The effect of scholar collaboration on impact and quality of academic papers

Massimo Franceschet*

Department of Mathematics and Computer Science, University of Udine
Via delle Scienze 206, 33100 Udine, Italy
Phone: +39 0432 558754 / Fax: +39 0432 558499

Antonio Costantini

Department of Agriculture and Environmental Sciences, University of Udine
Via delle Scienze 208, 33100 Udine, Italy

Abstract

We study how scholar collaboration varies across disciplines in science, social science, arts and humanities and the effects of author collaboration on impact and quality of co-authored papers. Impact is measured with the aid of citations collected by papers, while quality is determined by the judgements expressed by peer reviewers. To this end, we take advantage of the dataset provided by the first-ever national research assessment exercise of Italian universities, which involved 20 disciplinary areas, 102 research structures, 18500 research products, and 6661 peer reviewers. Collaboration intensity neatly varies across disciplines: it is inescapable is most sciences and negligible in most humanities. We measured a general positive association between the cardinality of the author set of a paper and the citational impact and peer quality of the contribution. The correlation is stronger when the affiliations of authors are heterogeneous. There exist, however, notable and interesting counter-examples.

Keywords: Scholar collaboration, Citational impact, Peer review

1. Introduction

Collaboration is a fundamental and common feature in scientific research. It assumes various forms, ranging from sharing of ideas among researchers to corporate partnerships and research joint ventures. Collaboration arises at different levels within the research system: *micro-level* (individuals, research groups), *meso-level* (departments, institutions), and *macro-level* (institutional sectors, in particular collaborative agreements between university and industry, or regions). Collaboration is encouraged by institutions, funding bodies and policymakers for a number of positive factors that are largely discussed in literature (Subramanyam, 1983; Luukkonen et al., 1992; Katz and Martin, 1997; Bordons and Gómez, 2000; Sonnenwald, 2007), and it is frequently organized by scientists themselves.

*Corresponding author
Email address: massimo.franceschet@dimi.uniud.it (Massimo Franceschet)
URL: http://users.dimi.uniud.it/~massimo.franceschet/ (Massimo Franceschet)

There are both scientific and extra-scientific advantages of collaboration. Researchers can derive scientific advantages by sharing knowledge, expertise and techniques, jointly controlling the accuracy and the significance of results, restricting isolation and giving substance to the cross-fertilization of ideas. For instance, theoretical investigation, experimental analysis, and compelling and elegant writing are all assignments that require different skills that are rarely enjoyed by the same scholar. Collaboration allows to cope better with the increasing specialization in science, with multidisciplinary approaches, and with the complexity of scientific instruments. Collaborative research has been associated with higher productivity: from an economic perspective, collaboration allows the division of labor leading to reduced costs and time saving, consent the access to scientific funding, to expensive (possibly large-scale) equipment, and to unique scientific data.

Furthermore, collaboration enhances visibility of results. By means of collaborative behaviour in co-authorship, the article is brought to the attention of a larger number of researchers through personal contacts, either formally (preprint posted on personal or institutional repositories, seminars, conferences) or by informal conversations. The visibility of the contribution is strengthened when co-authorship is carried out in more than one institution, and, in particular, international collaboration plays a more relevant role than domestic collaboration. This is in accordance with the view of co-authorship as a social relationship and with the social world described by Mark Granovetter is his famous paper *The Strength of Weak Ties* (Granovetter, 1973). Weak ties, that are links to a different community, play a more important role than links to our close friends, who inevitably move in the same circles and are exposed to the same information.

Collaboration, however, has not only advantages. A collaborative work needs deep integration among co-authors, since the final result should be a coherent and uniform piece of work. If integration among authors fails, the quality of the outcome definitely declines. Collaboration can entail time costs in jointly formulating the research problems, in deciding how to divide work or in keeping all the collaborators informed of the advances (Katz and Martin, 1997). Writing the results jointly may bring to disagreements among colleagues about findings and interpretation. As a consequence, time has to be spent in tuning up and gaining upon differences of opinion. Since collaboration is a social process it may imply a patient construction of personal relationships or adaptation in an unfamiliar environment, that again has a cost in terms of time. Collaboration may have operating costs if individuals have to move to different sites where parts of a research are developed or if equipments have to be transported. Furthermore, collaboration may be a restrain in career advancement for junior scientists, since their contribution to research products may be underestimated when their professional curriculum vitae is assessed, especially if they co-operate with well-known scientists (Merton, 1968; Sonnenwald, 2007).

Co-authorship in publications is widely considered as a reliable proxy for scientific collaboration. It has expanded in all academic fields in the last decades (Cronin et al., 2003; Persson et al., 2004; Moody, 2004; Larivière et al., 2006). Several bibliometric studies have explored the effect of co-authorship on the *impact* of individual articles, measured by the number of *citations* that papers have accrued. They point out a general positive correlation between the number of authors and the number of citations received by a paper: the more authors a paper has, the more citations it receives. This is, however, not true under all circumstances and for all scientific domains, since some studies have provided no support for a link between collaboration and citations. Citational impact is also partially related to the heterogeneity involved in collaboration: empirical evidences show that papers with *heterogeneous* collaborations are generally more cited than articles made in-house (in the same research institute).

In studying the effects of scientific collaboration, we feel that a primary issue is whether the increase of citational impact observed when the number of authors or institutions grows is ascribable to a real enhancement of paper quality or it is due to various advertising factors, like the obvious greater visibility and higher amount of self-citations of papers with many authors coming from different institutions. We assume that there are two separate dimensions underlying the impact of a co-authored article:

- A *qualitative factor*, that is the intrinsic value of the article in terms of originality, significance, depth, correctness, completeness, and clarity. It encapsulates the scientific acknowledgement by which an article deserves to be endorsed.

- An *advertising factor*, consistent with the view of co-authorship as a social relationship. As Goldfinch et al. (2003) noticed, "it may be that citation rates for an article are not simply a reflection of quality, but to some extent reflect the access to greater social networks the co-publication can allow".

The main purpose of the present investigation is to study how collaboration, at the micro-level of paper co-authorship, influences both the impact and the quality of academic contributions. More precisely, our investigation is shaped by the following research questions:

1. How scholar collaboration varies across disciplines in science, social science, arts and humanities?
2. What is the effect of scholar collaboration on citational impact and quality of papers?
3. Does heterogeneous collaboration enhance citational impact and quality of papers?

We took advantage of the comprehensive dataset of the first Italian research assessment exercise (VTR), which covered about 18,500 research products published from 2001 to 2003 in scientific-disciplinary areas covering science, social science, arts and humanities (Reale et al., 2007; Abramo et al., 2009; Franceschet and Costantini, 2010). VTR was a peer review exercise: each submitted product was judged by at least two referees who assigned it a quality rating. Furthermore, for scientific areas in which the standard publication is a journal article (mainly sciences and a limited part of social sciences) most of the submitted products are indexed in Thomson Reuters Web of Science (WoS) database. Thus, for all submitted products we have access to the qualitative judgement given by peer reviewers, which is a direct indicator of quality, and for a significant subset we have at disposal the number of citations they received from other papers in the WoS database, which can be regarded as an indicator of impact. This provides the possibility to analyse, on a large range of disciplines, both the relationship between co-authorship and paper citational impact and that between co-authorship and paper quality.

