ± 12.474	56.828 ± 20.363	29.099 ± 18.865	289
82	2.307 ± 5.251	12.537 ± 10.945	55.631 ± 19.251	29.525 ± 17.320	275
83	2.084 ± 3.601	11.856 ± 10.331	54.594 ± 19.476	31.466 ± 19.081	279
84	2.413 ± 5.634	13.262 ± 12.046	54.214 ± 19.589	30.111 ± 17.598	250
85	2.906 ± 6.011	12.006 ± 11.142	53.307 ± 19.023	31.781 ± 18.434	277
86	1.935 ± 6.884	12.048 ± 10.737	56.640 ± 18.970	29.376 ± 18.088	243
87	2.948 ± 8.689	12.396 ± 11.480	53.846 ± 19.963	30.810 ± 18.548	267
88	1.876 ± 3.957	11.642 ± 11.661	55.477 ± 20.183	31.005 ± 18.398	241
89	2.014 ± 3.353	12.898 ± 11.243	53.572 ± 18.834	31.515 ± 18.705	209
90	2.068 ± 5.421	11.075 ± 9.559	56.342 ± 17.139	30.515 ± 17.036	204
91	2.726 ± 7.159	10.376 ± 9.813	54.145 ± 19.719	32.753 ± 18.997	226
92	1.840 ± 3.979	11.475 ± 10.994	56.182 ± 19.041	30.503 ± 18.615	212
93	2.213 ± 3.586	12.058 ± 9.917	56.018 ± 18.624	29.711 ± 18.287	177
94	2.574 ± 7.842	12.326 ± 10.560	57.750 ± 21.297	27.351 ± 18.621	177
95	2.611 ± 7.487	10.869 ± 11.220	55.446 ± 20.354	31.073 ± 19.047	205
96	1.465 ± 2.483	10.915 ± 9.385	58.132 ± 19.983	29.489 ± 19.539	207
97	2.873 ± 8.125	11.834 ± 10.494	56.371 ± 19.763	28.923 ± 17.779	189
98	1.723 ± 3.703	11.758 ± 11.691	57.077 ± 19.098	29.442 ± 17.300	178
99	2.369 ± 5.029	10.693 ± 9.744	58.345 ± 19.177	28.592 ± 17.301	157
100	2.252 ± 3.747	11.568 ± 10.480	55.997 ± 19.712	30.183 ± 18.918	181
>101	2.293 ± 5.823	9.565 ± 9.766	57.883 ± 20.150	30.258 ± 17.890	7886
					Total: 351849

SUPPLEMENTARY TABLE 9. Percentage of single-, first-, middle- and last-authorship papers in respect to the size of portfolio for research articles. As the number of available portfolios decreases as the size of portfolio increases the data has been bootstrapped 10,000 times (especially crucial for the portfolios with >50 items, where there is less than 1,000 of portfolios passing the threshold).

Portfolio size	Single	First	Middle	Last	No. portfolios
3	1.380 ± 8.283	34.260 ± 33.051	52.941 ± 34.279	11.419 ± 23.654	44969
4	1.194 ± 7.166	33.674 ± 29.977	54.326 ± 31.185	10.806 ± 21.446	33681
5	1.190 ± 6.721	32.690 ± 27.301	55.801 ± 28.793	10.319 ± 20.004	26474
6	1.050 ± 5.994	32.168 ± 25.798	56.757 ± 27.003	10.025 ± 18.904	22044
7	1.088 ± 5.892	31.458 ± 24.409	57.122 ± 26.088	10.331 ± 18.354	18366
8	1.091 ± 5.544	30.528 ± 23.273	57.853 ± 25.045	10.529 ± 17.980	15894
9	1.092 ± 5.639	30.162 ± 22.592	57.709 ± 24.383	11.037 ± 18.029	13644
10	0.900 ± 4.764	29.007 ± 21.600	58.518 ± 23.845	11.575 ± 18.141	12189
11	0.998 ± 5.178	28.859 ± 20.875	58.559 ± 23.113	11.584 ± 17.683	10502
12	1.013 ± 4.720	28.066 ± 20.541	58.709 ± 22.735	12.213 ± 17.712	9528
