EIGENFACTOR CENTRALITY ANALYSIS OF THE AUTHORSHIP COOPERATION WITHIN THE ROMANIAN RESEARCH AREA

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Abstract: *The paper examines the cooperation in terms of authorship of research papers within the Romanian research area and its dynamics in 2006-2009. During this period of time the Romanian government funding of the scientific research had an unprecedented increase, resulting in a corresponding increase for the overall number of research papers published in scholarly journals. Some institutions favored a sustainable increase, reflected in the increase of both Eigenfactor and Authorship Cooperation scores. As a result we consider that these institutions further consolidated their position within the Romanian Research Area. For other institutions, despite the overall increase in the number of publications, both Eigenfactor and Authorship Cooperation scores decrease with possible negative impact of the medium term dynamics. The present analysis and the corresponding methodology could help institutional or national policy makers in actively promoting scientific cooperation in order to better use complementary expertise as well as the existing top research infrastructure.*

Keywords: scientific cooperation, research visibility, authorship cooperation, ISI papers, Romania.
JEL Classification*:* C6

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1. Introduction

Increasing the quality and international visibility of the scientific research results is the main target of the Romanian Authority for Scientific Research for the period 2007-2012 corresponding to the National Plan II. While the efforts are focused on integrating Romania within the European Research Area, it is equally important to promote the cooperation among Romanian researchers from different research entities (either universities or research institutes). This cooperation might cover several aspects related to the inputs (e.g. joint research projects, efficient use of top national research infrastructure) or outputs (e.g. research papers with authors from different institutions). Although cooperation among researchers is officially encouraged, in order to efficiently use complementary expertise or to promote inter- and trans-disciplinarity, the evaluation criteria definitely favour single author papers or teams of authors from the same Romanian research entity.

As a result, we consider that an analysis of the trends within the Romanian Research Area with respect to the collaborative authorship is quite useful in order to improve the coherence between stated goals and actual evaluation criteria and indicators, in order to send a clear message to the research community. Valuable conclusions can be obtained only by employing a rigorous quantitative approach in assessing the authorship cooperation issue.

According to the opinions stated in Nature (Braun, T., 2010), since the invention of the science citation index in the 1960s, quantitative measuring of the performance of researchers has become ever more prevalent, controversial and influential. It is now recognized the need to stop misusing rankings and instead demonstrate how they can improve science. In an editor's note in the Journal of Neuroscience (Bergstrom, C.T., 2008), it is also stated that the misuse of journal impact factor in hiring and promotion decision is a growing concern.

It is clear that once it is officially stated that a certain metrics is the leading decision criterion, the community is focusing on improving individual or institutional performance within that metrics.

As a result, once should carefully choose the methodology for assessing various aspects of the scientific research activities and results such that:

i) the methodology is robust and delivers consistent results quasi-independent of the various choices for the input or for algorithm's parameters;
ii) the results cannot be easily manipulated by simply shifting the current practice while disregarding the main goals of the scientific research (i.e. either solving open problems or pushing the knowledge frontiers).

In the present paper we employ an emerging methodology generally used for network analysis. According to West (2010) the *eigenvector centrality* approach was introduced by sociologist Bonacich (1972) who used a network's structure to find out who were the important people in the network. The most prominent commercial application of eigenvector centrality is Google's PageRank algorithm, which ranks the importance of Web sites by looking at the hyperlink structure of the World Wide Web (Page, L.S., 1998).

The concept of eigenvector centrality was used by Bergstrom in (Bergstrom, C.T., 2007) to develop the *Eigenfactor Metrics* for assessing quantitatively the importance of scientific journals. It is this metrics we employ in this paper to assess the collaborative authorship within the Romanian Research Area.

First we present the data we have collected for our analysis for a set of Romanian research entities, and the motivation of our choice. Then, we describe the methodology leading to the two main quantitative outputs: the eigenfactor score and the authorship cooperation score. The results obtained with the methodology adopted in this paper are then presented and discussed, with conclusions presented in the last section.