2. Dataset and methodology

The first Italian research assessment exercise, VTR, was managed by the Committee for the Evaluation of Research (CIVR) and was designed as an ex post assessment exercise based on *peer review*. CIVR divided the national research system into 20 scientific-disciplinary areas, 6 of which were interdisciplinary sectors, and set up an evaluation panel responsible for the assessment of each area. The exercise was then articulated in three phases, that were in charge of research structures, panels and CIVR, respectively.

In the initial phase, research institutions submitted to panels a set of autonomously selected research products. The only mandatory principle of selection stated that products of research should not exceed 50% of the full-time-equivalent researchers in the institution. The research structures submitted an overall sample of 18,500 products partitioned as follows: journal articles 72%, books 17%, book chapters 6%, patents 2% and the remaining typologies 3%. Research structures were also demanded to transmit to CIVR data and indicators about human resources, international mobility of researchers, funding for research projects, patents, spin-off and partnerships, allowing to reveal impact on employment.

In the second phase of the exercise panelists assigned research products to external referees. Each product was assessed by at least two referees who peer-reviewed it according to four aspects of merit: quality (the opinion of peer on the scientific excellence of the product compared to the international standard), importance, originality and internationalization. Referees also expressed a final score on the following four-point scale:

1. *excellent*: a product within the top 20% of the value in a scale shared by the international scientific community;
2. *good*: a product in the 60%-80% segment;
3. *acceptable*: a product in the 40%-60% segment;
4. *limited*: a product within the bottom 40%.

For every evaluated product panels drew up a consensus report where panelists re-examined the peer judgments and fixed the final score. Furthermore, CIVR weighted the peer review scores as follows: 1 (excellent), 0.8 (good), 0.6 (acceptable), and 0.2 (limited). The numeric formulation made it possible to sum product scores, in order to obtain a mean rating for single research structures providing a proxy for the value of the institution research performance and the possibility to compile corresponding rankings of structures. Panels provided a final report including ranking lists of the institutions in the surveyed area, highlighting strength and weakness points of the research area, and proposing possible actions of improvement.

In the final phase of the assessment exercise, CIVR produced a detailed analysis of requested data and indicators, integrating panel reports with collected data about human resources and project funding. The CIVR final report defines a first-ever comprehensive assessment of the national research system. In summer 2009, VTR outcomes have been used for the first time by Ministry of Education, University, and Research to allocate a 7% share of the Ordinary Fund for Higher Education.

Reale et al. (2007) showed that the peer review process of VTR complied with the assessment criteria proposed in literature for a reliable ex post evaluation. The authors found a general consensus between expert advice and showed that peer review was not biased toward prestige of institutions or reputation of scientists. Hence, we can reasonably assume that the rating assigned to products seizes their intrinsic quality.

Our analysis concerns with products belonging to the following 14 scientific disciplinary areas (we excluded the 6 interdisciplinary areas): mathematics and computer sciences (MCS), physics (PHY), chemistry (CHE), earth sciences (EAS), biology (BIO), medical sciences (MED), agricultural sciences and veterinary medicine (AVM), civil engineering and architecture (CEA), industrial and information engineering (IIE), philological-literary sciences, antiquities and arts (PAA), history, philosophy, psychology, and pedagogy (HPP), law (LAW), economics and statistics (ECS), and political and social sciences (PSS). The types of the document considered are articles, books and chapters of books. The dataset contains 15,301 products.

For each paper in the dataset we have at disposal the following variables: number of authors, degree of ownership (defined as the fraction of paper authors that are affiliated to the institute that submitted the product), and peer review judgement (in the scale described above). Furthermore, for each WoS article in the dataset, we tallied the number of citations that the article received up to June 2006. Since papers refer to period 2001-2003, this means that we used a citation window of minimum length of 2.5 years, maximum length of 5.5 years, and average length of 4 years. These periods are generally sufficient for a paper to collect the peak of citations in each of the surveyed disciplines.

3. Findings

3.1. How scholar collaboration varies across disciplines?

In this section we study how collaboration, at the author level, varies across disciplines. We adopt two attributes generally used in collaboration studies (Levitt and Thelwall, 2009). The first attribute, the *collaborative rate* (CR), is the proportion of papers with more than one author. The second, called *collaborative level* (CL), is the average number of authors per paper (CL). Since CL may be biased because of distortions caused by highly collaborative articles, we introduce two further indicators: the *median* number of authors per paper (medCL) and the *maximum* number of authors of a single paper (maxCL). The median CL provides an estimate of the cooperativity which is more robust and less affected by outliers than the mean CL, in particular for disciplines, like physics, where the distribution of papers by number of authors is very skewed.

Table 1 displays the values for the collaboration indicators CR, CL, medCL, and maxCL aggregated at the discipline level. It includes also the size of the area in terms of the number of submitted products. The collaboration rate reveals tangible discrepancies in collaboration intensity across disciplines. In all social sciences and humanities fields, with the exception of ECS, we obtained values for CR lower than 0.25, meaning that more than 75% of the submitted papers are written by a single author. Conversely, in all science fields, with the exception of MCS and CEA, the collaboration rate exceeds 0.9, witnessing a more important role of collaboration. In particular, in MED and BIO almost the whole sample contains co-authored papers. The figure for MCS is dominated by the lower collaboration rate of mathematicians (0.76) with respect to computer scientists (0.86). Values for ECS and CEA are relatively low (around 0.6), and this is due to the differences in research habits among the sub-fields included in these areas. CEA encompasses civil engineering and architecture: in the former CR

area	size	CR	CL	medCL	maxCL
MCS	721	0.78	2.24	2	7
PHY	1567	0.97	56.65	5	1412
CHE	1009	0.96	5.19	5	15
EAS	585	0.94	4.07	4	32
BIO	1514	0.98	6.66	6	99
MED	2537	0.99	8.66	8	119
AVM	750	0.96	4.81	4.5	20
CEA	703	0.64	2.33	2	21
IIE	989	0.91	3.48	3	21
PLA	1346	0.15	1.50	1	42
HPP	1177	0.25	1.65	1	13
LAW	1061	0.08	1.32	1	49
ECS	970	0.56	1.86	2	14
PSS	372	0.17	1.31	1	13

Table 1: Differences of scholar collaboration across disciplines.

is 0.82, in the latter is 0.18, a value that collocates architecture closer to the branch of humanities rather than to hard sciences. ECS is mainly composed of heterogeneous sub-fields as economics, management, and statistics, in which single authored products are, respectively, 45.7%, 62.8% and 23.4%.

