Coherent measures of the impact of co-authors in peer review journals and in proceedings publications

Marcel AUSLOOS

Royal Netherlands Academy of Arts and Sciences
Joan Muyskenweg 25, 1096 CJ Amsterdam, The Netherlands

School of Management, University of Leicester,
University Road, Leicester LE1 7RH, UK

GRAPES, r. Belle Jardinière, 483,
B-4031 Liege, Wallonia-Brussels Federation

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Abstract

This paper focuses on the coauthor effect in different types of publications, usually not equally respected in measuring research impact. A priori unexpected relationships are found between the total coauthor core value, $m_a$, of a leading investigator (LI), and the related values for their publications in either peer review journals ($j$) or in proceedings ($p$). A surprisingly linear relationship is found: $m_a(j) + 0.4 m_a(p) = m_a(j)p$. Furthermore, another relationship is found concerning the measure of the total number of citations, $A_a$, i.e. the surface of the citation size-rank histogram up to $m_a$. Another linear relationship exists: $A_a(j) + 1.36 A_a(p) = A_a(j)p$. These empirical findings coefficients (0.4 and 1.36) are supported by considerations based on an empirical power law found between the number of joint publications of an author and the rank of a coauthor. Moreover, a simple power law relationship is found between $m_a$ and the number ($r_M$) of coauthors of a LI: $m_a \simeq r_M^\mu$; the power law exponent $\mu$ depends on the type ($j$ or $p$) of publications. These simple relations, at this time limited to publications in physics, imply that coauthors are a "more positive measure" of a principal investigator role, in both types of scientific outputs, than the Hirsch index could indicate. Therefore, to scorn upon co-authors in publications, in particular in proceedings, is incorrect. On the contrary,
the findings suggest an immediate test of coherence of scientific authorship
in scientific policy processes.

1 Introduction

In recent years, studies of complex systems have become widespread among the
scientific community, specially in the statistical physics one. Many examples,
e.g., [1] [2] [8], pertain to social phenomena in general, indicating that physi-
cists have gone far from their traditional domain of investigations [4] [5] [6] [7].
Moreover, one very modern topics of investigation is the role of measuring (as
accurately and objectively as possibly done as in physics) the value of some
scientific production [8] [9].

In [10], it was shown that a Zipf-like law

\[ J \propto 1/r, \]  

exists, between the number (\( J \)) of joint publications (NJP) of a scientist, called
for short "leading investigator" (LI) with her/his coauthor(s) (CAs); \( r = 1, \ldots \)
is an integer allowing some hierarchical ranking of the CAs; \( r = 1 \) being the
most prolific coauthor with the PI. The number of different coauthors (NDCA)
is given by the highest possible rank \( r_M \). Several CAs have often the same NJP
with the LI.

It was observed that a hyperbolic (scaling) law is more appropriate, i.e.,

\[ J = J_0/r^\alpha, \]  

with \( \alpha \neq 1 \), usually such that \( \alpha \leq 1 \), and often decreases with the number
of CAs or with the number of joint publications, e.g. when the number of CAs
and when \( J \) are "not large". \( J_0 \) is a fit parameter, i.e. there is no meaning to
\( r = 0 \).

As the \( h \)-index [11] [12] [13] "defines" the core of papers of an author
from the relationship between the number of citations \( n_c \) and the corresponding rank
\( r \) of a paper, through a trivial threshold, i.e. if \( n_c \geq r_c \), then \( r_c \equiv h \), thus one
is allowed also to define the core of coauthors of a scientist through a threshold
[10], called the \( m_a \)-index,

\[ m_a \equiv r, \quad \text{as long as} \quad r \leq J. \]  

This is a specific measure of the core of the most relevant CAs in a research team,
centered on the LI. In brief, in the \( h \)-index method, one implicitly assumes
that the number of "important papers" of an author, those which are the most
often quoted, allows to measure the impact of a researcher [14] [15] [16] [17].
No need to discuss lengthily the \( h \)-index power, variants, or defects. However,
such a citation effect is often due to the activity of a research team, centered
on the LI [18] [19] [20] [21]. In fact, the size and structure of a temporary or
long lasting group is surely relevant to the productivity of an author [16]. In
contrast, the \( m_a \) index as introduced measures the role of coauthors, rather than
citations, to indicate the most important coworkers of a LI, allowing to measure the LI team core. Technically, one could thus measure the relevant strength of a research group centered on some leader and measure some impact of research collaboration, e.g., on scientific productivity [22]. The invisible college [23, 24] of a PI would become visible, easily quantified, whence pointing out to some selection in the community.

