INFORMETRICS 89/90
L. Egghe and R. Rousseau (Editors)

MULTIPLE AUTHORSHIP IN BIOCHEMISTRY AND OTHER FIELDS; A CASE STUDY OF THE JOURNAL OF BIOLOGICAL CHEMISTRY THROUGHOUT 1905-1988

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Abstract

Large samples of papers published in the Journal of Biological Chemistry were checked in order to study the multiple authorship pattern throughout the period from 1905 to 1988 in an internationally leading scientific journal with an especially high "citation impact". Both measures of mean number of authors per paper and proportion of multi-authored papers show that there has been a consistent growth during most of the period, best described by a "steps model", expressing recurring sharp increases following relatively steady periods. From 1975 on, however, growth has been accelerating, when measured at five-year intervals. Findings do not support some earlier predictions made by Price, Meadows, and others. A detailed comparison to a wide range of almost sixty fields shows considerable differences between sciences, technology, social sciences and humanities, as well as great variations among the sciences and the social sciences themselves. The order of the various fields in the comparative table suggests that multiple authorship seems to be one of the factors related to the "hardness" of a field. The JBC itself ranks among the top, albeit lower than some medical fields, but higher than other biochemistry journals, probably indicating its larger share in the more expensive, larger-teams-conducted, "big science" research.

INTRODUCTION

Called by Price [1] "one of the most violent transitions that can be measured in recent trends of scientific manpower and literature", the phenomenon of multiple authorship has drawn during recent decades a considerable amount of attention among students of the sociology of science. The strikingly accelerated increase in the number of authors per paper stirred some medical scientists to half-jokingly express the fear that, at the present rate of growth, each paper will have at least 24 authors by the year 2076 [2], while others suggested granting the Nobel Prize to et al, since it "is fast becoming the most prolific biomedical author today..." [3]. Having conceived the

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multiple authorship trend as part of the "big science" phenomenon, evolving out of growing financial, economic and professional dependence of scientists upon each other, Price [1] was one of the first to discuss it, followed by many others. Only a few studies, though, have tried to follow this trend in a certain subject field along the entire century until the present day, applying the two measures of multiple authorship mentioned below.

LITERATURE REVIEW

The topic of scientific and research collaboration has been historically reviewed in a series of three articles by Beaver and Rosen [4-6] and later by Subramanyam [7] from a somewhat different viewpoint. To be sure, the former's data does not exceed 1969-1970, while the latter overlooked some existing relevant studies and, except for a few lines, avoided making comparisons between rates found for various subject fields. At any rate, these reviews enable us to limit ourselves to the few most pertinent studies whose findings and conclusions are challenged in the present study.

Relying on data from *Chemical Abstracts* up to 1960, Price [1] stated (in 1963) that the phenomenon of collaborative work has been increasing steadily and ever more rapidly since the beginning of the century. While in 1900 more than 80 % of all papers had a single author, he predicted that, at the present rate, *by 1980 the single author paper will be extinct.*

Concluding probably from his data that three-author papers are accelerating more rapidly than the two-author ones, four-author more rapidly than three-author, and so on, Price made a second prediction saying that while in 1960 only about 25 % of all papers had *three or more* authors, by 1980 more than *half* will be in this category. Likewise, Price predicted that, if the trend holds, "we shall mode steadily toward an *infinity* of authors per paper". Price, however, did not publish his detailed data derived from *Chemical Abstracts*, but only a single graphic figure depicting the incidence of multiple authorship as a function of time.

Clarke [8] in 1964 contested some of Price's conclusions, arguing that his generalizations, derived from *Chemical Abstracts* data, are not necessarily valid for other fields of science. Analyzing papers in experimental biology, 1934-1963, Clarke showed that while most curves for the 1934-1946 period do parallel Price's graphs, for the 1947-1963 period there was *no* trend in most curves, and in the rest the evidence was inconclusive, indicating *no* continuation of a marked trend toward multiple authorship among biomedical writers. Thus, Clarke advised planners of biomedical journals to expect an average number of no more than 2.3 authors per paper even in 1980. She also speculated that the differences between her findings and Price's might lie in the much higher qualification of the authors in her sample, who were more mature and seasoned scientists and thus found less need for multiple research collaboration than do the Chemical writers who are, on the average, less well established as independent investigators.