1.1. Data for collaborative authorship

We have collected data from the Romanian Research Area for scientific papers with Romanian authors published in scholarly journals from Web of Science of Thomson-Reuters (further called ISI papers) as mention in (Velter, V., 2010). We consider two representative years, 2006 and 2009, respectively, since within this short period of time there was a rather steep increase in the government funding of the scientific research, with funding instruments that explicitly encouraged international visibility and partnership. We have chosen a set of 16 Romanian research entities as follows: University of Bucharest (UB), Babes-Bolyai University Cluj-

Napoca (UBB), Romanian Academy, including a set of its research institutes (AR), Al. I. Cuza University of Iasi (UAIC), Politehnica University of Bucharest (UPB), West University of Timisoara (UVT), Politehnica University of Timisoara (UPT), University of Medicine and Pharmacy Bucharest (UMFB), Technical University "Gh. Asachi" Iasi (UTI), Petru Poni Research Institute (IPP), Ilie Murgulescu Research Institute (IIM), Research Institute for Nuclear Physics (IFIN), University of Medicine and Pharmacy Cluj-Napoca (UMFC), Technical University of Cluj-Napoca (UTCN) and "Lucian Blaga" University of Sibiu (ULBS). This selection includes both universities and research institutes, and it is not a comprehensive one not it reflects a particular ranking. Tables 1a and 1b present the number of papers with authors from different institutions for the two years considered in the present analysis. The diagonal entries correspond to papers with all authors from the same institution. In terms of absolute values, one can easily notice a spectacular increase from the year 2006 to the year 2009, and this increase in total number of ISI papers is obviously directly correlated with the increase in research funding. Of course, one can further use these data for simple rankings, with possible weighting corresponding to the journal impact factor.

Recently, the funding instrument for the Exploratory Research Projects employed in the 2011 project competition the Article Influence Score of scholarly journals to assess the previous research activity of the project leader, with an eligibility threshold. Our goal in the present analysis is to examine the cooperation pattern for authorship and to assess whether or not the funding level significantly influences this pattern.

We do not aim for rankings or classifications.

Table no.1a. ISI papers with Romanian authors from various universities and research institutes, published in 2006

Institution	UB	UBB	AR	UAIC	UPB	UVT	UPT	UMFB	UTI	IPP	IIM	IFIN	UMFI	UMFC	UTCN	ULBS
UB	59	0	7	0	7	1	1	1	0	0	8	7	0	0	0	0
UBB	0	69	2	0	1	0	0	0	0	0	0	0	0	7	6	2
AR	7	2	42	5	10	7	7	2	1	0	0	0	0	0	0	0
UAIC	0	0	5	60	0	1	1	0	12	8	0	0	1	0	0	1
UPB	7	1	10	0	63	0	5	1	0	1	7	1	0	0	1	0
UVT	1	0	7	1	0	39	9	0	0	0	0	1	0	0	0	0
UPT	1	0	7	1	5	9	25	0	0	1	0	0	0	0	0	0
UMFB	1	0	2	0	1	0	0	2	0	0	0	0	0	0	0	0
UTI	0	0	1	12	0	0	0	0	21	8	0	0	4	0	0	0
IPP	0	0	0	8	1	0	1	0	8	52	0	0	0	0	0	1

Institution	UB	UBB	AR	UAIC	UPB	UVT	UPT	UMFB	UTI	IPP	IIM	IFIN	UMFI	UMFC	UTCN	ULBS
IIM	8	0	0	0	7	0	0	0	0	0	4	0	0	0	0	0
IFIN	7	0	0	0	1	1	0	0	0	0	0	8	0	0	0	0
UMFI	0	0	0	1	0	0	0	0	4	0	0	0	2	0	0	0
UMFC	0	7	0	0	0	0	0	0	0	0	0	0	0	1	0	1
UTCN	0	6	0	0	1	0	0	0	0	0	0	0	0	0	10	0
ULBS	0	2	0	1	0	0	0	0	0	1	0	0	0	1	0	3

Table no. 1b. ISI papers with Romanian authors from various universities and research institutes, published in 2009