CL and medCL indicators confirm the clear-cut difference in collaboration propensity between science, at one side, and social science and humanities, at the opposite side. Disciplines PHY, CHE, EAS, BIO, MED, and AVM all have mean and median collaboration levels above 4. At the opposite side, we find social sciences and humanities, with a mean collaboration level lower than 2 and, with the mild exception of ECS, with at least 50% of the papers written by a single author. In the middle, we have mathematics, computing and engineering.

The distribution of the maximum number of authors per paper among disciplines is also instructive. We notice the disproportionately high maximum collaboration level of physics (1412 authors in a single paper), which neatly contrasts with the figure for a relatively close discipline, mathematics and computer sciences, whose most collaborative paper has only 7 authors. The values of maxCL are particularly high also for BIO and MED. Among humanities, PLA and LAW have a relatively high maxCL, indicating that, although most papers in these disciplines are written by a single author, there are also unusual highly collaborative contributions.

The collaboration level for physics deserves a word of caution. The mean number of co-authors in physics, 55.65, is clearly inflated by highly collaborative articles: 13% of the papers in physics have more than 100 authors, and there are papers with more than 1000 authors. These figures reflect the collectivistic practice that Cronin (2001) calls *hyperauthorship*: the inclusion in the author list of all people involved with a research endeavor. This is typical of some subsectors of physics (e.g., high energy physics), in which the scale and the complexity of research projects imply a professional organization in large teams. A closer look to the authorship distribution in physics reveals that it is highly right skewed: there are many papers with few authors and few ones with a very large number of authors. The median number of authors per paper is 5, meaning that at least 50% of the papers have at most 5 authors, a figure comparable with other sciences. The median indicator corrects for the bias introduced in the mean and hence better reflects the relative collaboration strength of the discipline.

3.2. What is the effect of scholar collaboration on citational impact and quality of papers?

Tables 2 and 3 in the paper appendix show the average impact (number of received citations) and quality (judgement received by peer reviewers) for homogeneous classes of paper authors. Products are grouped into mutually exclusive classes of comparable sizes according to the frequency distribution found for the number of authors. In social science and humanities areas, with the exception of ECS, products are grouped into two classes, single-authored and multi-authored, because the great majority of products belong to the former.

Let us first consider the relationship between number of co-authors and citations. The analysis involves 10 fields with an adequate WoS coverage: we excluded from the original sample social sciences and humanities, with the exception of ECS. As a first investigation, we performed an analysis of variance (ANOVA), with classes of co-authors as factors, to assess whether the citation averages for the different author classes significantly differ from each other. Citations were log-transformed to meet the assumptions of normality and homoscedasticity required by ANOVA. The F-test allowed to reject the hypothesis, with a p-value less than 0.05, that all means are equal for the following 7 fields: MCS, PHY, BIO, MED, AVM, IIE, and ECS. Hence, in most areas, co-authorship has a tangible effect on citational impact.

To appreciate the sign and magnitude of such effect, we performed further investigations. The average number of citations increases monotonically with the number of authors in 6 out of 10 areas: MCS, EAS, AVM, CEA, IIE, and ECS, while MED is very close to this pattern (see Figure 1 for the case of medical sciences). The citation mean is higher for the class with the largest number of authors in all areas with the exception of PHY and CHE. We furthermore computed the Spearman rank-order coefficient between the variables number of authors and number of citations for each discipline paper sample. The magnitude of the coefficient is modest and significantly positive at the 1% level for areas MCS, EAS, BIO, MED, AVM, IIE, and ECS, while for CEA it is significant at the 5% level.

All in all, the general tendency supports the hypothesis that author collaboration produces higher citational impact of papers. However, notable counterexamples exist. The most striking one is physics, where papers with few authors collect the largest number of citations and, moreover, hyperauthored papers harvest much less endorsements with respect to papers with a customary number of authors. In chemistry, papers with at most 3 authors are the most cited. However, papers with at least 8 authors are also highly endorsed. In biology, papers with few authors have more impact than papers with an average number of collaborators; nonetheless, articles co-authored by at least 9 authors attract a considerably higher share of impact.

We now focus on the relationship between collaboration and peer judgments for all the 14 disciplines we surveyed in this paper. Since qualitative ratings assigned by reviewers can be interpreted as an ordinal variable taking four values (limited, acceptable, good, and excellent), we displayed the frequency distribution of products by classes of co-authors and peer rating in cross classification tables (Tables 4 and 5 in the paper appendix). Furthermore, in order to determine whether there is a statistical association between the involved variables,

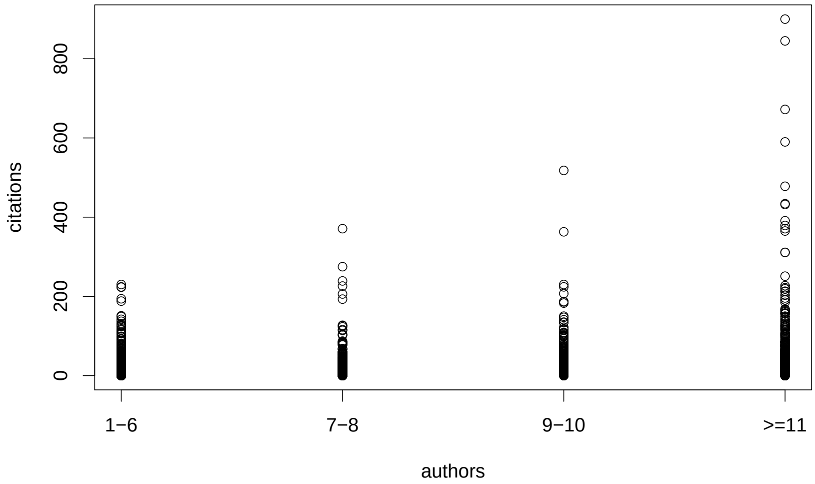

Figure 1: A scatterplot showing classes of authors against citations received by papers in medical sciences. Each point in the plot represents the number of citations collected by a paper in the corresponding author class.

for each scientific field we computed the Pearson χ^2 statistic, which tests the hypothesis that number of authors and peer rating are independent variables. As a result, in 6 areas out of 14, namely EAS, BIO, MED, AVM, HPP, and ECS, we can reject the independence hypotheses at a 1% significance level. For instance, consider the case of papers in medical sciences (depicted in Figures 2 and 3). A share of 25.5% of the products have been valued as excellent works by peer reviewers. If we restrict the analysis to products in the lowest author class only, which are co-authored by at most 6 scholars, the percentage of excellent products drops to 20.4%. On the other hand, if we consider articles in the highest author class only, which are co-authored by at least 11 scholars, the share of excellent products rises to 35.2%. To identify the strength of the association in the mentioned areas, we computed Spearman rank-order coefficient. Coefficients are modest in magnitude and ranges from 0.10 (HPP) to 0.26 (ECS) but they are all significant at the 1% level.