Zuckerman's 1965 study [9] supported Price's main thesis, showing a consistent increase in the percentage of multi-authored papers in certain fields in each of the broad areas of the sciences, social sciences and humanities. Her data, however, reaches 1959 only, and is limited to several fields in each area. Likewise, presenting aggregate data of two remote years (2nd and 7th) from each decade as its surrogates might sometimes partly blur certain changes occurring in the meantime.

About a decade later (1974), A.J. Meadows [10] raised the question of how much further the trend of decrease in the proportion of single-author papers can go, and postulated a model representing that decrease as a function of time by a

quasi-logistic (i.e. S-shaped) curve. A preliminary period of a slow decline is followed by a period of very rapid decrease, and then by a final period during which the curve flattens off again, but at a much lower level, in which the single-author papers constitute less than 20 % of all papers.

Admitting that it was too early as yet in 1974 to judge what the final outcome in terms of multiplicity of authors would be, Meadows predicts that "unless there is a continuing drive toward more and more authors per paper, one must suppose that the final state will be some steady state distribution of papers with different numbers of authors". Likewise, Beaver and Rosen [6] in 1979 repeated the prediction that "... the growth of collaboration is rapidly approaching its saturation limit".

Analyzing papers published during 1976-1983 by Indian agricultural researchers, Begum and Sami [11], recently found that, contrary to Price's predictions, the number of authors per paper has remained steady, at about 2.3, and there was no noticeable decline in the proportion of single-authored papers. Consequently, they conclude that the extent of collaboration is decided by nature of a discipline, and that Price was probably wrong in generalizing implicitly upon the basis of a survey of *Chemical Abstracts* to all fields of science.

One should, however, be cautious regarding Begum and Sami's conclusions since they studied a relatively short period of time, covering only seven years. Unfortunately, many of the multiple authorship studies ignored the *time* factor, giving one average figure for a relatively long period of 25 years, for example [12,13]. In fact, most studies were limited either to several fields in a certain single year, or to a long-term comparison, but for a few selection fields only. Most earlier studies used either the measure of mean number of authors per paper, or the measure of the proportion of multi-authored papers, *and not both of them together, as should be done.*

Concerning the field of biochemistry, Lindsey [14] checked only those papers published during 1970-1975, and Subramanyam and Stephens [15] limited their comparative study of collaboration and funding to the period 1965-1980 only, providing mostly aggregate figures for the period as a whole, except for annual means, and with no further details concerning the frequency distribution of the multi-authored papers.

PURPOSE OF THE STUDY

The objectives of the present study were :

1. To identify the *long-term* collaborative authorship patterns in the field of biological chemistry.
2. To examine to what extent these patterns support Price's [1] aforementioned generalizations and predictions, Clarke's [8] patterns and predictions, or Meadows' [10] model, rule and predictions.

To put it more specifically :

(a) Has there been a noticeably continuous decline in the proportion of single-authored papers?
(b) Was the single-author paper extinct by 1980, or is it at least approaching extinction toward 1990 or 2000?, or does Meadows' [10] S-shaped curve model better fit the data?
(c) Has there been a parallel steady increase in the average number of authors per paper?
(d) Did papers of three or more authors become *half* of all papers by 1980?
(e) Was Meadows [10] *right* in stating a general rule (following Price's 1962 finding in chemistry [1]) that "the higher the multiplicity of authorship, the lower the proportion of papers published with that number of authors, but the faster the rate at which the proportion is accelerating"?

(f) Does recent data support Meadows' [10] and Beaver and Rosen's [6] predictions that the saturation limit of the growth of collaboration and a final state of steady distribution of multiple authorship are rapidly approaching?

3. To make an assessment of the extent of multiple authorship in biochemistry by a long-term comparison with findings of former studies in a wide range of other fields. Such a wide comparison might also test the validity of Price and Beaver's [36] statement regarding the existence of only "*minor* variations from field to field of science" as far as the rate of authors per paper is concerned.

METHODOLOGY

In order to avoid a possible obstacle of subject or journal differences it was decided to limit the investigation to a single well-established journal, preferably an internationally leading one.