Institution	UB	UBB	AR	UAIC	UPB	UVT	UPT	UMFB	UTI	IPP	IIM	IFIN	UMFI	UMFC	UTCN	ULBS
UB	116	0	29	3	18	1	1	17	0	0	12	10	0	0	0	0
UBB	0	148	8	1	3	0	1	0	0	1	0	0	0	22	8	2
AR	29	8	95	18	13	10	7	15	6	4	0	5	2	0	0	0
UAIC	3	1	18	98	2	1	2	0	29	19	0	0	4	0	0	2
UPB	18	3	13	2	207	1	9	4	3	1	7	5	1	0	5	1
UVT	1	0	10	1	1	66	9	0	0	0	0	0	0	0	0	0
UPT	1	1	7	2	9	9	54	1	4	0	1	0	0	0	0	0
UMFB	17	0	15	0	4	0	1	42	0	0	0	0	2	2	0	1
UTI	0	0	6	29	3	0	4	0	80	17	1	1	10	0	1	0
IPP	0	1	4	19	1	0	0	0	17	85	0	0	4	0	0	0
IIM	12	0	0	0	7	0	1	0	1	0	4	0	1	0	0	0
IFIN	10	0	5	0	5	0	0	0	1	0	0	18	0	0	0	0
UMFI	0	0	2	4	1	0	0	2	10	4	1	0	30	0	0	0
UMFC	0	22	0	0	0	0	0	2	0	0	0	0	0	32	3	0
UTCN	0	8	0	0	5	0	0	0	1	0	0	0	0	3	38	0
ULBS	0	2	0	2	1	0	0	1	0	0	0	0	0	0	0	8

Table no. 2. Scientific papers affiliated with each Romanian research entity and the article vector for papers with Romanian authors only

Research entity index	Research entity name	Year 2006			Year 2009		
		Number of ISI papers	Number of ISI papers (RO authors only)	Article vector	Number of ISI papers	Number of ISI papers (RO authors only)	Article vector
1	UB	259	125	0.1351	499	294	0.1224
2	UBB	218	104	0.1124	451	260	0.1082
3	AR	219	105	0.1135	429	239	0.0995
4	UAIC	162	96	0.1038	289	194	0.0808
5	UPB	195	159	0.1719	502	411	0.1711
6	UVT	79	59	0.0638	129	100	0.0416
7	UPT	70	54	0.0584	131	112	0.0466

Research entity index	Research entity name	Year 2006			Year 2009		
		Number of ISI papers	Number of ISI papers (RO authors only)	Article vector	Number of ISI papers	Number of ISI papers (RO authors only)	Article vector
8	UMFB	24	17	0.0184	176	147	0.0612
9	UTI	75	50	0.0541	260	185	0.0770
10	IPP	99	69	0.0746	181	137	0.0570
11	IIM	32	22	0.0238	45	32	0.0133
12	IFIN	102	19	0.0205	153	44	0.0183
13	UMFI	16	9	0.0097	90	80	0.0333
14	UMFC	17	12	0.0130	115	87	0.0362
15	UTCN	17	18	0.0195	82	60	0.0250
16	ULBS	7	7	0.0076	22	20	0.0083

2. Methodology

Data from either Table 1a or Table 1

Table no. *1* bare included in the "authorship matrix" *A*, which obviously is a symmetric matrix. The matrix entry $\mathcal{A}_{ij}$ means the number of papers with authors affiliated either to the research entity i i or j. A diagonal entry $\mathcal{A}_{ii}$ corresponds to the number of papers with authors only from the research entity i. We focus in this paper only on scientific papers with Romanian authors, since we are concerned with the national authorship cooperation in correlation with the increase in the national research funding. The total number of papers with Romanian authors only, as shown in Table 2 is larger than the sum of the corresponding rows/columns in the matrix $\mathcal{A}$ since we have presented in Table 1a and Table 1b only a subset of 16 Romanian research entities.

We examine in this paper the papers written in cooperation between authors from Romanian research entities only. As a result, the cooperation matrix $\mathcal{A}$ will be modified as follows:

- Set the matrix diagonal to zero, $\mathcal{A}_{ij} = 0$. This is done in order to account only for papers with authors affiliated to different research entities.
- Normalize the columns of the cooperation matrix, i.e. divide each entry in a column by the sum of the entries in that column, $\mathcal{A}_{ij} / \sum_i \mathcal{A}_{ij} \rightarrow \mathcal{A}_{ij}$. By construction, the cooperation matrix has $\sum_i \mathcal{A}_{ij} > 0$.