Furthermore, in 8 out of 14 areas, namely, EAS, BIO, MED, AVM, PAA, HPP, ECS, and PSS, the average peer rating increases monotonically with the number of authors, and in 11 areas the highest average rating is achieved by the class of products with the larger number of authors (the exceptions are MCS, CEA and LAW; see Tables 2 and 3 in the paper appendix). In the remaining areas, namely MCS, CHE, CEA, IIE, LAW, and partially also in PHY, co-authorship and peer rating appear to be independent factors. For instance, in mathematics and computer science, single-authored papers and papers with at least 3 authors have both judgments below the average, while the best papers, according to peers, are those with 2 authors. It seems that, in this area, collaboration is effective when it is moderate in numbers.

Finally, in only 3 areas (EAS, AVM and ECS) both citational impact and quality of papers grow monotonically with number of papers, and MED follows

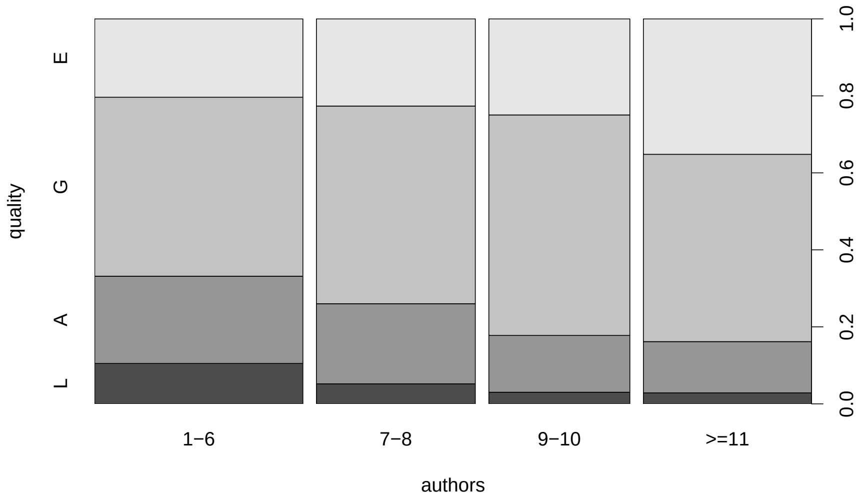

Figure 2: A spineplot showing classes of authors against peer judgements received by papers in medical sciences. The widths of the bars correspond to the relative frequencies of author classes, and the heights of the bars correspond to the conditional relative frequencies of judgements in every author class. Notice how the share of limited (and also limited and acceptable) products decrease as the number of authors raise, and, on the contrary, the proportion of excellent products increase as the number of authors grow.

very closely this pattern. In MCS, CEA, and IIE impact grows with number of authors, but this increase is not matched by a similar rise in the quality of papers as perceived by peers, suggesting that the higher impact is due to the broader visibility of a multi-authored contribution. On the other hand, in BIO, the quality increases with collaboration, but impact does not strictly follow this pattern. In both PHY and CHE, impact and quality are not significantly related to the number of authors. Interestingly enough, in both these disciplines, the highest impact is achieved by papers with few authors, but the best quality papers are those with the largest number of authors. This reveals a substantial disagreement, for these disciplines, between the pool of reviewing experts and the whole community of discipline scholars that expressed their judgements by consenting or declining the endorsement of papers through the academic citation practice.

3.3. Does heterogeneous collaboration enhance citational impact and quality of papers?

In this section we investigate the relationships, if any, between collaboration with heterogeneous research structures and citational impact, on the one hand, and with quality assessed by peers, on the other hand. To this end, we take advantage of the *degree of ownership* of a paper, defined as the fraction of paper authors that are affiliated to the institute that submitted the product. The analysis takes into account only multi-authored products (single-author papers do not involve any collaboration) and excludes social sciences and humanities areas (with the exception of ECS), in which multi-institutional research is a

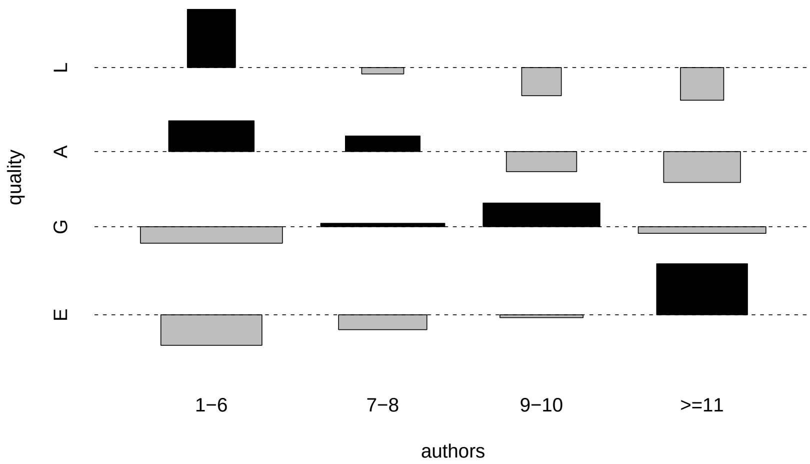

Figure 3: A Cohen-Friendly association plot indicating deviations from independence for variables collaboration and quality of papers in medical sciences. The area of each box is proportional to the difference in observed and expected frequencies in case of independence. The rectangles in each row are positioned relative to a baseline indicating independence. If the observed frequency of a cell is greater than the expected one, the box rises above the baseline and is shaded in black; otherwise, the box falls below the baseline and is shaded in grey.

marginal phenomenon within the inspected set of papers. The degree of ownership of a paper takes a value close to 0 when heterogeneous collaboration, in terms of research institutions, is involved in the production of the work. On the other hand, the degree is close to 1 when the great majority of the scholars that co-authored the paper work in the same institution.

As shown in Tables 6 and 7 in the appendix of the paper, the citational impact monotonically decreases as the degree of ownership increases in all disciplines but PHY, in which there are some oscillations in the middle of the range. This means that, in general, in-house made papers are less endorsed than papers with heterogeneous collaboration. This phenomenon is particularly noticeable in MED, BIO and PHY: in MED the average impact of heterogeneous papers is 2.3 times higher the average impact of in-house made papers, while in BIO and PHY this ratio is almost 2. Spearman rank-order correlation coefficients are negative for all disciplines, with significant scores for all areas except MCS, CEA, and ECS.