Several other measure definitions can be deduced, as in the $h$-method, i.e. taking into account the whole surface of the histogram, i.e. the cumulated number of joint publications (NJP)

$$\Sigma = \sum_{r=1}^{r_M} J_r,$$  \hspace{1cm} (4)

for the CA with rank $r$ has published $J_r$ publications with the LI. A often discussed part of the histogram is that up to the treshold; it corresponds to the cumulated NJP limited to the core, i.e.

$$A_a = \sum_{r=1}^{m_a} J_r.$$  \hspace{1cm} (5)

The notation is reminiscent of the $A$–index [25, 26, 27], in the Hirsch scientific output measurement method of an author. Of course, $A_a / \Sigma$ gives the relative weight of the core CAs in the cumulated NJP.

Moreover, one can define an $a_a$-index [10] which measures the surface below the empirical data of the number of joint publications till the CA of rank $m_a$, normalized to $m_a$, i.e.

$$a_a = \frac{1}{m_a} \sum_{r=1}^{m_a} J_r = \frac{A_a}{m_a},$$  \hspace{1cm} (6)

and similarly the index

$$a_M = \frac{1}{m_a} \sum_{r=1}^{r_M} J_r = \frac{\Sigma}{m_a},$$  \hspace{1cm} (7)

measured from the whole histogram surface. Obviously, $A_a / \Sigma \equiv a_a/a_M$. The notations are similar to those of the $h$-index scheme, where they somewhat measure the average number of citations of papers in the Hirsch core [13].

Note that the true mean $\mu$ of the $J$ vs. $r$ distributions, i.e. the average NJP per CA, is obtained from

$$\mu = \frac{\Sigma}{(NDCA)} \equiv \frac{\Sigma}{r_M}.$$  \hspace{1cm} (8)

In practical terms, these indirect measures are attempts to improve the sensitivity of the threshold forced index in order to take into account the number of co-authors whatever the number of joint publications among the most frequent co-authors, and introduce a contrast between the most frequent CAs and the less
frequent ones. Indeed, JP have often a mix of different CAs\(^1\) [28]. It has also been observed in previous fits, through Eq.(2), that unusual (long or short) lists of coauthors, as well as the hapax-like CA, i.e. accidental or rare CAs, but with necessarily large \(r\) values, have much influence on \(J_0\) and \(\alpha\), and the resulting \(R^2\).

Moreover, it is somewhat commonly accepted that proceedings papers, e.g. resulting from conference presentations, have to be distinguished from peer review journal publications. Miskiewicz [29] has discussed whether such different types of publications have some impact on the core number and on the ranking of CAs. For completeness, note that a complementary question was also examined, i.e. whether a "binary scientific star"-like system implies some deviation from Eq.(2), - the "binary scientific star" (BSS) being defined as the couple formed by a LI and one of his most frequent CAs [30].

In the following sections, an amazingly simple relationship is reported to be found between \(m_a^{(jp)}\) and its related value for publications in peer review journals (j) and in proceedings (p), i.e. \(m_a^{(j)} + 0.4\ m_a^{(p)} = m_a^{(jp)}\). Moreover, another relationship is found concerning the \(A_a\) index, i.e. the surface of the \(J\ vs. r\) histogram up to \(m_a\), i.e., \(A_a^{(j)} + 1.36\ A_a^{(p)} = A_a^{(jp)}\). A discussion of other empirical (linear) relations is presented. The illustrative data of the coauthorship features is quickly recalled for the few published cases, in Sect. 2. In Sect. 3 some hint is presented on some origin of the, surprising (or unexpected), relationship, and for the coefficient values. The case of anomalous data points is also discussed. Some justification is based on the empirical power laws \(J(t) \propto r^{-\alpha(t)}\), [10], emphasizing that \(\alpha(t)\) depends on the type \((t)\) of publication, even if only slightly. A bonus (?) is found to be the simple power law relationship between the \(m_a\) core value and the number of different coauthors, see an Appendix.