13	0.935 ± 4.474	27.175 ± 19.659	59.270 ± 22.280	12.620 ± 17.794	8647
14	0.939 ± 4.510	26.187 ± 19.080	59.335 ± 22.141	13.539 ± 18.230	7798
15	0.939 ± 4.524	25.676 ± 18.784	59.676 ± 21.906	13.709 ± 17.953	7228
16	0.934 ± 4.528	24.763 ± 18.391	59.692 ± 21.640	14.611 ± 18.551	6350
17	1.047 ± 5.222	24.708 ± 17.999	59.620 ± 21.731	14.624 ± 18.611	5934
18	0.872 ± 4.081	23.809 ± 17.650	59.409 ± 21.325	15.909 ± 18.841	5479
19	0.781 ± 3.718	23.155 ± 17.509	59.820 ± 21.460	16.244 ± 18.628	4992
20	0.798 ± 3.681	22.613 ± 17.073	59.856 ± 21.485	16.734 ± 19.026	4721
21	1.007 ± 4.440	22.195 ± 16.848	59.525 ± 21.153	17.272 ± 18.905	4255
22	1.037 ± 4.417	21.585 ± 16.549	59.745 ± 20.976	17.633 ± 18.936	3907
23	0.780 ± 3.390	20.918 ± 15.660	59.989 ± 20.416	18.313 ± 19.177	3718
24	0.825 ± 3.758	20.361 ± 15.753	59.776 ± 21.321	19.038 ± 19.749	3447
25	0.817 ± 3.535	20.423 ± 15.685	59.348 ± 20.385	19.412 ± 19.549	3252
26	0.823 ± 3.566	19.858 ± 15.579	59.656 ± 20.768	19.663 ± 19.353	2974
27	0.837 ± 3.389	19.707 ± 15.259	60.049 ± 20.443	19.407 ± 19.284	2689
28	0.847 ± 3.757	19.522 ± 15.294	59.747 ± 20.486	19.885 ± 18.817	2578
29	0.804 ± 2.975	18.969 ± 14.936	59.666 ± 20.249	20.561 ± 19.078	2442
30	0.804 ± 3.237	18.399 ± 15.049	58.998 ± 21.029	21.799 ± 20.121	2234
31	0.795 ± 3.992	18.275 ± 14.785	60.129 ± 20.624	20.801 ± 19.723	2171
32	0.793 ± 3.632	17.629 ± 14.525	59.301 ± 20.682	22.276 ± 19.986	1980
33	0.998 ± 4.098	17.819 ± 14.898	58.910 ± 20.638	22.273 ± 19.557	1861
34	0.752 ± 2.616	16.903 ± 13.841	59.441 ± 20.248	22.904 ± 19.627	1783
35	0.791 ± 2.761	17.363 ± 14.089	58.970 ± 19.909	22.876 ± 19.380	1697
36	0.843 ± 3.157	17.037 ± 14.214	58.169 ± 20.440	23.951 ± 20.197	1552
37	0.750 ± 3.422	15.701 ± 13.679	59.334 ± 20.200	24.215 ± 19.952	1586
38	0.718 ± 2.631	16.091 ± 13.549	58.903 ± 20.521	24.289 ± 20.183	1405
39	0.814 ± 3.360	15.664 ± 13.227	59.550 ± 20.078	23.972 ± 19.744	1303
40	0.686 ± 2.273	15.795 ± 13.456	59.847 ± 20.506	23.671 ± 19.594	1233
41	0.831 ± 3.193	15.473 ± 13.486	58.801 ± 20.478	24.895 ± 20.100	1207
42	0.751 ± 3.817	14.576 ± 12.733	60.057 ± 19.942	24.616 ± 19.912	1165
43	0.762 ± 2.439	15.430 ± 13.221	59.556 ± 20.352	24.252 ± 19.879	1108
44	0.687 ± 1.901	14.642 ± 13.166	59.259 ± 19.913	25.411 ± 19.689	1048
45	0.923 ± 4.101	14.603 ± 12.966	58.937 ± 20.414	25.538 ± 20.127	1014
46	0.801 ± 3.131	13.514 ± 12.028	60.824 ± 19.865	24.861 ± 19.094	939
47	0.743 ± 2.187	14.492 ± 13.046	58.906 ± 19.720	25.858 ± 19.684	930
48	0.849 ± 3.477	13.913 ± 13.105	59.010 ± 19.788	26.229 ± 19.483	827
49	0.753 ± 2.591	14.131 ± 12.877	60.214 ± 20.416	24.902 ± 19.415	772