Tables 6 and 7 also show that the quality of papers monotonically decreases as the degree of ownership increases in all disciplines, with the exceptions of MCS and BIO, where, however, deviations from the general rule are not striking. Hence, the best papers, as judged by peers, are the ones that are made with the aid of heterogeneous collaboration. The most noticeable discipline in this respect is economics and statistics, where the quality of in-house papers is acceptable, while papers with heterogeneous collaboration are assessed as good by peers. Spearman rank-order correlation coefficients are significantly negative

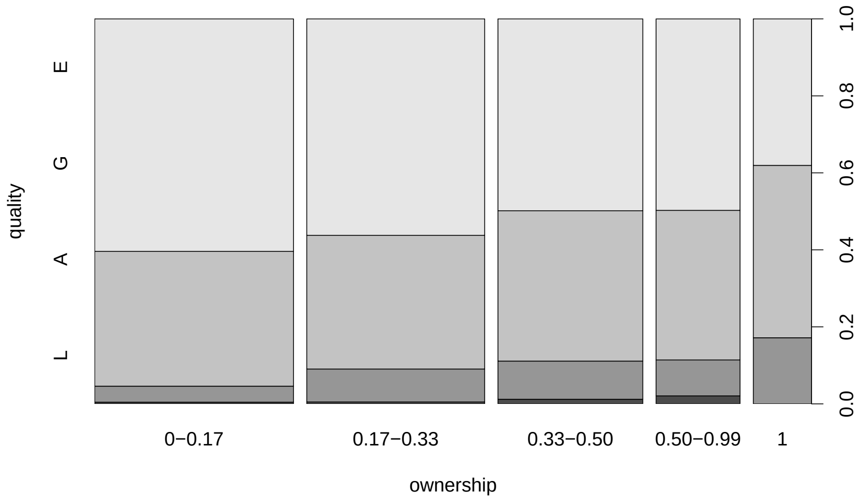

Figure 4: A spineplot showing classes of ownership against peer judgements received by papers in physics. Notice how the share of poor quality (limited or acceptable) products increase as the degree of ownership raises, and, on the contrary, the proportion of excellent products decrease as the degree of ownership grows.

for all disciplines. We can reach similar conclusions by analysing the cross tabulation including in rows the intervals of the degree of ownership and the peer judgements as columns (Tables 8 and 9 in the paper appendix): in most cases, the proportion of products rated excellent drops, sometimes with a pronounced decline, when the degree of ownership increases, and in all cases excellent papers made in-house are significantly less frequent than excellent papers in the lowest ownership class. Moreover, limited and acceptable papers are generally more frequent when the degree of ownership is 1. For instance, consider the case of papers in physics (depicted in Figures 4 and 5). A fraction of 60.4% of the papers with degree of ownership close to 0 are excellent, while only 38.1% of those with degree of ownership equal to 1 have received the same judgement (the overall share of excellent papers for the discipline is 53.6%). Moreover, 8.4% of papers are acceptable; this percentage rises to 17.2% if only in-house papers are considered, and decreases to 4.2% if we restrict the analysis to papers with a very low degree of ownership (the number of limited products in physics is very low and hence not significant).

4. Related work

Moody (2004) observes that the propensity of scholars to collaborate widely differs among disciplines, and it is more common in natural sciences than in social sciences. A clear dichotomy between sciences and humanities pertaining to papers collaborative rates has been detected by Larivière et al. (2006). They computed the collaborative rate for different scientific fields, using the whole set of Canadian papers that were published during period 1980-2002. They noticed that almost all articles in natural sciences were joint publications, whereas the

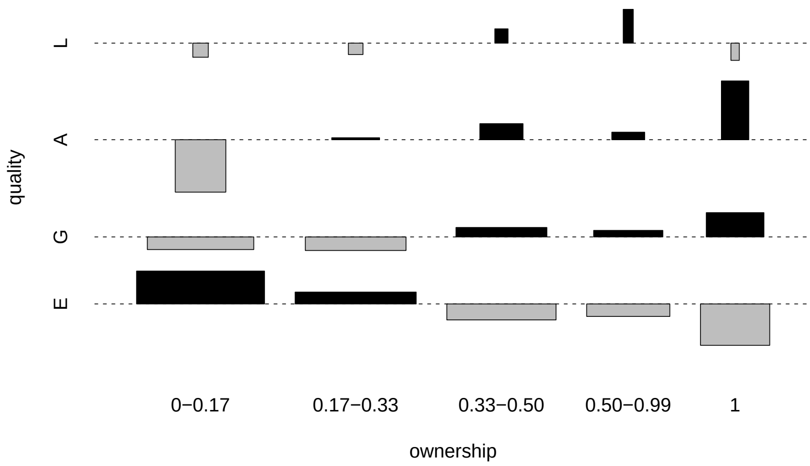

Figure 5: A Cohen-Friendly association plot indicating deviations from independence for variables degree of ownership and quality of papers in physics.

collaboration rate in the humanities was not far from 10%. Glänzel (2002) found a collaborative rate greater than 0.9 for chemistry and biomedical research, and about 0.6 in mathematics. As to social sciences, Cronin et al. (2003) observed that co-authorship has recently become the norm in psychology, while philosophers are more inclined to work alone even though collaboration in this field is increasing. These outcomes generally match our findings.

Most studies exploring the connection between research collaboration (taking co-authorship as a unit of measurement) and citational impact have pointed out a positive correlation between the two variables. Here we provide a necessarily brief account. Asknes (2003) concentrated on the population of Norwegian articles during 1981-1996, and found that, at an aggregated level, the average citation rate grows together with the number of authors. At the opposite side of the planet, Goldfinch et al. (2003) found that in nine New Zealand Crown Research Institutes, despite variations across institutes, increasing number of authors lead to higher citation counts. They explained this finding with the greater visibility of collaborative papers, especially when they are the result of international research. In the analysis of Persson et al. (2004) based on all papers indexed in Web of Science from 1980 to 2000, the number of authors and the mean citation score grow together according to a linear trend. Additionally, a positive association between co-authorship and article impact was detected for chemistry, biomedical science, and mathematics by Glänzel (2002), for library and information science by Levitt and Thelwall (2009), and for cancer research by Lawani (1986).

On the other hand, not all studies agree on the positive effect of collaboration on the citational impact of papers. Leimu and Koricheva (2005) identified only minor benefits of collaboration on citation rates for ecology articles, and the positive correlation between co-authorship and impact was attributed to the selfcitation practice, a conclusion reached by Herbertz (1995) as well in molecular biology. By inspecting the literature of academic librarianship, although limited to only two journals, Hart (2007) found no evidence that co-authorship leads to higher rates of citation, and Medoff (2003) reached the same conclusions using a dataset of articles published in 1990 in 8 top economic journals.

Bibliometric surveys that recur to judgments assigned by peers to papers in order to analyse links between research collaboration and publication quality are not so common in literature. As to the few studies that we found, however, the results are oriented toward a positive effect of collaboration on quality. Lawani (1986) considered peer judgments of the editorial board of oncology journals and observed that the proportion of high quality papers increases with the number of authors. Presser (1980) cross-classified by number of authors the editorial review decisions about manuscripts submitted to a leading psychological journal and found slight evidence that multi-authored submissions are judged more favourably than single-authored ones. Interestingly, he suggested that "*collaboration leads less to producing very good papers and more to avoiding bad ones*".