Note that there is at first no reason to predict that a simple relationship will be found between the various quantities here above introduced. In fact an examination of the distributions led to ambiguous results [30]. There is apparently no other previous investigation of this matter. In fine, modeling likely requests much more thinking. Sect. 4 serves as a conclusion on the respective relevance of different types of publications in "evaluating" a LI and his/her CAs, and with some suggestion for future work. Nevertheless, the findings could imply practical considerations on subsequent measurements of publication activities during a career, -as self-citations might do [31].

Note also that several other so called laws have been predicted or discovered about relations between number of authors, number of publications, number of citations, fundings, dissertation production, citations, or the number of journals or scientific books, time intervals, etc. [32].

\(^1\)The order of authors is at this level not discussed.
Figure 1: Empirical proof of the linear relationship between the total CA core value $m_a^{(jp)}$ and the corresponding ones, but distinguishing between peer review journals (j) and "proceedings" (p) papers, i.e. $m_a^{(j)} + 0.414 m_a^{(p)} \simeq m_a^{(jp)}$; $R^2 = 0.894$; the dash line indicates the best possible two parameter linear fit; several data points overlap each other.
Figure 2: Empirical proof of the linear relationship, $A_{a}^{(jp)} \simeq A_{a}^{(j)} + 1.36 A_{a}^{(p)}$, between $A_{a}$'s, i.e. the (Number of joint publications-Coauthor rank) histogram $J$ vs. $r$ surface below $m_{a}$ [10], and the $A_{a}$ corresponding values for peer review journals (j) and "proceedings" (p); $R^2 = 0.998$; the dash line indicates the best possible two parameter linear fit; several data points overlap each other
Figure 3: Empirical linear relationship, $a_M^{(jp)} \simeq a_M^{(j)} + 0.225\, a_M^{(p)}$, between the whole $a_M$'s and the corresponding ones for joint papers with coauthors in peer review journals (j) and "proceedings" (p); $R^2 \simeq 0.581$; if either the (DG) and the (AP) and (MM) points are not considered in the fit, as being possible "outliers", the relationship numerical values are slightly modified. N.B. The best possible linear two parameter fits are not shown though have a higher $R^2$, see text for values, but the abscissa at the origin can hardly be interpreted.
Figure 4: Empirical proof of the linear relationship, $a_a^{(jp)} \simeq a_a^{(j)} + 0.503 a_a^{(p)}$, between $a_a$ values resulting from the (Number of joint publications (jp)-Coauthor rank) histogram, $J$ vs. $r$, surface below the core value $m_a$, and that of peer review journals ($j$) and "proceedings" ($p$); $R^2 = 0.957$, when (JM) and (HSSB) points are not considered, as being outliers, see text; inclusion of such points are shown by the blue dash line; the best linear two parameter fits are not shown because the abscissa at the origin can hardly be interpreted.
2 Data sample

For the following study and discussion the same LIs as those investigated in previous publications [10, 28, 29, 30] are considered. The LIs span a large range of scientific research topics, though in statistical physics mainly. They are mentioned by their initials. Most of them are males, except two. They come from mainly Poland, 7, i.e. RW, JMK, AP, KSW, JM, and MM; 4 are from the ”western world”, HES, DS, MA, and PC. They are half several senior (JMK, AP, HES, DS, MA, PC) and half rather junior scientists. In previous reports [10, 28, 29, 30], their publication list has been summarized and is thus not recalled here. Beside the LIs, 4 BSS cases [30], i.e. so called HSSH, HSSB, MARC and MANV has been made for further completing the up to-day rather rare data. This leads to examine 15 cases. 