Next, we construct the article vector by taking into consideration only the number of ISI papers with Romanian authors. The article vector entries are also normalized to the total number of ISI papers with Romanian authors, $a_i / \sum_i a_i \rightarrow a_i$. Note that the article vector, by construction, takes into consideration also the paper numbers with authors only from the same research entity, i.e. the diagonal entries $\mathcal{A}_{ii}$ that have been set to zero in the cooperation matrix.

The above normalization procedure insures that all entries in each column in the cooperation matrix, as well as in the article vector, sum to one. Next we build the transition matrix $\mathcal{P}$ defined as:

$$P_{ij} = \alpha A_{ij} + (1-\alpha) a_i \qquad \textbf{(1)}$$

If $\alpha = 1$ then the transition matrix corresponds to the cooperation matrix, $\mathcal{P}_{ij} = \mathcal{A}_{ij}$.

If $\alpha = 0$ we have $\mathcal{P}_{ij} = a_i$, i.e. we have a $n \times n$ matrix with identical columns repeated n times, each column corresponding to the article vector a. The name "transition matrix" for P actually means that through the weight factor α we insure a continuous transition from the cooperation information in matrix $\mathcal{A}$, which completely removed through normalization the absolute number of papers, to the matrix with identical columns a which accounts only for the share of scientific papers published by each institution from the overall scientific production.

According to the Perron-Frobenius theorem, the transition matrix P will have a unique largest real eigenvalue and that the corresponding eigenvector has strictly positive components. The leading eigenvector of the second term in Equ (1) is obviously a.

For the present investigations we compute the leading eigenvector of the matrix P using the EVCRG subroutine from the International Mathematics and Statistics Library, (IMSL, 1994). This leading eigenvector π is delivered by the EVCRG subroutine normalized to have Euclidian length equal to the value one. However, consistent with the normalization used in this paper we will normalize the leading eigenvector as

$$\pi_i / \sum_i \pi_i \to \pi_i .$$

The *Eigenfactor Score* for each research entity is defined as $EF = \mathcal{A} \cdot \pi$, then normalized to the sum 1 and multiplied by 100 to express the result in percents:

$$EF_i = 100 \frac{\sum_j \mathcal{A}_{ij} \pi_j}{\sum_k (\sum_j \mathcal{A}_{kj} \pi_j)} [\%] \quad (2)$$

We further define the *Authorship Cooperation Score* as,

$$AU_i = \frac{0.01 EF_i}{a_i} \quad (3)$$

3. Results and Discussion

The algorithm presented in the previous section includes a weighting factor α which can run from 0 to 1. The value chosen for a particular analysis must be related to the aim of that analysis. For example, when aiming at cooperation issues disregarding the size of the scientific production one can choose $\alpha = 1$, while if the size of scientific production (or the share within the national overall scientific production) is favoured then $\alpha = 1$. It is therefore relevant to use the above extreme values for α in order to see its effect on the results. The algorithm presented in the previous section includes a weighting factor which can runs from 0 to 1. The value chosen for a particular analysis must be related to the aim of that analysis. For example, when aiming at cooperation issues disregarding the size of the scientific production one can choose, while if the size of scientific production (or the share within the national overall scientific production) is favoured then. It is therefore relevant to use the above extreme values for in order to see its effect on the results. Table 3 and Table 4 show the results obtained for the two years analyzed in the paper, showing that for the majority of the entities the differences do not change the overall picture and

Table *no. 4* show the results obtained for the two years analyzed in the paper, showing that for the majority of the entities the differences do not change the overall picture.

Table no. 3. Eigenfactor Score and Authorship Cooperation Score for year 2006, using the extreme values of the weight coefficient α.