The *Journal of Biological Chemistry (JBC)* was found suitable to be used as an object for this study for several reasons : its leading role in the field, both qualitatively and quantitatively, and hence, its indispensability for every scientific library, its seniority (established in 1905), which enabled a "long view" comparison, as well as close familiarity with it from day-to-day work in a biology library. It has been presupposed that the JBC patterns of authorship might represent and illustrate lines of development typical to many scientific journals. Recent studies show that the JBC is one of the most often cited scientific journals. Garfield's citation analyses ranked the JBC at least twice in the *third* place in the total number of citations received from other scientific journals. Concerning "impact factor" (average number of citations per published item) the JBC ranked in the 19th place in 1969, and in the 9th place in 1974. It usually has the highest percentage in lists of most cited articles in biochemistry [16-18].

Like Henkle [19] in 1938, Sengupta [20] in 1968-1970 ranked the JBC at the top of 533 journals cited in the *Annual Review of Biochemistry*. Analyzing the quality of papers in *Biochimica et Biophysica Acta (BBA)*, Slater [21] admits that the average citation frequency of an article in BBA is below that of the JBC, which has been publishing more top papers. Comparing the "citation impact" of eight leading "general" biochemical journals in 1983, Slater's table shows JBC's factor (6.11) to exceed considerably all others (*Biochemistry* - 3.84, BBA - 2.54, for example). Out of more than 2300 scientific journals in 1973 checked by Narin [22], the "Influence Weight" for the JBC (3.70) was among the highest assigned.

Starting with volume no. 1 (1905-1906) the appropriate JBC volumes of each fifth calendar year up to 1988 were examined. In most volumes the *entire* population of regular (ordinary) papers was checked. From the rest (1950, 1955 and 1975 to 1988) a systematic sample of regular papers was drawn from each volume. When several volumes appeared in one calendar year, they were considered one volume and *all* regular papers included in them were examined, or at least systematically sampled. In those few cases of a large annual output of papers samples were taken, their sizes usually varying between 30 to 70 percent of the entire population, including at least 350 papers.

For each of the papers examined the number of authors per paper was recorded. "Regular papers" were defined as ordinary full-length research articles, published in the main part of the journal, *excluding* review papers as well as all kinds of *short* publications, such as : "Scientific Proceedings of the ASBC" (up to the 1940's), "Letters to the Editors" (1939-1949), "Preliminary Communications" (1960-1965), and "Communications" (1966 on).

FINDINGS

Table 1 shows very clearly that there has been a clear-cut trend towards multiple authorship in papers published in the JBC since its founding in 1905. This trend is reflected in both the measure of the average number of authors per paper, as well as in the proportion of single-authored papers among the total amount of papers published. It has been shown by us elsewhere [23] that both measures should be used when checking the multiple authorship patterns in a certain field.

The former measure shows that, except for 1960, there has been a consistent and steady increase, almost a *three*-fold one, from 1.36 in 1905-1907 to 3.83 in 1988. The rate of this increase, however, was not even. The figures in Table 1 indicate that the main upward changes in multiple authorship patterns occurred between 1910 to 1915, 1920 to 1925, 1935 to 1940, and from 1970 on consecutively.

Concerning the second measure, it is obvious that between 1910 and 1980 (with the exception of 1945 and 1960) there has been an almost consistent, and sometimes sharp, decline in the proportion of single-authored papers, from about 67 % to 3.5 %. Or, using Subramanyam's [7] measure, we may say that the "ratio of collaboration" rose from 33 % in 1910 to 96.5 % in 1980. But, again, the rate of this marked decline in single authorship was uneven. The figures indicate that the main decreases occurred between 1910 to 1915 (-22.6 %), 1920 to 1925 (-12 %), 1930 to 1940 (-11 %), 1945 to 1950 (-9.2 %), and between 1960 to 1975 (-10 %). During other periods the proportion of single-authored papers remained fairly stable, or even rose slightly but insignificantly (1920, 1930, 1960). Between 1950 and 1960, for example, changes were marginal.