A priori, the data does not seem to be specifically biased.

The best power law fits, through Eq.(2), $\alpha$ and $m_a$ value, and the distribution main statistical characteristics, i.e., the mean $\mu$ and $r_M$, are given in Table 1. This well illustrates the similarity in behavior, but points to differences to be examined next in more detail. One may expect, from a general point of view, that the subsets, i.e. joint publications in peer review journals (j) and in proceedings (p), might have some influence on characteristics of those for the whole (jp) set since they form the structure. However, the problem is highly non linear in essence, since the ”rank” is not a usual variable. Nevertheless, in line with modern statistical analysis, and in order to detect some substructure, several fits can be attempted, i.e. power law, exponential, logistic, ... and polynomial, the most simple being the linear one.

The deduced values of $\sum, A_a, a_M$ and $a_a$ are given for the three sets, i.e. (jp), (j) and (p), in Table 2. The empirically found laws are presented in Figs. 1-4, for the $m_a, A_a, a_M, a_a$ quantities.

A simple relation is found between the core measures, i.e.

$$m_a^{(j)} + 0.414 m_a^{(p)} = m_a^{(jp)}$$

with a high regression coefficient $R^2$, i.e. $\sim 0.894$, and between the histogram surfaces below the corresponding core measures

$$A_a^{(j)} + 1.36 A_a^{(p)} = A_a^{(jp)}$$

with a very high regression coefficient $R^2$, i.e. $\sim 0.998$, as seen in Figs. 1-2 respectively. In both cases, a classical two parameter linear fit has been attempted. It has been found that $m_a^{(jp)} = m_a^{(j)} + 0.452 m_a^{(p)} - 0.321$ and $A_a^{(jp)} = A_a^{(j)} + 1.354 A_a^{(p)} + 1.917$ respectively, with the corresponding $R^2$ values being equal to 0.904 and 0.998. Such fits are shown in Figs. 1-2.

Let it be observed that one has necessarily

$$\Sigma^{(j)} + \Sigma^{(p)} = \Sigma^{(jp)}$$

which is nothing else that a normalization condition on the NJP, as exemplified in Table 2.
Subsequently, $a_M$ has been examined. The result is reported in Fig. 3. One finds
\[ a_{(j)}^{(M)} + 0.225 \, a_{(p)}^{(M)} = a_{(j)}^{(M)}, \] 
but with a low $R^2 \approx 0.581$. More discussion, stemming from the presence of anomalous data, so called "outliers", is found in Sect. 3.

Finally, a fine linear fit is found for $a_a$ as seen in Fig. 4
\[ a_{(j)}^{(a)} + 0.503 \, a_{(p)}^{(a)} = a_{(j)}^{(p)}, \]
with $R^2 \approx 0.957$, even with the presence of anomalous (outlier) data, as discussed in Sect. 3.

3 Discussion

3.1 Outliers

First let us discuss the cases of $a_M$ and $a_a$, before introducing an estimate of the numerical coefficients. Visual inspection shows that there are a few data points looking like outliers in Fig. 3 and Fig. 4. They are called (DG), (AP), and (MM) on one hand and (JM) and (HSSB) on the other hand.

For the $a_M$ case, Fig. 3, it is remarked that (DG) has a specially high number of CAs, i.e. 93, having only one ("proceedings") joint publication with DG. This stems from some work by DG in high-energy physics before he turned towards statistical mechanics research. If such a data point is included in a proportionality fit between $a_{(j)}^{(M)} - a_{(j)}^{(M)}$ and $a_{(p)}^{(M)}$, one obtains a proportionality coefficient equal to 0.335, and a $R^2$ value equal to 0.312. Concerning (AP) and (MM), it is observed that $a_{(j)}^{(M)} - a_{(j)}^{(M)} \leq 0$, which may at first appear awkward and unattractive. Note that the respective values of $\sum a$ and $m_a$ seem "reasonable". However, the origin of the negative value is likely attributable to the fact that AP and MM have very few "proceedings" papers, having mainly concentrated their research output into peer review journals, and few papers resulting from scientific meetings. In some sense, through these two authors, one point out to the effect of duplicate-like papers.