50	0.909 ± 3.396	13.783 ± 12.561	59.228 ± 19.876	26.080 ± 19.957	774
51	0.835 ± 3.998	13.808 ± 12.211	58.557 ± 19.669	26.800 ± 19.015	702
52	0.853 ± 2.703	13.529 ± 12.358	59.052 ± 20.204	26.565 ± 20.275	715
53	0.655 ± 2.225	13.789 ± 12.249	58.539 ± 19.942	27.016 ± 19.158	656
54	0.836 ± 2.482	12.679 ± 11.868	58.645 ± 20.151	27.840 ± 20.131	688
55	0.648 ± 1.866	11.975 ± 11.085	59.745 ± 19.839	27.632 ± 19.849	616
56	0.971 ± 3.946	13.365 ± 13.641	58.799 ± 20.030	26.865 ± 19.565	616
57	1.177 ± 5.208	12.247 ± 12.119	59.518 ± 20.079	27.058 ± 19.349	615
58	0.617 ± 3.432	10.347 ± 11.880	65.948 ± 23.328	23.088 ± 20.562	640
59	0.780 ± 2.596	12.534 ± 11.795	59.886 ± 20.541	26.799 ± 19.484	552
60	0.763 ± 2.786	12.278 ± 11.559	58.173 ± 19.616	28.786 ± 19.499	559
61	0.689 ± 2.331	11.254 ± 11.263	59.291 ± 19.111	28.766 ± 19.487	463
62	0.610 ± 1.663	12.005 ± 11.923	58.757 ± 19.578	28.629 ± 19.416	447
63	0.750 ± 2.379	11.751 ± 11.751	59.358 ± 19.507	28.141 ± 19.881	424
64	0.613 ± 1.822	11.784 ± 11.490	58.273 ± 20.658	29.330 ± 20.369	429
65	0.652 ± 1.446	12.257 ± 12.254	57.313 ± 19.124	29.779 ± 19.361	401
66	0.732 ± 2.138	11.831 ± 11.231	59.378 ± 18.293	28.060 ± 18.161	429
67	0.813 ± 2.362	11.519 ± 10.763	57.974 ± 18.953	29.694 ± 18.606	386
68	0.986 ± 4.039	11.317 ± 12.043	60.323 ± 20.463	27.374 ± 19.186	383
69	0.711 ± 1.733	11.889 ± 11.604	59.726 ± 20.278	27.675 ± 19.361	346
70	0.915 ± 4.095	11.176 ± 9.823	58.476 ± 18.274	29.433 ± 18.873	350
71	0.581 ± 1.559	11.211 ± 11.290	60.264 ± 19.644	27.945 ± 19.235	371
72	0.597 ± 1.428	10.572 ± 11.089	59.816 ± 19.944	29.016 ± 19.653	303
73	1.285 ± 6.514	11.571 ± 11.709	56.214 ± 20.008	30.931 ± 19.798	323
74	0.710 ± 2.612	10.699 ± 10.892	58.622 ± 19.189	29.970 ± 18.964	316
75	0.990 ± 2.595	10.047 ± 10.631	61.387 ± 20.152	27.576 ± 19.779	292
76	1.046 ± 4.652	11.238 ± 11.583	58.666 ± 20.003	29.050 ± 19.957	294
77	0.716 ± 2.580	10.629 ± 11.040	59.610 ± 20.770	29.046 ± 20.478	301
78	0.610 ± 1.849	9.325 ± 9.723	61.094 ± 19.908	28.971 ± 18.368	261
79	0.909 ± 2.570	9.528 ± 9.396	58.509 ± 19.882	31.054 ± 19.028	260
80	0.598 ± 1.293	9.263 ± 8.634	60.192 ± 18.345	29.948 ± 18.184	251
81	0.905 ± 3.267	9.458 ± 10.038	60.201 ± 21.051	29.436 ± 19.844	238
82	0.578 ± 1.836	10.464 ± 10.024	60.869 ± 18.375	28.088 ± 18.615	232
83	0.643 ± 1.441	10.352 ± 9.920	60.152 ± 18.069	28.853 ± 17.875	212
84	0.861 ± 2.705	9.442 ± 9.311	57.823 ± 17.191	31.875 ± 17.827	210
85	0.555 ± 1.399	9.657 ± 9.854	58.577 ± 17.922	31.211 ± 19.017	226
86	0.813 ± 3.363	9.772 ± 10.393	58.877 ± 19.054	30.539 ± 19.014	196
87	1.073 ± 3.856	9.510 ± 10.790	57.054 ± 20.211	32.363 ± 20.356	188
