

Analysis of patterns of cooperation in the preparation of scientific publications

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Abstract

The analysis of the structure of authors' teams of research publications is the main goal of the paper. The study will concern the following features of teams: number of team members, team structure with respect to demographic attributes, scientific degrees, positions or affiliation. During the study typical forms of cooperation ("patterns of cooperation") among authors will be identified. Also the analysis of durability of authors' teams will be discussed. The empirical part of the research presents the analysis of patterns of cooperation existing among researchers working for the Cracow University of Economics. The scope of analysis will cover all research publications published in twelve-year period of scientific activity.

Keywords: research productivity, scientific publications, publishing activity.

JEL Classification: C82, O32

1. Introduction

In the research literature the growing importance of scientific cooperation can be observed. It is focused on the development of science and on scientific achievements of individual scientists. Finally it causes the increase in the number of publications written in co-authorship. Sonnenwald defines scientific cooperation as an interaction taking place within a social context among two or more scientists that facilitates the sharing of meaning and completion of tasks with respect to a mutually shared, superordinate goal (Sonnenwald, 2007). In the definition of science presented in the publication "Science of Science" references to scientific cooperation can be found: *Science can be described as a complex, self-organizing, and evolving network of scholars, projects, papers, and ideas. This representation has unveiled patterns characterizing the emergence of new scientific fields through the study of collaboration networks and the path of impactful discoveries through the study of citation networks* (Fortunato et al., 2018).

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Publications on issues related to scientific cooperation point to the numerous advantages of this form of activity that are relevant to an individual researcher. They include, among others:

- The opportunity to develop more complex and complicated theories that would be hard to master for a single scientist (Beaver, 2001; Katz and Martin, 1997). It is important, especially in the natural sciences, engineering and interdisciplinary research (Beaver, 2001);
- The costs of research requiring the use of specialized research devices may be very high for a single researcher (Duque *et al.*, 2005; Laband and Tollison, 2000). In the case of cooperation within a scientific team, scientists can use limited funds that will allow them access to expensive scientific equipment (Beaver, 2001);
- Scientific cooperation has a beneficial effect on the prestige of the researcher and recognition in the scientific community (Katz and Martin, 1997; Beaver, 2001) as well as scientific cooperation creates the opportunity to expand methodological and conceptual knowledge through the experience of other researchers (Beaver, 2001; Katz and Martin, 1997);
- Cooperation is a factor that positively affects the level of scientific productivity expressed in both the number of publications and the number of citations (Chung *et al.*, 2009; Laband and Tollison, 2000).

By studying the literature, some unfavourable aspects associated with undertaking scientific cooperation can be indicated. These aspects mainly refer to the lower quality of publications (Fox and Faver, 1984), the adverse impact of co-author's publications on scientific promotion or underestimation of the contribution of young researchers to the benefit of those already experienced (Fox and Faver, 1984).

Confidence in teamwork has increased over the past decades, which is a fundamental change in the way research is conducted. Numerous publications indicate an increase in the number of publications written in co-authorship. In 1955, in social science individual authors wrote 17.5% of their papers in teams. Since then, there has been an increase in co-authored publications and in 2013 the percentage of articles written by science teams was 90% (Fortunato *et al.*, 2018). In the research, we can also observe a certain tendency related to the increasing number of scientists working within scientific teams across various disciplines. This trend indicates the following relationship: a smaller team of scientists starting cooperation and as a result of achieving a satisfactory level of scientific productivity attracts new scientists through the process of cumulative advantage (Palla *et al.*, 2007; Fortunato *et al.*, 2018). Scientists also

point to the fact that large research teams achieve a better level of scientific productivity expressed in the number of citations in publications from various disciplines.

It was also noticed that teams of many researchers are solving existing research problems while smaller ones tend to formulate new research problems (Wu *et al.*, 2019). Small teams survive longer if they maintain a stable core, but larger teams persist longer if they manifest a mechanism for membership turnover (Palla *et al.*, 2007; Fortunato *et al.*, 2018). There is a tendency related to the size of research teams across different disciplines. Natural sciences or physical sciences are characterized by a larger research team than e.g. social sciences. Research indicates that the average size of the biological sciences team is 6,624, for physical sciences it is equal to 5,254 and for social sciences 4,634. (Xie *et al.*, 2018).

During the research process the authors were going to analyse the structure and the durability of Polish researchers' teams preparing publications in the field of economics and management. The empirical part of the research presents the analysis of patterns of cooperation existing among researchers working for the Cracow University of Economics. The scope of analysis will cover all research publications published in twelve-year period of scientific activity.