Interestingly, the figures for the recent 15 years (from 1975 on) do not substantiate the claim for an imminent extinction of the single-author paper as far as the JBC is concerned. However, concurrently, both the annual means and the frequency distributions of the multi-author categories show, from 1975 on, a clear-cut prevailing trend towards a greater number of authors per paper. Nevertheless, there still seems to exist a certain proportion, though relatively small (+ 4 %) of single research, stubbornly persisting and refusing to disappear from the JBC pages. Remarkably, the proportion of papers signed by *two* authors remained fairly stable during most of the long period under study (1915 to 1970, with the exception of 1940 and 1945) fluctuating between 47 and 51 percent. In 1975, however, their proportion fell to 41 %, which may indicate the end of a long-term steady-state, while papers with three or more authors comprise in that year more than 53 % of the total (as compared to only 39 % in 1970).

Similarly, the proportion of three-author papers remained fairly stable during 1940-1970 (again, except for 1945) fluctuating around 25 %, and rising to 30.5 % only in 1975. Likewise, papers of two or three authors, which comprised most of the population (about 75 %) throughout 1950 to 1970, gradually dropped to 70 % in 1975, 68 % (1980), 62 % (1985), and then to only 46 % in 1988. Thus, it seems that the major recent change in authorship patterns started between 1970 and 1975.

RECENT TRENDS

Summarizing part of Table 1, Table 2 points out another facet of the major changes occurring from 1975 on.

The proportion of papers with up to three authors dropped from 86 % in 1970 to 50 % in 1988, while those papers with *four* or more authors increased almost *four-fold*, comprising more than *half* of the sample in 1988.

Table 1 : Number of Authors per Paper in the Journal of Biological Chemistry (JBC)
(in % of total papers published in the JBC during that year)

Number of Authors per Paper	*1905-1907	*1909-1911	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985	1988
1	64.4	66.7	44.1	44.3	32.3	35.6	28.3	22.5	26.0	16.8	14.4	15.8	11.6	10.4	5.9	3.5	4.2	3.9
2	35.6	30.1	51.5	50.4	49.8	47.1	50.4	43.4	42.6	50.4	48.2	47.8	49.0	50.7	40.7	37.0	32.3	23.7
3		3.2	3.5	4.8	12.9	15.3	18.8	24.4	20.8	23.2	25.9	26.4	26.9	25.2	30.5	30.8	29.3	22.3
4			0.9	--	4.6	3.4	1.7	8.0	7.4	7.5	7.6	7.1	9.2	9.0	14.5	17.1	16.6	19.2
5				0.4	--	0.3	0.8	1.3	2.5	1.6	3.0	2.3	1.9	3.1	5.3	7.5	7.6	13.3
6					0.4	0.3	--	0.3	0.5	0.3	0.5	0.5	0.6	1.1	1.5	2.1	5.4	10.2
7									--	--	--	--	0.7	0.1	1.1	1.5	1.7	3.5
8 or more									0.3	0.3	0.8	0.1	--	0.3	0.4	0.4	2.9	3.9
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Proportion of Multi-Authored Papers	35.6	33.3	55.9	55.7	67.7	66.4	71.7	77.5	74.0	83.2	85.6	84.2	88.4	89.6	94.1	96.5	95.8	96.1
Mean Number of Authors per Paper	1.56	1.37	1.61	1.62	1.91	1.91	1.96	2.23	2.22	2.29	2.40	2.34	2.46	2.50	2.84	3.04	3.31	3.83
Size of Sample (No. of Papers Checked)	N=73	N=93	N=229	N=228	N=263	N=295	N=357	N=373	N=366	N=375	N=367	N=663	N=672	N=885	N=455	N=519	N=523	N=860
Size of Entire Population	73	93	229	228	263	295	357	373	366	541	546	663	693	885	1293	1654	2270	ca.2590 (est.)

• Since the annual number of papers published was relatively small, two consecutive volumes have been checked in their entirety.