88	0.587 ± 1.701	10.994 ± 12.358	58.868 ± 20.416	29.551 ± 19.698	180
89	1.163 ± 4.010	8.492 ± 9.073	60.683 ± 18.656	29.661 ± 17.923	176
90	0.606 ± 1.298	9.532 ± 9.371	58.402 ± 18.139	31.459 ± 18.583	144
91	0.502 ± 1.386	8.379 ± 9.133	58.610 ± 20.110	32.508 ± 19.768	170
92	1.185 ± 6.106	8.558 ± 8.160	59.011 ± 20.369	31.246 ± 20.021	171
93	0.513 ± 1.049	8.568 ± 8.092	61.236 ± 17.628	29.682 ± 18.231	144
94	0.627 ± 1.439	8.993 ± 8.827	61.518 ± 18.521	28.862 ± 17.611	158
95	0.508 ± 1.091	9.190 ± 10.099	64.794 ± 19.374	25.508 ± 19.080	143
96	0.582 ± 1.409	8.927 ± 11.546	59.708 ± 20.188	30.783 ± 18.316	159
97	0.758 ± 1.473	8.880 ± 8.247	62.519 ± 17.751	27.844 ± 16.956	136
98	0.562 ± 1.834	8.543 ± 9.439	60.384 ± 18.139	30.511 ± 18.632	143
99	0.964 ± 2.528	8.635 ± 9.823	60.370 ± 21.707	30.030 ± 20.460	129
100	0.536 ± 1.226	7.586 ± 7.629	60.952 ± 19.619	30.926 ± 19.352	142
>100	0.638 ± 2.156	7.161 ± 8.847	62.791 ± 20.440	29.409 ± 18.944	5712
					Total: 338889

SUPPLEMENTARY TABLE 10. A selection of bibliometric statistics for some prominent scientists. For the screenshots from fCite see http://www.fcite.org/examples.html

Name	Field	In HCR	Articles Number	Avg No Authors	Single %	First %	Middle %	Last %	fCite							Google Scholar	
									$FLAE_{RCR}$	EC_{RCR}	Total RCR	FLAE/RCR	$FLAE_{Cit}$	EC_{Cit}	Citations	H-index	Citations
Scientist A (ro) Scientist A (all)	Clinical Medicine	1	132 163	12.7 15.8	0.00 0.61	5.30 4.29	10.61 85.28	84.09 9.82	35.5 44.2	56.7 69.7	803.4 1239.9	4.4 % 3.6 %	1017 1248	1604 1952	21081 32061	-	-
Scientist B (ro) Scientist B (all)	Physics	0	544 548	1379.3 1369.2	0.18 0.36	0.37 0.36	0.18 0.36	99.26 98.91	1.3 2.5	2.0 2.8	335.6 338.0	0.4 % 0.7 %	26 54	43 61	2661 2717	191	283,988
Scientist C (ro) Scientist C (all)	Molecular Biology & Genetics	0	33 35	15.3 14.9	36.36 34.29	21.21 22.86	36.36 37.14	6.06 5.71	1087.8 1090.1	1064.7 1025.8	1286.7 1290.4	84.5 % 84.5 %	28429 28510	27311 27372	32268 32391	34	60,753
Scientist D (ro) Scientist D (all)	Physics	0	174 174	2208.9 2208.9	0.00 0.00	0.0 0.0	100.00 100.00	0.00 0.00	0.05 0.05	0.05 0.05	114.3 114.3	0.0 % 0.0 %	0.3 0.3	0.3 0.3	697 697	168	127,547
Scientist E (ro) Scientist E (all)	Materials Science	1	108 112	10.2 10.0	0.00 0.00	5.56 5.36	65.74 65.18	28.70 29.46	100.0 103.9	67.8 74.8	512.7 551.7	19.3 % 18.8 %	2323 2400	1497 1605	11436 12037	107	99,769
Scientist F (ro) Scientist F (all)	Clinical Medicine	1	156 296	32.4 20.6	10.26 14.19	10.90 15.54	53.85 44.93	25.00 25.34	69.5 121.1	78.6 140.2	2305.8 2769.5	3.0 % 4.4 %	1606 2402	1690 2695	31927 39986	102	104,919