Research entity index	Research entity name	α=1.0		α=0.0	
		Eigenfactor Score [%]	Authorship Cooperation Score	Eigenfactor Score [%]	Authorship Cooperation Score
1	UB	10.8844	0.8054	9.3815	0.6942
2	UBB	6.1225	0.5445	4.1651	0.3705
3	AR	13.9456	1.2285	16.2381	1.4305
4	UAIC	9.8640	0.9504	8.0446	0.7751
5	UPB	11.5646	0.6728	10.0337	0.5837
6	UVT	6.4626	1.0132	5.1356	0.8052
7	UPT	8.1633	1.3983	8.6600	1.4834
8	UMFB	1.3605	0.7403	1.4816	0.8062
9	UTI	8.5034	1.5731	8.4906	1.5708
10	IPP	6.4626	0.8664	5.4929	0.7364
11	IIM	5.1020	2.1452	6.9173	2.9084
12	IFIN	3.0612	1.4903	3.7974	1.8487
13	UMFI	1.7007	1.7479	1.2227	1.2567
14	UMFC	2.7211	2.0975	4.5237	3.4870
15	UTCN	2.3810	1.2235	4.2533	2.1857
16	ULBS	1.7007	2.2473	2.1619	1.0268

Table no. 4. Eigenfactor Score and Authorship Cooperation Score for year 2009, using the extreme values of the weight coefficient α.

Research entity index	Research entity name	α=1.0		α=0.0	
		Eigenfactor Score [%]	Authorship Cooperation Score	Eigenfactor Score [%]	Authorship Cooperation Score
1	UB	12.2641	1.0020	11.3830	0.9300
2	UBB	6.1995	0.5727	6.1447	0.5677
3	AR	15.7682	1.5847	17.4871	1.7575
4	UAIC	10.9164	1.3516	9.3847	1.1620
5	UPB	9.8383	0.5750	8.7202	0.5096
6	UVT	2.9650	0.7122	2.5180	0.6048
7	UPT	4.7170	1.0116	5.6114	1.2034

Research entity index	Research entity name	α=1.0		α=0.0	
		Eigenfactor Score [%]	Authorship Cooperation Score	Eigenfactor Score [%]	Authorship Cooperation Score
8	UMFB	5.6604	0.9249	5.3176	0.8689
9	UTI	9.7035	1.2599	8.4283	1.0943
10	IPP	6.1995	1.0869	5.0780	0.8903
11	IIM	2.9650	2.2256	3.6338	2.7276
12	IFIN	2.8302	1.5450	3.0492	1.6646
13	UMFI	3.2345	0.9712	2.7210	0.8170
14	UMFC	3.6388	1.0046	5.9091	1.6314
15	UTCN	2.2911	0.9172	3.5639	1.4267
16	ULBS	0.8086	0.9712	1.0502	1.2612

As a result, we adopt a value α=0.85 as it was previously chosen by Jevin West and Carl T. Bergstrom, with more emphasis on authorship cooperation while also accounting for the share in the scientific production.

Table no. 5. Eigenfactor Score and Authorship Cooperation Score for data from Table1a and Table1b, with α=0.85

Research entity index	Research entity name	Year 2006		Year 2009		Dynamics 2006 → 2009	
		Eigenfactor Score [%]	Authorship Cooperation Score	Eigenfactor Score [%]	Authorship Cooperation Score	Eigenfactor Score	Authorship Cooperation Score
1	UB	10.8690	0.8043	12.1632	0.9937	+	+
2	UBB	6.4315	0.5720	6.7504	0.6236	+	+
3	AR	14.1639	1.2478	15.8894	1.5969	+	+
4	UAIC	9.2800	0.8942	10.3875	1.2861	+	+
5	UPB	11.5387	0.6713	9.7803	0.5716	-	-
6	UVT	6.2861	0.9855	2.9204	0.7015	-	-
7	UPT	8.1604	1.3978	4.8123	1.0321	-	-
8	UMFB	1.3867	0.7545	5.6375	0.9212	+	+
9	UTI	8.0614	1.4914	9.1958	1.1940	+	-
10	IPP	6.0772	0.8147	5.8107	1.0188	-	+
11	IIM	5.3665	2.2564	3.0390	2.2812	-	-
12	IFIN	3.1602	1.5385	2.8486	1.5551	-	+
13	UMFI	1.5518	1.5949	3.0496	0.9156	+	-
14	UMFC	3.1116	2.3985	4.2505	1.1735	+	-
15	UTCN	2.7487	1.4125	2.6119	1.0456	-	-
16	ULBS	1.8062	2.3867	0.8530	1.0244	-	-