Table 2 : Number of Authors per Paper in the JBC (in % of total papers published in the JBC during that year)

Number of Authors per Paper	1970	1975	1980	1985	1988
Up to 3	86.3	77.1	71.3	65.8	49.9
4 or more	13.7	22.9	28.7	34.2	50.1
Total	100%	100%	100%	100%	100%
5 or more	4.6	8.3	11.5	17.6	30.9
Rate of Growth of their Proportion		1.80	1.38	1.53	1.76

The very recent 1988 figures clearly indicate that, while single-author papers still hold a relatively small but unchanged proportion of the population, papers signed by two or three authors are dropping fast, leaving the scene for papers by *four* authors or more. In a matter of three years the proportion of the latter ones increased from 34 % to 50 %, indicating an accelerating rate of growth. The main acceleration occurred in the proportion of papers by *five* or more authors. As shown in Table 2, the five-year rate of growth of their proportion increased from 1.38 to 1.53 and then to 1.76. The latter figure refers to a period of *three* years only, between 1985 and 1988. Measured in 1990, for a full period of five years it will probably be even higher

DISCUSSION

The findings presented in Tables 1 and 2 indicate that :

1. The noticeable decline in the proportion of single-authored papers has been ongoing, but at a slower pace than that predicted by Price [1]. The single-author paper was extinct neither by 1980, nor by 1988. Even though it has dropped in the recent decade to a very low proportion (+ 4 %) its rates in 1985 (4.2 %) and even in 1988 (3.9 %) are still slightly higher than in 1980 (3.5 %), and no indication of an approaching extinction is to be seen.

2. Table 1 long-term figures do *not* support at all Meadows' [10] S-shaped curve model for the behavior of the proportions of *single*-author papers. Neither the preliminary slow decline period, nor the following one of "very rapid decrease" are indicated by our data. The only part of the model which is confirmed is the final third period during which the curve flattens off at a much lower level (see 1980 on). However, Meadows talks about a decline from 90 % in the first phase to less than 20 % in the last phase, vs. a decrease from about 65 % to about 4 % in our data. This means a flattening off on a much lower level than predicted by Meadows [10].

   Our data suggests a rather different model which might be called "steps model" or "stairs model" expressing an iterative pattern characterized by a steady-state for a 10-15 year period, then a sharp decrease, then again 10-15 stable years, followed again by a sharp decline, and so on.

3. Price's [1] second prediction has been overfulfilled as far as the JBC was concerned. The proportion of papers by three or more authors passed the

50 % mark already in 1975, five years earlier than predicted. In 1985 they amounted to 63.5 %. In fact, when making his prediction (1960) the proportion of such papers was already much higher among the JBC papers (36 %) than among the *Chemical Abstracts* papers (25 %). In view of the very recent accelerated growth in the proportions of the "upper" categories (five authors or more) it is difficult to challenge Price's prediction that "if the trend holds... we shall move steadily toward an infinity of authors per paper". It is worth noting that the proportion of eight or more-authored papers has reached in 1988 the proportion of single-authored papers (3.9 %).

4. Table 1 figures show a steady, though sometimes slow, growth of the *average* number of authors per paper throughout the long period under study. Although differences between averages of close periods might be statistically insignificant (as happened to Subramanyam and Stephens [15]),the long-term growth trend is indisputable, especially if one looks at recent averages. The consistent growth of the average from 2.34 to 3.83, between 1960 to 1988, an increase of about *64 %* does not leave any more room for doubt regarding the significance of the change. Likewise, the 1980 average of 3.04 *refutes* the 2.30 figure predicted by Clarke [8] for biomedical research papers in 1980.

5. At the present rate, if it took about 60 years for this measure to double itself (from 1.57 in 1920 to 3.04 in 1980), it might take approximately another 60 years for it to double itself again, reaching an average of 6 authors per paper towards the year 2040. However, the 1985 figures for papers signed by *six* or more authors indicate an accelerated growth. The proportion of such papers increased almost *seven-fold* within 15 years : from 1.5 % only in 1970 to 4 % in 1980 and to 10 % in 1985. The first half of the present decade alone shows a significant increase of 150 % in their proportion, as well as a significant increase in the proportion of papers signed by *eight* or more authors. The latter jumped up from a negligible fraction in 1980 (0.4 %) to almost 4 % in 1988. Thus, a doubling of the average to six authors per paper might precede 2040.

6. Hence, it may be said that our data support *neither* Meadows' [10] supposition regarding a final steady-state distribution of multi-authored papers, *nor* Beaver and Rosen's [6] prediction concerning the rapidly approaching saturation limit. The 1980's figures, and especially the means, clearly indicate that the drive towards more and more authors per paper is still continuing, and even accelerating.