The literature offers a number of contributions also about the influence of multi-institutional co-authorship, mainly international, on citational impact. Katz and Hicks (1997) analysed the UK R&D publications in the time window 1981-1994 and demonstrated that papers with no institutional collaboration have the lowest impact in all the considered scientific fields (life sciences, natural sciences, engineering & materials, and multidisciplinary). Goldfinch et al. (2003) noticed that multi-institutional international collaboration leads to higher citation rates and gave a hint to scholars working in peripheral institutions to strive in linking their research to international colleagues. Finally, Iribarren-Maestro et al. (2009), who dedicated their speculation to a series of departments of distinct scientific sectors affiliated to the Madrid Carlos III University, signal that multi-institutional authorship raises the number of citations of papers and, furthermore, international papers are cited in journals with high Impact Factor.

5. Conclusion

With the aid of a large-scale dataset taken from the first national research assessment exercise in Italy, we have investigated the effect of scholar collaboration in different disciplines of science, social science, arts and humanities. Our main conclusions can be summarized as follows.

The intensity of research collaboration is negligible in arts and humanities: the set of paper co-authors is frequently a singleton. Social science researchers often work in team, sharing competencies and other resources, but collaborations are smaller in scale and formality compared to science disciplines. By contrast, collaborative work is heavily exploited in science, in particular in physics and medicine. Collaboration is, however, moderate in mathematics, computer science, and engineering. Collaboration has clear advantages, like division of tasks and share of competencies and abilities, but also possible inconveniences, like lack of understanding and integration among collaborators. Since research is a complex self-organized system with the objective of maximizing the production of knowledge, these differences in collaboration intensity can be interpreted as the result of a *rational balance* between advantages and disadvantages of collaboration in each discipline. Thus, our investigation is useful to identify the fields where the advantages of collaboration dominate its drawbacks and disciplines where collaborating is not worth the pain to compromise with colleagues. Interestingly, some fields, like computer science, stay in an intermediate situation, where a little collaboration, but not more than that, seems fruitful.

In most cases, collaboration pays in terms of impact, measured with the popular bibliometric practice that tallies the number of citations that a work receives from other papers. Moreover, collaborative works are generally valued higher by peer experts. Both impact and quality are further enhanced when the affiliations of authors are heterogeneous. These might be valuable guidelines for researchers that aim to maximize the impact of their research contributions. Interesting counterexamples hold, however. The most striking one concerns with the practice of hyperauthoring which is common in physics: when citations are counted, papers with an extraordinary number of co-authors, the hubs of the author distribution, are rewarded significantly less than papers with a few authors. Furthermore, in all disciplines, papers with a single author are generally positively judged by peer experts and receive a good share of endorsements from other researchers.

References

Abramo, G., D'Angelo, C. A., Caprasecca, A., 2009. Allocative efficiency in public research funding: can bibliometrics help? Research policy 38 (1), 206–215.

Asknes, D. W., 2003. Characteristics of highly cited papers. Research evaluation 12 (3), 159–170.

Bordons, M., Gómez, I., 2000. Collaboration networks in science. In: Cronin, B., Atkins, H. B. (Eds.), The web of knowledge: a festschrift in honor of Eugene Garfield. American Society for Information Science Monograph Series, pp. 197–213.

Cronin, B., 2001. Hyperauthorship: a postmodern perversion or evidence of a structural shift in scholarly communication practices. Journal of the American Society for Information Science and Technology 52 (7), 558–569.

Cronin, B., Shaw, D., Barre, K. L., 2003. A cast of thousands: coauthorship and subauthorship collaboration in the 20th century as manifested in the scholarly journal literature of psychology and philosophy. Journal of the American Society for Information Science and Technology 54 (9), 855–871.

Franceschet, M., Costantini, A., 2010. The first Italian research assessment exercise: a bibliometric perspective. Retrieved May 1, 2010, from `http://arxiv.org/abs/0912.2601`.

Glänzel, W., 2002. Coauthorship patterns and trends in the sciences (1980-1998): a bibliometric study with implications for database indexing and search strategies. Library trends 50 (3), 461–473.

Goldfinch, S., Dale, T., Rouen, K. D., 2003. Science from the periphery: publication, collaboration and 'periphery effects' in article citation rates of the New Zealand Crown Research Institutes 1995-2000. Scientometrics 57 (3), 321–337.

Granovetter, M. S., 1973. The strength of weak ties. American Journal of Sociology 78, 1360–1380.

Hart, R. L., 2007. Collaboration and article quality in the literature of academic librarianship. The journal of academic librarianship 33 (2), 190–195.

Herbertz, H., 1995. Does it pay to cooperate? A bibliometric case study in molecular biology. Scientometrics 33 (1), 117–122.

Iribarren-Maestro, I., Lascurain-Sànchez, M. L., Sanz-Casado, E., 2009. Are multi-authorship and visibility related? Study of ten research areas at Carlos III University of Madrid. Scientometrics 79 (1), 191–200.

Katz, J. S., Hicks, D., 1997. How much is a collaboration worth? A calibrated bibliometric model. Scientometrics 40 (3), 541–554.

Katz, J. S., Martin, B. R., 1997. What is research collaboration? Research policy 26 (11), 1–18.

Larivière, V., Gingras, Y., Archambault, E., 2006. Canadian collaboration networks: a comparative analysis of the natural sciences, social sciences and the humanities. Scientometrics 68 (3), 519–533.

Lawani, S. M., 1986. Some bibliometric correlates of quality in scientific research. Scientometrics 9 (1-2), 13–25.

Leimu, R., Koricheva, J., 2005. Does scientific collaboration increase the impact of ecological articles? BioScience 55 (5), 436–443.

Levitt, J. M., Thelwall, M., 2009. Citation levels and collaboration within library and information science. Journal of the American Society for Information Science and Technology 60 (3), 434–442.

Luukkonen, T., Persson, O., Sivertsen, G., 1992. Understanding patterns of international scientific collaboration. Science, technology and human values 17 (1), 101–126.

Medoff, M., 2003. Collaboration and the quality of economics research. Labour Economics 10 (5), 597–608.

Merton, R. K., 1968. The Matthew Effect in science. Science 159 (3810), 56–63.

Moody, J., 2004. The structure of a social science collaboration network: disciplinary cohesion from 1963 to 1999. American Sociological Review 69 (2), 213–238.

Persson, O., Glänzel, W., Danell, R., 2004. Inflationary bibliometric values: the role of scientific collaboration and the need for relative indicators in evaluative studies. Scientometrics 60 (3), 421–432.

Presser, S., 1980. Collaboration and the quality of research. Social Studies of Science 10 (1), 95–101.

Reale, E., Barbara, A., Costantini, A., 2007. Peer review for the evaluation of academic research: lessons from the Italian experience. Research evaluation 16 (3), 216–228.

Sonnenwald, D. H., 2007. Scientific collaboration. Annual Review of Information Science and Technology 41 (1), 643–681.

Subramanyam, K., 1983. Bibliometric studies of research collaboration: a review. Journal of information science 6 (1), 33–38.