2. Research methodology

The empirical analysis presented in the paper is based on the information concerning publishing activity of academic staff of the Cracow University of Economics and covers the following issues:

- the structure of publications in terms of size of authors' teams. To achieve this goal, the analysis of lists of authors of publications registered in the period 2004-2015 in the *Dorobek* database used by the Main Library of the Cracow University of Economics was performed;
- the durability of authors teams. The durability can be defined as the ability to work together to prepare subsequent publications. Two methods of durability evaluation were used. Using the first method, lists of authors were treated as sets and the number of occurrences for every set was calculated. In the second approach, for every set of authors all two-element combinations without repetition were generated and for every pair of authors the number of appearances were assessed. It was assumed that the more frequent occurrence of the measures presented above proves greater durability of the author's teams;
- the structure of authors' teams with respect to authors' gender, department employing team members, scientific degree or titles of authors and their position. Such calculations had to

be preceded by the creation of a programming solution to supplement the data about publications' authors with information specifying their gender, scientific degree or title, position or department in which they are employed.

All calculations were performed with the use of programs prepared in R language.

3. The analysis of authors' teams at the Cracow University of Economics

During the research the information about the publications prepared by the academic staff of the Cracow University of Economics (CUE) was used. The scope of analysis covered publications registered at the *Dorobek*³ database from 2004 to 2015. The total number of research publications (monographs, journal papers, chapters in monographs and publications published in conference proceedings) in this period was equal to 14874.

The structure of publications with respect to the size of authors' teams

The analysis of publications structure with respect to the size of authors teams was the main goal of the first stage of the study. The detailed information about all works from the period 2004-2015 is presented in the Table 1.

Table 1. The structure of the scientific publications prepared by the CUE academic staff from 2004 to 2015 with respect to the size of authors' teams

Year	The size of an authors' team										Total
	1		2		3		4		5 or more		
	N	%	N	%	N	%	N	%	N	%	
2004	829	79.8%	173	16.7%	23	2.2%	8	0.8%	6	0.6%	1039
2005	724	77.8%	165	17.7%	29	3.1%	6	0.6%	6	0.6%	930
2006	798	76.4%	195	18.7%	36	3.4%	4	0.4%	11	1.1%	1044
2007	853	77.3%	200	18.1%	38	3.4%	8	0.7%	5	0.5%	1104
2008	933	79.2%	193	16.4%	35	3.0%	7	0.6%	10	0.8%	1178
2009	955	78.7%	215	17.7%	27	2.2%	4	0.3%	13	1.1%	1214
2010	1062	80.8%	199	15.1%	31	2.4%	8	0.6%	15	1.1%	1315
2011	1245	81.2%	238	15.5%	29	1.9%	7	0.5%	15	1.0%	1534
2012	1129	77.5%	255	17.5%	35	2.4%	16	1.1%	21	1.4%	1456
2013	1113	77.3%	237	16.5%	59	4.1%	18	1.3%	12	0.8%	1439
2014	1102	74.4%	257	17.3%	74	5.0%	24	1.6%	25	1.7%	1482
2015	762	66.9%	247	21.7%	72	6.3%	25	2.2%	33	2.9%	1139
Total	11505	77.3%	2574	17.3%	488	3.3%	135	0.9%	172	1.2%	14874

³ <https://bazybg.uek.krakow.pl/dorobek>.

The analysis of data presented in the Table 1 shows that the structure of publications with respect to the size of authors' teams was stable over time. About 77% of all works were issued as one-author publications. Taking into account advantages of cooperation, this result can be considered as unsatisfactory because the potential benefits of cooperation remain under-exploited.

Durability analysis of authors' teams

The durability of a given authors' team was measured by the number of publications prepared by its members. Only authors who were employees of the CUE with an employment contract in the period 2004-2015 were included in this analysis. In this period 1862 multi-author publications prepared by authors from the CUE were registered in the *Dorobek* database. These works were prepared by 776 various authors' teams. The number of occurrences of teams is presented in the Table 2.

Table 2. The number of occurrences of authors' teams composed of the CUE employees

Number of Occurrences	Number of teams	%	Number of Occurrences	Number of teams	%
1	428	55.15%	12	4	0.52%
2	158	20.36%	13	1	0.13%
3	60	7.73%	14	3	0.39%
4	36	4.64%	15	1	0.13%
5	26	3.35%	16	2	0.26%
6	15	1.93%	17	1	0.13%
7	16	2.06%	19	1	0.13%
8	9	1.16%	22	1	0.13%
9	5	0.64%	24	1	0.13%
10	5	0.64%	26	2	0.26%
11	1	0.13%	Total	776	100.00%

The results shown in the Table 2 indicates that the durability of authors' team is rather low. About 55% of teams prepared only one publication and 20.3% of teams prepared two works. On the other hand, four teams registered have very high durability and each of them prepared 20 or more research publications.

The second approach used for the analysis of teams' durability was based on the analysis of common publications prepared by pairs of authors from the CUE. In the period 2004-2015, 1109 various pairs of authors were identified. It was assumed that two authors form a pair if they appear at least once in the list of authors of the same publication. The results are presented

in the Table 3. Unfortunately, the results presented in the Table 3 confirms previous findings. About 46.5% of authors' pairs appear only once.