7. Data from Table 1 far from fully substantiates Meadows' [10] rule (following Price's [1] finding for *Chemical Abstracts*) claiming that the higher the multiplicity of authorship, the lower the proportion of papers published with that number of authors, but the faster its rate of acceleration. Our data indeed supports its first part, that the higher the number of authors per paper, the lower the proportion of such papers (even though recent data indicates that even this part of the rule might not be true for certain categories in the near future since the gap between the proportions of three-author and two-author papers has been narrowing steadily).

   The second part of Meadows' rule, however, is not supported by our data. Besides the very recent 1980's even growth in the proportion of five-or-more-author papers discussed above, the figures in Table 1 show that during a great part of the period under study the proportion of three-author papers was *not* growing more rapidly than the proportion of two-author papers, and the same is true for the behavior of the other categories. It seems that the "terrace model", proposed above for the behavior of the single-author proportions, represents faithfully also the long-term behavior of the multi-author categories presented in Table 1.

COMPARISON TO OTHER FIELDS

Table 3 presents in descending order mean values of authors/paper found in about sixty various subject fields, in the sciences, the social sciences and the humanities, throughout 1950 to 1980. Most figures were taken out of former studies, and in several cases it was necessary to calculate the mean out of raw data found. In many other cases, however, mainly in social sciences and humanities fields, the sources for the mean figures were our original unpublished data. Unfortunately, the table is incomplete since in many cases figures were available for only a part of the period.

Such comparative data should usually be treated with a considerable amount of caution due to differences in sources of samples (i.e. journals), in methods and in scopes of subject fields involved. Besides the expected sampling error, these differences are probably the main reason for most of the discrepancies in rates found for the same field in the same year. However, with all due caution, several points might be indicated from Table 3.

1. There is a clear concentration of scientific fields at the top of the table vs. similar concentration of the social sciences towards its bottom, marking considerable differences between means derived from each of these groups of fields. In fact, Zuckerman [9] studying Nobel laureates in the United States, has reached a similar conclusion by comparing percentages of multi-authored papers in various fields. However, her data reached only up to 1959, and included only a few fields from each of the three broad areas of knowledge, while Table 3 is more comprehensive, including many more subject fields and indicating the existence of wide variations among the sciences themselves (see 2). These variations can hardly be considered "minor", as claimed by Price and Beaver [36].

   Table 3 reflects the fact that in its "upper" fields research is characterized by work teams operating in elaborate laboratories that require complex equipment, extensive funding, and a division of labor. On the other hand, research in those fields located at the bottom of the table is mostly done by individuals working alone, and usually with no need for expensive research equipment.

   According to an unpublished study by Hirsch and Singleton [36] confirmed later by others [6, 15, 35], the prevalence of multiple authorship in a field is closely related to the amount of financial support - government, foundation, or private - given to the research producing these papers. Subramanyam and Stephens [15] are apparently right when assuming that teams of researchers have a greater "pulling-power" than individual ones in attracting external funding for research. The extensive funding and division of labor needed for the operation of elaborate laboratories, with their complex equipment reflects social recognition of the utility of science [6]. Thus it can be said that the descending order of the fields listed in Table 3 reflects, at least partly, social recognition of their utility.

2. Some science and technology fields have a relatively low rate of authors/paper, as already indicated by Beaver and Rosen's findings for 1970. One may find in this list, besides mathematics and computer science, technology fields like metallurgy and mining, aerospace research and aeronautics, agriculture, electronics, engineering and the like. However, while Beaver and Rosen's list was limited mainly to fields in science and technology, Table 3 by incorporating an equally long list of social science fields (marked by *), clearly indicates a "twilight zone" in which some "upper" social science fields rank higher than some science and technology fields which are relatively "lower" among the sciences list. Thus, psychology and psychiatry rank higher than metallurgy, agriculture, botany, and electronics; sociometry ranks higher than geophysics and computers; and womens' studies