The comment on the "(DG) effect" implies that one should deduce that the proportionality coefficient is likely to be dependent on the research field. On the other hand, the comment on the "(AP)-(MM) effect" indicates that one should allow for a negative value of $a_{(j)}^{(M)} - a_{(j)}^{(M)}$, and propose that the coefficient to be accepted is 0.228 rather than 0.225.

For completeness, a classical two parameter linear fit has been made either taking into account all data points, or removing outliers. The following relations have been obtained, for the $a_M$

- taking into account all data points, $y = 0.255 + 0.33x$, with $R^2 = 0.349$,
• without the (DG), (AP) and (MM) points, $y = 2.964 + 0.164x$, with $R^2 = 0.769$,

• without the (DG) point, $y = 1.232 + 0.197x$, with $R^2 = 0.718$.

For the $a_a$ cases, see Fig. 4. HSSB is seen to have a very high $a_a^{(jp)} - a_a^{(j)}$ positive value, while for JM, one obtains $a_M^{(jp)} - a_M^{(j)} \leq 0$. It is fair to emphasize that there is a similarity between $a_a$ and $a_M$ cases. However, the deductions originate from different surfaces, i.e. below the cores in the $a_a$ cases, to be contrasted with the whole surfaces for the $a_M$ cases.

Since HSSB have almost equal NJP, with their main CAs, in either $p$ or $j$ set, one might wonder if these are duplicate results, since they imply the same and main CAs. The case of JM shows that this is not a duplicate finding: indeed, on the contrary, JM has very few $p$-type publications with his/her main CAs. Moreover, the different "behavior" of HSSB and JM enlightens the fact that JM has rather a concentration of scientific output in peer review journals with his/her main CAs (like for AP and MM, in fact).

For completeness, a classical two parameter linear fit has been made taking into account all data points, or removing outliers. The following relations have been obtained, for the $a_M$

• taking into account all data points, $y = -0.671 + 0.608x$, with $R^2 = 0.775$,

• without the (HSSB) and (JM) points, $y = -0.07 + 0.507x$, with $R^2 = 0.957$.

Note that one should not be impressed by the respective $R^2$ values, - obviously depending on the number of data points, and the fact that these are two parameter fits, - in contrast to the values given here above and in either Eq.(12) or Eq.(13).

The positive or negative value of the abscissa at the origin can be attributed to the fact that the resulting combination $(jp)$ between the $(j)$ and $(p)$ set is a priori highly non-linear. Indeed the various ranks do not sum up, since a CA in one set may appear at two rank values totally unrelated to the resulting rank for the $(jp)$ set.

Finally, in all cases, one may deduce that these (outlier-like) results arise from different scientific (or other) behavior of the respective scientists, but this discussion is outside the realm of the present paper.

### 3.2 Theoretical estimates

The numerical proportionality coefficients, as well as those resulting from a two linear parameter fit, can be discussed, going to the continuum limit for the respective histograms. Indeed, within a continuum approximation, one has

$$
\sum_{r=1}^{r} J_r \rightarrow \int_{1}^{r} J(r) \, dr \equiv \int_{1}^{r} \frac{1}{r^\alpha} \, dr = J_0 \left[ r^{(1-\alpha)} - 1 \right].
$$

(14)
Consequently,
\[ \sum_{r=1}^{r_M} J_r \equiv \Sigma \rightarrow = J_0 \left[ r_M^{(1-\alpha)} - 1 \right], \] (15)
\[ A_a \equiv \sum_{r=1}^{m_a} J_r \rightarrow = J_0 \left[ m_a^{(1-\alpha)} - 1 \right], \] (16)
\[ \sum_{m_a} \rightarrow = \frac{J_0}{m_a} \left[ r_M^{(1-\alpha)} - 1 \right], \] (17)
\[ \frac{A_a}{m_a} \rightarrow = J_0 \left[ m_a^{\alpha} - m_a^{-1} \right]. \] (18)