Scientist G (ro) Scientist G (all)	Physics	1	237 246	8.1 8.0	0.42 1.22	2.38 3.25	62.03 60.57	34.18 34.96	93.4 95.8	113.9 115.7	924.9 934.7	10.1 % 10.2 %	1694 1724	1820 1845	14612 14735	152	113,094
Scientist H (ro) Scientist H (all)	Molecular Biology & Genetics	1	185 197	30.0 30.4	0.54 0.51	0.00 0.51	64.86 65.48	34.59 33.50	391.4 394.6	484.8 489.5	2949.4 2982.0	13.3 % 13.2 %	12021 12111	14808 14939	90148 90864	128	173,483
Scientist I (ro) Scientist I (all)	Biology & Biochemistry	1	75 83	19.3 18.3	0.00 1.20	14.67 16.87	85.33 80.72	0.00 1.20	106.1 110.0	84.7 87.6	939.3 948.2	11.3 % 11.6 %	2283 2372	1791 1857	20596 20816	71	58,008
Scientist J (ro) Scientist J (all)	Biology & Biochemistry	1	296 350	9.1 8.8	0.00 2.00	0.68 1.43	63.18 60.86	36.15 35.71	145.9 183.4	182.9 222.7	856.8 1022.6	17.0 % 17.9 %	4172 5520	5100 6490	23419 29112	115	68,249
Scientist K (ro) Scientist K (all)	Chemistry	1	286 297	7.0 6.9	0.35 0.34	0.70 1.01	59.09 59.26	39.86 39.39	111.2 131.7	132.3 149.2	748.5 848.7	14.9 % 15.5 %	2177 2523	2504 2769	12871 14407	128	67,952
Scientist L (ro) Scientist L (all)	Chemistry	1	194 206	8.2 8.0	0.00 0.00	2.00 1.94	55.15 55.34	42.78 42.72	65.3 73.5	56.4 67.8	394.1 448.6	16.6 % 16.4 %	1197 1284	1058 1203	7313 7984	87	37,474
Scientist M (ro) Scientist M (all)	Immunology	1	187 254	10.1 8.4	1.07 3.94	0.00 5.91	66.84 54.72	32.09 35.43	139.7 226.9	163.8 256.3	1011.0 1233.2	13.8 % 18.4 %	5321 9036	6451 10199	34327 42998	135	97,049
Scientist N (ro) Scientist N (all)	Immunology	1	470 629	17.5 14.6	0.64 1.59	1.27 3.81	74.73 64.44	23.14 30.00	79.7 153.1	68.4 140.2	1082.3 1368.9	7.4 % 6.9 %	2492 4639	1945 3892	28841 36113	132	65,087
Scientist O (ro) Scientist O (all)	Microbiology	1	243 310	9.8 8.4	0.00 2.26	1.65 5.48	65.02 53.87	33.33 38.39	100.9 165.5	99.7 161.6	727.0 884.9	13.9 % 18.7 %	3085 4665	3127 4558	21307 24533	108	44,840
Scientist P (ro) Scientist P (all)	Microbiology	1	485 558	15.1 14.4	0.41 1.25	1.44 1.79	86.80 80.65	11.34 16.31	141.9 152.1	168.4 182.1	2488.7 2562.0	5.7 % 5.9 %	3183 3433	3318 3635	51992 53533	135	93,706
Scientist Q (ro) Scientist Q (all)	Plant & Animal Science	1	164 191	3.8 3.6	3.05 5.76	9.15 9.95	22.56 19.90	65.24 64.40	161.6 240.8	178.2 267.1	529.0 711.1	30.6 % 33.9 %	4094 6192	4502 6727	13216 17729	107	38,678
Scientist R (ro) Scientist R (all)	Plant & Animal Science	1	135 177	8.0 7.1	0.74 1.13	4.44 7.91	60.00 50.85	34.81 40.11	35.9 55.9	38.9 60.7	249.4 313.4	14.4 % 17.8 %	779 1211	811 1261	4771 5909	66	12,896

***In HCR** – means that the researcher is included among Highly Cited Researchers 2018 list by Clarivate Analytics*
***ro**/**all** – **r**esearch **o**nly or **all** articles*