Table 3 : Mean Number of Authors per Paper in Various Subject Fields

Subject Field	1950	1955	1960	1965	1970	1975	1980
Lunear Research [24]					4.3		
Medicine [2,3,25-27]	1.75-2.0	1.9	2.3-2.8		3.5	3.4-4.2	4.5 (1977)
Health Physics [28]						3.1	
Cardiovasc. Sys. [6] Chest [29]					2.74	3.0	
Astronomy [10,30] (observational)	1.35		1.42		1.96-2.65		2.88
Drug Literature [31-32]					2.00-2.63		
JBC	*2.29*	*2.40*	*2.34*	*2.46*	*2.50*	*2.84*	*3.04*
Cancer [6]					2.49		
Biochemistry [14,15,33]				2.4	2.40-2.47	2.8	2.9
Chemistry [1,6,33-36]		2.32			2.06-2.41	2.56	
Biomedical Literature [8]	2.35	2.22	2.30	2.26			
Physiology [29]						2.50	
Biochemistry [6,29]					2.26	2.40	
Medicine [6,37]					2.16		2.9
Microbiology [6,38]	2.15	2.23	2.16		2.15		
Nuclear Sci. & Techn. [6]					2.13		
Physics [6,33,39]			1.8		1.94-2.13		
Biology [6,35]					2.02	2.11	
Chemical Engineering [6,15]				2.05	1.84-2.00	2.29	2.27
Pulsars research [10]					2.00		
Genetics [33]					1.92		
Cont.							

Table 3 : Continued

Subject Field	1950	1955	1960	1965	1970	1975	1980
* Child Development [37]			1.88	1.89	1.91	1.93	1.96
* Psychiatry [14]					1.90		
* Psychology [14,35,40,41]	1.4-1.5	1.70		1.80	1.84	1.91	
Metallurgy & Mining [6]					1.82		
Astronomy [6,10,30]	1.33		1.39		1.50-1.80		2.54
* Industrial Psychology [37]					1.80	1.86	1.93
Oceanography [33]					1.78		
* Gerontology [42]					1.78		
Agriculture [6,11]					1.74	1.41	2.48
Meteorology [33]					1.69		
Aerospace Science [6]					1.68		
Botany [6]					1.66		
* Ecology & Environ.Sci. [33,37]			1.54	1.59	1.66	1.75	1.87
Electronics [6]					1.63		
Material Science [6]					1.57		
* *Social Science* [41]	1.31	1.32	1.35	1.44			
Sociometry [41]	1.30			1.70			
Geophysics [33]					1.52		
Astronomy (theoretical) [30]	1.27		1.32		1.51		1.81
Computers [6]					1.47		
* Women Studies [44]					1.46		
* Criminology [37]						1.55	1.58
Information Science [37,43]					1.40	1.44	1.57
Cont.							

Table 3 : Continued

Subject Field	1950	1955	1960	1965	1970	1975	1980
* Geography [37]					1.40	1.42	1.44
Engineering [6]					1.39		
Aeronautics [6]					1.35		
Mathematics [6,37,47]	1.11	1.19	1.16	1.19	1.34	1.26	1.30
* Library Science [45,37]	1.04	1.08	1.15	1.27	1.40	1.34	1.28
* Social Work [14,37]					1.38		1.46
* Sociology [14,37]			1.27	1.29	1.31-1.34	1.37	1.42
* Urban Studies [37]			1.25	1.28	1.31	1.34	1.39
* Political Science [35]						1.33	
* Education [6,37]					1.30	1.39	1.55
* Archaeology [37]			1.19	1.23	1.25	1.28	1.32
* Anthropology [37]					1.25	1.26	1.28
Musicology [13]					1.20+		
* Economics [14,37]					1.18	1.29	1.41
Biblical Studies [37,46]					1.05	1.05	1.05
History [37]			1.04	1.04	1.05	1.07	1.06

and criminology rank higher than engineering, aeronautics and mathematics.

The relatively higher rank of psychology and psychiatry may be related to the fact that some of their sub-fields belong, in fact, more to the sciences. Gerontology, ecology, and environmental sciences probably owe their relatively high rank to their being interdisciplinary fields in nature, relying to a great extent on several fields from the sciences, especially medicine.

3. Remarkably, the JBC papers feature very high rates of authors/paper, placing them clearly among the medical fields. To what extent do these rates reflect the situation in the whole field of biochemistry? Some answer might be given by the rates found in former studies of biochemistry [14,15] during a much shorter period (1965-1980), which yielded fairly close, though somewhat lower rates.