Recall that these quantities depend both on the type of publication set and on the LI. For example, for one specific LI, and some publication set, one has from Eq. (16),
\[ (A_a/J_0) + 1 = m_a^{1-\alpha}, \] (19)
while from Eq. (15), one finds
\[ \left[ \sum_{r=1}^{r_M} J_r \right] + 1 = r_M^{1-\alpha}. \] (20)

Observe that
\[ \sum_{m_a} + J_0 \rightarrow \frac{J_0}{m_a} \left( r_M^{(1-\alpha)} \right). \] (21)
for each LI and each type of scientific publication. Some elementary, but very tedious algebra, can follow. From Eq. (21), one can extract \( \Sigma \), and rewrite explicitly Eq. (11), in order to obtain a linear relationship between the three \( A_a \) quantities, such that one can write
\[ A_a^{(jp)} = \Lambda_j A_a^{(j)} + \Lambda_p A_a^{(p)} + \left[ \ldots \right], \] (22)
where each \( \Lambda \) and \( \left[ \ldots \right] \) are functions of \( r_M \) and \( m_a \). Moreover, as shown in Appendix, one has a (surprisingly simple) power law relationship between \( m_a \) and \( r_M \), i.e. \( m_a = v r_M^\beta M \), (or \( r_M = u m_a^\gamma \)), see Figs. 5-6. Therefore, one can evaluate the ratio \( \Lambda_p/A_j \) for the various cases; it is about \( v_p/v_j \sim (2.9/5.0)^{-2/3} \sim 1.44 \), not too far from 1.36. The complicated \( \left[ \ldots \right] \) term can be roughly estimated, according to the various numerical values. It is found rather small with respect to the other terms, whence corroborating the finding in Eq. (10).

To "verify" Eq. (9) is more subtle and complicated. Indeed, one has to start from Eq. (11), in which one substitutes each Eq. (15). This leads to a highly non linear relationship of the type
\[ M_a^{(jp)} = \Omega_j M_a^{(j)} + \Omega_p M_a^{(p)} + \left[ \ldots \right], \] (23)
where
\[ M_a \equiv m_a^{\gamma(1-\alpha)}. \] (24)
To extract a linear relationship, analytically, like $m_{a}^{(jp)} = \omega_{j} m_{a}^{(j)} + \omega_{p} m_{a}^{(p)} + \ldots$, similar to Eq. (9) seems feasible only if $\gamma(1 - \alpha) \equiv (1/k)$, where $k$ is an integer. For the sake of argument, taking $\gamma = 3/2$ and $\alpha = 1/3$, thus $k = 1$, one can estimate according to the values in Tables 1-2 and those in the Appendix that the ratio $\omega_{p} / \omega_{j} \sim J_{0}^{(p)}/J_{0}^{(j)} \simeq 0.5$, not too far from 0.4 in Eq. (9).

4 Conclusions

In summary, recall that the core $m_{a}$ of coauthors (CAs) of a leading investigator (LI) is well defined through a criterion similar to the $h$-index. Through a $J$ vs. $r$ histogram, one describes a CA "impact" according to the number of his/her joint publications $J$ with a LI. It is usually considered that scientific publications in proceedings differ, in various ways, "values", from those in peer review journals. This belief was here above questioned. In fact, one can distinguish the core of coauthors of a LI, according to the type of joint publications. Next, it was wondered whether the relative hierarchy in estimating the value of publications in journals or proceedings can be carried to the core of co-authors. Finally, the question was raised: "is there any numerical proof of the usual belief in a qualitative difference"?

Visually, it appears that the hierarchy exists, i.e. $m_{a}^{(jp)} > m_{a}^{(j)} > m_{a}^{(p)}$, but, somewhat surprisingly, the relationship turns out to have a simple analytic form: $m_{a}^{(j)} + 0.4 m_{a}^{(p)} = m_{a}^{(jp)}$. Moreover, another relationship is found concerning the $A_{a}$ index, i.e. the surface of the $J$ vs. $r$ histogram up to $m_{a}$, i.e., $A_{a}^{(j)} + 1.36 A_{a}^{(p)} = A_{a}^{(jp)}$. These linear relationships also hold for subsequently derived measures.