One can see that although the overall number of publications has increased from year 2006 to year 2009, the dynamics of the Eigenfactor Score and of the Authorship Cooperation Score, respectively, show a different pattern. Half of the research entities have an increase in the

Eigenfactor Score, five of which (UB, UBB, AR, UAIC and UMFB) having also an increase in the Authorship Cooperation Score as shown in the grey rows. We consider this a sustainable growth, both in terms of national scientific production and ability to attract research partners. Six research entities (UPB, UVT, UPT, IIM, UTCN and ULBS) do not display a sustainable growth of the scientific production according to the definition above, since despite the overall growth in number of publications their Eigenfactor Score and Authorship Cooperation Score have decreased. The remaining five research entities (UTI, IPP, IFIN, UMFI and UMFC) definitely have the potential to reach the sustainable growth status.

The above qualitative conclusions might be useful for the research entities policy makers in order to adjust their practice and promote inter-institutional cooperation in order to insure a sustainable growth of the scientific production.

4. Conclusions

The paper is focus on the scientific cooperation within the Romanian Research Area through the authorship of papers published in scholarly journals. We apply the eigenfactor centrality methodology to assess the steep growth in the number of scientific papers published from year2006 and 2009, when there was an unprecedented increase in the government funding of the scientific research.

The primary data we considered correspond to the authorship cooperation matrix for a selected set of Romanian research entities, both universities and research institutes. Using the eigenfactor centrality approach we compute the Eigenfactor Score and the Authorship Cooperation Score for each research entity considered.

It is shown that although all institutions have an increase in the overall number of scientific papers, only five out of sixteen institutions have an increase in both Eigenfactor Score and the Authorship Cooperation Score. We associate this type of dynamics with a sustainable growth, since these institutions managed to further consolidate their importance and visibility within the Romanian Research Area by promoting the cooperation with other research actors. The institutions with a decrease in both Eigenfactor and the Authorship Cooperation scores may not have a sustainable growth on medium/long period of time, since their position in terms of cooperation

and position within the Romanian Research Area was not improved. These conclusions may help the policy makers within each research entity to adjust their strategies toward joint research projects and collaborative research, with the benefit of using complementary expertise and research infrastructure to boost the scientific production as well as its quality and visibility.

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References

Bergstrom, C.T., (2007). Eigenfactor: measuring the value and prestige of scholarly journals.*College and Research Libraries News*. 68(5), 314-316.

Bergstrom, C.T., West, J.D., & Wiseman, M.A., (2008). The Eigenfactor™ Metrics.*Journal of Neuroscience*. 28(45), 11433-11434.

Bonacich, P., (1972). Factoring and weighting approaches to clique identification. *Journal of Mathematical Sociology*. 2, 113-120.

Braun, T., Bergstrom, C.T., Frey, B.S., Osterloh, M. West, J.D., Pendlebury, D., & Rohn, J., (2010).How to improve the use of metrics.*Nature*. 465(7300), 870-872.

Velter, V., (2010). „ISI“ publications management through performance indicators. *Annals of the Constantin Brancusi University of Targu Jiu*. Economy Series, 3, 119-128.

West, J.D., Bergstrom, T.C., & Bergstrom, C.T., (2010). The Eigenfactor Metrics: A Network Approach to Assessing Scholarly Journals.*College and Research Libraries*. 71(3), 236-244.

IMSL-MATH/LIBRARY: FORTRAN, 1994, Subroutines for Mathematical Applications, Visual Numerics Inc.

Page, L.S., Brin, Motwani, R., & Winograd T., (1998). The pagerank citation ranking: bringing order to the web. *Technical Report.Stanford Digital Library Technologies Project*.http://ilpubs.stanford.edu:8090/422/.