Mathematics and computer sciences

authors	articles	quality	impact
1	158	0.82	2.99
2	312	0.84	3.87
≥ 3	251	0.82	4.79
All	721	0.83	4.00

Physics

authors	articles	quality	impact
1–3	440	0.88	25.55
4–5	359	0.87	24.78
6–16	387	0.88	24.33
17–100	151	0.90	25.25
≥ 101	230	0.91	22.94
All	1567	0.88	24.66

Chemistry

authors	articles	quality	impact
1–3	246	0.82	18.28
4–5	373	0.81	14.62
6–7	235	0.80	15.50
≥ 8	155	0.84	17.34
All	1009	0.81	16.14

Earth sciences

authors	articles	quality	impact
1–2	143	0.82	6.51
3–4	261	0.83	6.98
≥ 5	181	0.85	8.48
All	585	0.84	7.33

Biology

authors	articles	quality	impact
1–4	440	0.81	22.03
5–6	442	0.82	19.36
7–8	308	0.84	21.58
≥ 9	324	0.86	37.98
All	1514	0.83	24.58

Medical sciences

authors	articles	quality	impact
1–6	781	0.73	19.99
7–8	596	0.77	19.88
9–10	529	0.80	25.01
≥ 11	631	0.83	42.77
All	2537	0.78	26.68

Table 2: Effect of collaboration on quality and impact of papers (part I).

Agricultural sciences and veterinary medicine

authors	articles	quality	impact
1–3	230	0.66	7.34
4–5	270	0.72	7.96
≥ 6	250	0.75	9.20
All	750	0.71	8.26

Civil engineering and architecture

authors	articles	quality	impact
1	254	0.76	2.65
2	211	0.77	3.72
≥ 3	238	0.73	3.77
All	703	0.75	3.60

Industrial and information engineering

authors	articles	quality	impact
1–2	288	0.78	3.38
3	295	0.78	4.41
4	211	0.76	5.73
≥ 5	195	0.79	6.40
All	989	0.78	4.78

Philological-literary sciences, antiquities and arts

authors	articles	quality	impact
1	1139	0.88	–
>1	207	0.91	–
All	1346	0.88	–

History, philosophy, psychology, and pedagogy

authors	articles	quality	impact
1	885	0.78	–
>1	292	0.81	–
All	1177	0.79	–

Law

authors	articles	quality	impact
1	978	0.74	–
>1	83	0.74	–
All	1061	0.74	–

Economics and statistics

authors	articles	quality	impact
1	424	0.60	1.51
2	344	0.73	2.95
≥ 3	202	0.74	5.45
All	970	0.67	3.17

Political and social sciences

authors	articles	quality	impact
1	310	0.70	–
>1	62	0.77	–
All	372	0.71	–

Table 3: Effect of collaboration on quality and impact of papers (part II).

Mathematics and computer sciences

authors	Limited	Acceptable	Good	Excellent	Total
1	2.5%	13.3%	51.3%	32.9%	100%
2	2.9%	11.2%	45.2%	40.7%	100%
≥ 3	1.6%	15.5%	52.2%	30.7%	100%
All	2.4%	13.1%	49.0%	35.5%	100%

Physics

authors	Limited	Acceptable	Good	Excellent	Total
1-3	0.9%	8.2%	38.4%	52.5%	100%
4-5	1.4%	10.6%	38.4%	49.6%	100%
6-16	0.5%	10.6%	38.0%	50.9%	100%
17-100	0.0%	6.0%	37.7%	56.3%	100%
≥ 101	0.9%	3.0%	33.9%	62.2%	100%
All	0.8%	8.4%	37.6%	53.2%	100%

Chemistry

authors	Limited	Acceptable	Good	Excellent	Total
1-3	1.6%	15.9%	52.0%	30.5%	100%
4-5	2.9%	17.4%	48.3%	31.4%	100%
6-7	4.7%	17.9%	47.6%	29.8%	100%
≥ 8	1.3%	16.8%	42.5%	39.4%	100%
All	2.8%	17.0%	48.2%	32.0%	100%

Earth sciences

authors	Limited	Acceptable	Good	Excellent	Total
1-2	0.0%	16.8%	56.6%	26.6%	100%
3-4	0.8%	13.4%	54.8%	31.0%	100%
≥ 5	3.3%	7.7%	44.2%	44.8%	100%
All	1.3%	12.5%	52.0%	34.2%	100%

Biology

authors	Limited	Acceptable	Good	Excellent	Total
1-4	2.7%	13.4%	57.3%	26.6%	100%
5-6	1.6%	17.0%	50.4%	31.0%	100%
7-8	1.0%	11.0%	51.6%	36.4%	100%
≥ 9	0.3%	10.2%	46.6%	42.9%	100%
All	1.5%	13.3%	51.8%	33.4%	100%

Medical sciences

authors	Limited	Acceptable	Good	Excellent	Total
1-6	10.5%	22.7%	46.5%	20.3%	100%
7-8	5.2%	20.8%	51.3%	22.7%	100%
9-10	3.0%	14.7%	57.3%	25.0%	100%
≥ 11	2.9%	13.3%	48.6%	35.2%	100%
All	5.8%	18.2%	50.5%	25.5%	100%

Table 4: Effect of collaboration on peer judgements of papers (part I).

Agricultural sciences and veterinary medicine

authors	Limited	Acceptable	Good	Excellent	Total
1-3	12.6%	39.1%	40.5%	7.8%	100%
4-5	8.5%	25.6%	56.6%	9.3%	100%
≥ 6	4.4%	23.6%	58.8%	13.2%	100%
All	8.4%	29.1%	52.4%	10.1%	100%

Civil engineering and architecture

authors	Limited	Acceptable	Good	Excellent	Total
1	6.3%	26.0%	42.9%	24.8%	100%
2	4.3%	26.0%	44.1%	25.6%	100%
≥ 3	7.6%	30.2%	44.1%	18.1%	100%
All	6.1%	27.5%	43.6%	22.8%	100%

Industrial and information engineering

authors	Limited	Acceptable	Good	Excellent	Total
1-2	1.4%	27.4%	48.6%	22.6%	100%
3	2.4%	21.7%	55.6%	20.3%	100%
4	3.8%	27.0%	48.8%	20.4%	100%
≥ 5	2.1%	21.0%	56.4%	20.5%	100%
All	2.3%	24.4%	52.3%	21.0%	100%

Philological-literary sciences, antiquities and arts

authors	Limited	Acceptable	Good	Excellent	Total
1	1.5%	7.2%	41.7%	49.6%	100%
≥ 2	0.0%	3.9%	39.1%	57.0%	100%
All	1.3%	6.7%	41.3%	50.7%	100%

History, philosophy, psychology, and pedagogy

authors	Limited	Acceptable	Good	Excellent	Total
1	4.5%	21.9%	48.0%	25.6%	100%
≥ 2	4.1%	16.4%	43.5%	36.0%	100%
All	4.4%	20.6%	46.8%	28.2%	100%

Law

authors	Limited	Acceptable	Good	Excellent	Total
1	8.4%	22.8%	48.4%	20.4%	100%
≥ 2	8.4%	20.5%	54.2%	16.9%	100%
All	8.4%	22.6%	48.8%	20.2%	100%

Economics and statistics

authors	Limited	Acceptable	Good	Excellent	Total
1	26.2%	33.2%	30.7%	9.9%	100%
2	11.9%	23.0%	42.7%	22.4%	100%
≥ 3	10.4%	22.3%	43.5%	23.8%	100%
All	17.9%	27.3%	37.6%	17.2%	100%

Political and social sciences

authors	Limited	Acceptable	Good	Excellent	Total
1	11.9%	31.0%	38.7%	18.4%	100%
≥ 2	4.9%	30.6%	35.5%	29.0%	100%
All	10.8%	30.9%	38.1%	20.2%	100%

Table 5: Effect of collaboration on peer judgements of papers (part II).