The findings have been illustrated gathering data for a dozen or so LIs, and for 4 couples, i.e. publications in which a LI is systematically with a specific CA. Even though the data, about scientists working in the research field of statistical physics, is of finite size, the result does not seem to be biased. A $\chi^{2}$ test indicates the reliability of the found features. Yet, in one case, a LI, having previously worked in high energy physics and having many (93) CAs for one publication, of the (p)-type, some anomalous behavior occurs. This outlying feature should not distract from the main findings.

The main text analysis points out to the interest of the measures of CA cores according to types of publications. The results of course suggest to investigate other scientific domains. In fact, it can be done through a bonus, the discovery that $m_{a}$ is tied with the maximum number of CAs of a LI, i.e. $r_{M}$, through a simple power law. In so doing, one may observe that outliers are easily found [33, 34], - thus removing them leads to a large increase in the $\chi^{2}$ coefficient, in fine giving much weight to the interest of such numerical findings. It is also obvious that the analysis is rather simple for policy makers, - when the list of publications is available.

Theoretical work, whence explanations, have been shown not to be trivial, because the systems are highly non-linear. A CA might appear in one type ($j$ or $p$).
Figure 5: Empirical proof of the power law relationship, $m_a \simeq r_M^β$, resulting from the (Number of joint publications (jp)-Coauthor rank) histogram, $J$ vs. $r$, surface and that for peer review journals (j) and "proceedings" (p), when the (DG) point is not considered, as being an outlier.
Figure 6: Empirical proof of the power law relationship, $r_M \approx m_a^\gamma$, when the outlier (DG) point is not considered, for the cases of peer review journals (j) and "proceedings" (p), and the total (jp) number of joint publications.
of publications, but not in the other type. However, as it is more frequently seen, a CA appears in both types of publication. However, it might be at a quite different ranking. This is the case when a CA does not have "many" publications with a LI. In fact, the ranking of some CA in some type of publication does not simply add up with the ranking in another type of publications. A CA ranking is usually not conserved, but depends on the publication type. Whence, there is a priori no reason why a linear relationship should be found between such measures.

However, there is one "normalizing condition", in general not appreciated, which imposes further consideration of such co-authorship measures: the surface of the histogram \( J \) vs. \( r \) for the whole set of publications is necessarily the sum of the surfaces for the two types of publications. Thus, since a the continuum limit, \( J \propto 1/r^\alpha \), one can measure such surfaces as a function of \( \alpha \) and \( r_M \), and later derive an estimate of the numerical coefficients obtained through empirical fits.

Finally, one should not simply consider that these are numerical games. They lead to remarkable proportionality measures of CA roles. It appears that the number of CAs "of interest" for measuring the core of CA of a LI is mainly arising from the joint publications in peer review journals. Indeed, only about \((0.4/1.4 \simeq 30\%) \) stem from "proceedings". Similarly, it appears that the "contribution" to the number of joint publications by the main CAs is about 50\% of the whole.

This implies to elaborate practical considerations on subsequent measurements of publication activities during a career, on the role and effects of coauthors \([35, 36, 37]\). The case of outliers is also of interest, since it carries some weight in estimating \( \alpha \) and subsequent numerical coefficients.

These simple relations imply that coauthors are a "more positive measure" of a principal investigator role, in both types of scientific outputs, than the Hirsch index which barely counts the number of citations independently of the co-author (number nor a fortiori rank). Therefore, to scorn upon co-authors in publications, in particular in proceedings, is highly incorrect. On the contrary, the findings suggest an immediate test of coherence of scientific authorship in scientific policy processes. This could imply many practical considerations on the role of CAs with respect to a LI and on the respective roles of different types of publications in "measuring" a LI team work. A discussion of criteria based on the above for estimating, e.g the financing of a LI or a team, is outside the realm of the present paper. Nevertheless, with softwares actually available to policy makers, the development and application of such findings should be easily possible.