   Assuming that Price [48] was right in stating that the amount of multiple authorship measures the economic value accorded to each field by society, one may conclude that the economic value attributed by society to the fields of medicine and biochemistry is relatively higher than most other fields of study and research. Remarkably, the association found by Heffner [35] between financial support and collaboration was particularly strong in biological science and chemistry, as compared to the other two disciplines he checked (political science and psychology). Similarly, Kull's findings [38] for the *Journal of Bacteriology* for 1950-1963 show clearly (though not associated explicitly by him) a growing increase both in multiple authorship and in the proportion of papers citing grant support. The latter proportion grew from 38 % in 1950 to 64 % in 1963. Lindsey [14] found 74 % of the articles in biochemistry in 1970-1975 acknowledging outside funding.

   The fact that JBC papers are relatively more multi-authored than a pooled sample [14], or a sample out of the journal *Biochemistry* [15], might indicate a relatively larger share of the JBC in the more sophisticated and expensive 'big science' research, requiring extensive equipment and larger teams of researchers.

   Having relatively more multi-authored papers, might be related to the fact that the JBC has been, and still is, considered a highly prestigious journal, with rigorous editorial policy and referees and a higher rejection rate. Slater [21] of BBA, admits that the JBC has been publishing "more top papers than BBA" during recent decades. Zuckerman and Merton [49] followed by Presser [50], have already found that multi-authored papers have a better chance of being accepted than single-authored papers.

   Oromaner [51] has already found for the three most prominent American sociological journals that multi-authored papers are somewhat more likely to have a higher impact than are single-authored papers. Lindsey [14] found for biochemistry that the "influence of collaboration is to increase the number of citations" attracted by a certain paper, up to four authors when citations appear to reach a plateau and descend. Now, the fact that JBC "citation impact" (in 1983 for example) was found to be about twice as much (6.11) than those found for seven other leading "general" biochemical journals [21], coupled with our finding regarding its higher proportion of multi-authored papers, might provide additional, although indirect, evidence to the relationship between multiple authorship and citation impact. One may wonder whether this finding does not reflect the "vicious cycle" phenomenon, in which top quality papers submitted to, and published by, a certain journal result in a higher "citation impact", and this latter factor in turn, spurs the submission of more top quality papers to this highly cited journal. In fact, it seems to illustrate once more the "success-breeds-success" phenomenon already discussed in the literature [52,53].

4. The figures of the social sciences fields for which long-term data were available, indicate a growth of the rates there too, although at a slower place compared to the sciences, especially in recent years.

5. As is well known, Hagstrom [54], Storer [55], and Price [48] proposed several distinctions between "hard" and "soft" sciences. Price, in fact, rejected the idea of using the proportion of multi-authored papers in a field as a measure of its "hardness". In his opinion, a soft subject highly subsidized would become as collaborative as high energy physics, and he conjectured (in 1970) that "it would be interesting to see what happens to urbanology". Meadows [10] however, proposed (in 1974) that multiple authorship seems to be one of the factors related to the "hardness" of a field.

   Generally speaking, Table 3 figures and order tend to support Meadows' proposition rather than Price's, notwithstanding some exceptions like computer science which rates fairly low in our table, but is high on Price's Index (percent of all references dated within the last 5 years) [48]. Our data also generally corroborates Storer's [55] classifying table, (measuring the proportion of papers using initials-only footnotes in various fields) with the exception of economics and botany which rate higher there. However, Price's [48] table of the proportion of Ph.D. graduates employed in college or university presents too many exceptions to our data. Engineering, psychology, botany and mathematics which are low in our table, are considered hard sciences according to Price's table while the biosciences which rate very high in our table are fairly low in Price's table, very close to the social sciences and the humanities.

   It is worth noting that Price's aforementioned conjecture regarding urbanology has *not* come through yet, as shown by its relatively low rates presented in our table. However, no firm conclusion can be reached until detailed data is collected regarding the amount of subsidy (i.e. research grants) this field has been getting during recent decades.

   In summation, to the extent that the JBC represents other fields of science, there is yet no indication that the multiple authorship trend is coming to an end. Evidently, a similar trend is observed in the social sciences. Yet, further long-term studies are needed in other fields of the sciences, the social sciences, and the humanities in order to establish the long-term trend for each.

The authors are grateful to Dr. Henry Knopf, senior librarian at Bar-Ilan University, for his kind assistance in styling this article.

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