Mathematics and computer sciences

ownership	articles	quality	impact
0.13 – 0.40	121	0.84	5.22
0.40 – 0.99	292	0.85	4.14
1	147	0.80	3.78
All	560	0.83	4.28

Physics

ownership	articles	quality	impact
0.002 – 0.17	457	0.91	29.25
0.17 – 0.33	409	0.89	27.22
0.33 – 0.50	333	0.87	19.76
0.50 – 0.99	193	0.87	24.91
1	134	0.84	15.18
All	1526	0.89	24.85

Chemistry

ownership	articles	quality	impact
0.06 – 0.43	255	0.84	16.73
0.43 – 0.99	390	0.81	16.12
1	324	0.80	15.69
All	969	0.82	16.14

Earth sciences

ownership	articles	quality	impact
0.03 – 0.36	147	0.87	8.66
0.36 – 0.99	159	0.84	7.51
1	144	0.81	5.81
All	550	0.84	7.37

Biology

ownership	articles	quality	impact
0.01 – 0.42	380	0.84	32.28
0.42 – 0.67	413	0.85	25.94
0.67 – 0.99	290	0.83	24.49
1	397	0.80	16.28
All	1480	0.83	24.69

Table 6: Effect of heterogeneous collaboration on quality and impact of papers (part I).

Medical sciences

ownership	articles	quality	impact
0.01 – 0.29	653	0.82	43.16
0.29 – 0.60	661	0.79	24.59
0.60 – 0.99	627	0.77	19.69
1	568	0.73	18.61
All	2509	0.78	26.85

Agricultural sciences and veterinary medicine

ownership	articles	quality	impact
0.05 – 0.40	200	0.75	10.15
0.40 – 0.99	276	0.72	8.49
1	247	0.68	6.41
All	723	0.71	8.34

Civil engineering and architecture

ownership	articles	quality	impact
< 1	241	0.77	4.07
1	208	0.72	3.34
All	449	0.75	3.74

Industrial and information engineering

ownership	articles	quality	impact
0.11 – 0.50	280	0.81	5.73
0.50 – 0.99	212	0.77	5.42
1	408	0.77	4.13
All	900	0.78	4.93

Economics and statistics

ownership	articles	quality	impact
< 1	431	0.76	4.10
1	115	0.62	2.54
All	546	0.73	3.78

Table 7: Effect of heterogeneous collaboration on quality and impact of papers (part II).

Mathematics and computer sciences

ownership	Limited	Acceptable	Good	Excellent	Total
0.13–0.40	1.6%	11.5%	48.4%	38.5%	100%
0.40–0.99	2.0%	11.6%	45.9%	40.5%	100%
1	3.4%	17.7%	53.0%	25.9%	100%
All	2.3%	13.2%	48.3%	36.2%	100%

Physics

ownership	Limited	Acceptable	Good	Excellent	Total
0.002–0.17	0.4%	4.2%	35.0%	60.4%	100%
0.17–0.33	0.5%	8.5%	34.9%	56.1%	100%
0.33–0.50	1.2%	9.9%	39.1%	49.8%	100%
0.50–0.99	2.1%	9.3%	38.9%	49.7%	100%
1	0.0%	17.2%	44.8%	38.0%	100%
All	0.8%	8.4%	37.2%	53.6%	100%

Chemistry

ownership	Limited	Acceptable	Good	Excellent	Total
0.06–0.43	1.2%	14.1%	47.8%	36.9%	100%
0.43–0.99	3.6%	17.4%	46.0%	33.0%	100%
1	2.5%	18.4%	50.8%	28.3%	100%
All	2.6%	16.9%	48.1%	32.4%	100%

Earth sciences

ownership	Limited	Acceptable	Good	Excellent	Total
0.03–0.36	1.4%	9.5%	41.5%	47.6%	100%
0.36–0.99	0.4%	13.5%	51.9%	34.2%	100%
1	3.5%	11.1%	59.0%	26.4%	100%
All	1.5%	11.7%	51.0%	35.8%	100%

Biology

ownership	Limited	Acceptable	Good	Excellent	Total
0.01–0.42	1.3%	12.6%	47.1%	39.0%	100%
0.42–0.67	0.5%	12.8%	48.0%	38.7%	100%
0.67–0.99	2.4%	11.4%	54.5%	31.7%	100%
1	2.0%	15.6%	58.3%	24.1%	100%
All	1.5%	13.2%	51.8%	33.5%	100%

Table 8: Effect of heterogeneous collaboration on peer judgements of papers (part I).

Medical sciences

ownership	Limited	Acceptable	Good	Excellent	Total
0.01–0.29	3.2%	12.3%	50.3%	34.2%	100%
0.29–0.60	5.0%	18.2%	48.7%	28.1%	100%
0.60–0.99	5.7%	20.4%	51.7%	22.2%	100%
1	9.5%	22.7%	50.9%	16.9%	100%
All	5.7%	18.2%	50.4%	25.7%	100%

Agricultural sciences and veterinary medicine

ownership	Limited	Acceptable	Good	Excellent	Total
0.05–0.40	5.0%	28.0%	51.5%	15.5%	100%
0.40–0.99	7.6%	26.1%	57.2%	9.1%	100%
1	10.5%	33.6%	48.6%	7.3%	100%
All	7.9%	29.2%	52.7%	10.2%	100%

Civil engineering and architecture

ownership	Limited	Acceptable	Good	Excellent	Total
<1	5.0%	24.5%	44.4%	26.1%	100%
1	7.2%	32.7%	43.8%	16.3%	100%
All	6.0%	28.3%	44.1%	21.6%	100%

Industrial and information engineering

ownership	Limited	Acceptable	Good	Excellent	Total
0.11–0.50	1.1%	17.5%	56.4%	25.0%	100%
0.50–0.99	2.8%	24.0%	54.9%	18.3%	100%
1	2.9%	27.0%	49.9%	20.2%	100%
All	2.3%	23.4%	53.1%	21.2%	100%

Economics and statistics

ownership	Limited	Acceptable	Good	Excellent	Total
<1	8.4%	20.2%	45.2%	26.2%	100%
1	22.6%	32.2%	34.8%	10.4%	100%
All	11.4%	22.7%	43.0%	22.9%	100%

Table 9: Effect of heterogeneous collaboration on peer judgements of papers (part II).