Note three final points: (i) each rank-frequency form, like Eq. (1) or Eq. (2), has an equivalent size-frequency one \([38]\). One should become curious about whether similar equalities hold for the size-frequency cases; (ii) the above considerations suggest to investigate if similar relationships exist for the \( h \)-index, distinguishing between \( h^j \), \( h^p \), and \( h^{jp} \), and to draw ad hoc conclusions; (iii) complex systems do not necessarily lead to find non linear laws.
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Appendix

Other empirical laws: $m_a$ vs. $r_M$ and $r_M$ vs. $m_a$, with or without outliers

For the theoretical estimation of the numerical values in Eqs. (9)-(13), in particular in order to proceed beyond Eq. (21), it appears that it is useful to find whether a relationship exists between $r_M$ and $m_a$ on average.

The most simple power law fits for $m_a$ vs. $r_M$, i.e. $m_a \approx r_M^\gamma$, give, taking into account all data points,

- $m_a^{(j;p)} = 0.392 \left[ r_M^{(j;p)} \right]^{(0.645)}$, with $R^2 = 0.893$
- $m_a^{(j)} = 0.405 \left[ r_M^{(j)} \right]^{(0.629)}$, with $R^2 = 0.978$
- $m_a^{(p)} = 0.904 \left[ r_M^{(p)} \right]^{(0.415)}$, with $R^2 = 0.760$

but lead to

- $m_a^{(j;p)} = 0.393 \left[ r_M^{(j;p)} \right]^{(0.667)}$, with $R^2 = 0.946$
- $m_a^{(j)} = 0.405 \left[ r_M^{(j)} \right]^{(0.629)}$, with $R^2 = 0.978$
- $m_a^{(p)} = 0.842 \left[ r_M^{(p)} \right]^{(0.460)}$, with $R^2 = 0.917$

when the outlier (DG) data point is not taken into account, i.e. roughly speaking $m_a \approx 0.5 m_a^\gamma$, with $\gamma \approx 1/2$ or $2/3$. Similarly, the best power law fits for $r_M$ vs. $m_a$ give, when taking into account all data points,

- $r_M^{(j;p)} = 8.691 \left[ m_a^{(j;p)} \right]^{(1.175)}$, with $R^2 = 0.893$
- $r_M^{(j)} = 5.013 \left[ m_a^{(j)} \right]^{(1.483)}$, with $R^2 = 0.969$
- $r_M^{(p)} = 4.261 \left[ m_a^{(p)} \right]^{(1.507)}$, with $R^2 = 0.867$

but become

- $r_M^{(j;p)} = 4.589 \left[ m_a^{(j;p)} \right]^{(1.438)}$, with $R^2 = 0.936$
- $r_M^{(j)} = 5.013 \left[ m_a^{(j)} \right]^{(1.483)}$, with $R^2 = 0.969$
- $r_M^{(p)} = 2.871 \left[ m_a^{(p)} \right]^{(1.683)}$, with $R^2 = 0.960$

when the outlier (DG) is not taken into account, i.e. roughly speaking $r_M \approx 4.5 m_a^\beta$, with $\beta \approx 3/2$ or $5/3$. The ”no (DG)” cases are shown in Figs. 5-6 for illustration of the findings. Note the large $R^2$ values.

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Table 1: Summary of direct data values for 11 LIs and 4 BSSs: $m_a$ is the core measure [10]; $\alpha$ is the exponent of the empirical power law, Eq. (2); $\mu$ is the mean of the distribution ($J$ vs. $r$); $r_M$ the total number of different CAs (NDCA); always distinguishing among of joint publications, the total (jp) sum, the journals (j) and the "proceedings" (p)
Table 2: Summary of indirect data values for 11 LIIs and 4 BSSs: $a_M = \Sigma/m_a$, where $m_a$ is the CA core measure; $\Sigma$ is the surface below the histogram ($J$ vs. $r$), i.e. TNCA: $A_a$ is the surface below the $J$ vs. $r$ histogram, limited to the core value $m_a$; $a_A = A_a/m_a$; each value for the total (jp) number of joint publications, journals (j) or "proceedings" (p).