Table 3. The number of occurrences of authors' pairs composed of the CUE employees

Number of occurrences	Number of pairs	%	Number of occurrences	Number of pairs	%
1	516	46.53%	13	1	0.09%
2	237	21.37%	14	5	0.45%
3	117	10.55%	15	3	0.27%
4	58	5.23%	16	2	0.18%
5	51	4.60%	17	3	0.27%
6	36	3.25%	18	5	0.45%
7	32	2.89%	19	1	0.09%
8	12	1.08%	24	1	0.09%
9	9	0.81%	26	1	0.09%
10	7	0.63%	31	1	0.09%
11	5	0.45%	36	1	0.09%
12	4	0.36%	40	1	0.09%
			Total	1109	100.00%

Authors' teams structure

Next step of the analysis was focused on the analysis of the structure of authors' teams. During the study, the structure of teams by authors' gender, department employing team members, scientific degree or titles of authors and their position.

The structure of teams in terms of gender is presented in the Table 4. For teams composed of two authors, in 60% of cases both authors represented the same gender.

The analysis with respect to department is presented in the Table 5.

Table 4. The structure of authors teams with respect to authors' gender

Number of authors in one authors' team	Number of all teams	Number of authors' teams with the same values for all members of an authors' team	Number of authors' teams with various values for members of an authors' team
2	1550	935 (60.3%)	615 (39.7%)
3	236	78 (33.0%)	158 (70.0%)
4	40	10 (25.0%)	30 (75.0%)
5	17	2 (11.8%)	15 (88.2%)
6 or more	19	5 (26.3%)	14 (73.6%)

Table 5. The structure of authors teams with respect to departments employing authors

Number of authors in one authors' team	Number of all teams	Number of authors' teams with the same values for all members of an authors' team	Number of authors' teams with various values for members of an authors' team
2	1550	1279 (82.5%)	two values: 271 (17.5%)
3	236	192 (81.4%)	two values: 43 (18.2%) three values: 1 (0.4%)
4	40	31 (77.5%)	two values: 7 (17.5%) three values: 2 (5.0%)
5	17	13 (76.5%)	two values: 3 (17.6%) four values: 1 (5.9%)
6 or more	19	12 (63.2%)	two values: 3 (15.8%) four values: 4 (21.1%)

The results show that in most cases, all members of authors' teams work at the same department. For example, 82.5% of teams composed of two authors were formed by authors from the same department. The similar situation may be observed also for large teams. Taking into account teams of size 6 or greater, in 63.2% of cases all members work for the same department.

The analysis of authors' teams with respect to scientific degree or title is presented in the Table 6.

Table 6. The structure of authors teams with respect to scientific degree or title of authors

Number of authors in one authors' team	Number of all teams	Number of authors' teams with the same values for all members of an authors' team	Number of authors' teams with various values for members of an authors' team
2	1550	573 (37%)	two values: 977 (63%)
3	236	37 (15.7%)	two values: 134 (56.8%) three values: 65 (27.5%)
4	40	10 (25%)	two values: 13 (32.5%) three values: 17 (42.5%)
5	17	1 (5.9%)	two values: 9 (52.9%) three values: 5 (29.4%) four values: 2 (11.8%)
6 or more	19	2 (10.5%)	two values: 7 (36.8%) three values: 8 (42.1%) four values: 2 (10.5%)

In the last step, the structure of teams due to position of authors were analyzed. The results present the Table 7. It can be said that the structure of teams in terms of degrees or positions is rather diverse.

4. Conclusions

The results obtained during the study allow to formulate the following conclusions:

- the substantial minority of scientific publications at the Cracow University of Economics are written by authors' teams (77.3% of publications registered in Dorobek database in the period 2004-2015 were prepared by a single author),
- the durability of authors' team is low (55% of teams and 47% of pairs of authors prepared only one common publication),
- teams are diverse by scientific degree or title and positions held by authors; at the same time teams are usually homogeneous in terms of the authors' membership in university departments.

Table 7. The structure of authors teams with respect to position of authors

Number of authors in one authors' team	Number of all teams	Number of authors' teams with the same values for all members of an authors' team	Number of authors' teams with various values for members of an authors' team
2	1550	542 (35.4%)	two values: 1002 (64.6%)
3	236	40 (16.9%)	two values: 120 (50.8%) three values: 76 (32.2%)
4	40	10 (25.0%)	two values: 13 (32.5%) three values: 16 (40.0%) four values: 1 (2.5%)
5	17	0	two values: 12 (70.6%) three values: 2 (11.8%) four values: 3 (17.6%)
6 or more	19	1 (5.2%)	two values: 5 (26.3%) three values: 8 (42.1%) four values: 5 (26.3%)

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