Journal of Scientometric Res. 2017; 6(3):195-203
http://www.jscires.org

Research Note

Another Approach to Evaluating Scientific Collaboration

Adedayo AV[1,2*]

[1]*Department of Materials Science and Engineering, Obafemi Awolowo University, Ile-Ife,* NIGERIA.
[2]*Department of Metallurgical Engineering, Kwara State Polytechnic, PMB 1375, Ilorin,* NIGERIA.

ABSTRACT

Purpose: This paper presents another approach to evaluating scientific collaborations. **Design/methodology/approach:** Weaknesses of existing schemes used in measuring scientific collaborations were identified and discussed. The identified weaknesses were used as basis to identify other parameters useful in measuring collaboration. With these parameters, a new relationship to quantify collaboration was introduced and applied to measure individual collaborations of academic staff of Centre for Science and Technology Studies (CWTS), Leiden; **Netherlands Findings:** Overall, the result shows that, total number of publications, number of collaborators per publication and the relative position of the collaborators in the published research are very important in the measurement of scientific Collaboration. **Originality/value:** The approach in the new scheme introduces a new feature which considers the position of scientists in the author list of their published works. With this perspective, the study is original, and has great potentials.

Keywords: Co-Authorship, Authorship order, Research collaboration, Publication count, Scientific productivity.

Correspondence

Adedayo AV

Department of Materials Science and Engineering, Obafemi Awolowo University, Ile-Ife, NIGERIA.

E-mail: a.v.adedayo@gmail.com

DOI: 10.5530/jscires.6.3.27

Received: 08-06-17

Revised: 11-08-17

Accepted: 14-09-17

INTRODUCTION

One of the top interests in science policy is the issue of research collaboration.[1] *Collaboration* is an arrangement between two or more people or organizations to work together to realize or achieve a goal. Research collaboration is a sophisticated cooperative arrangements among individuals, groups, departments, institutions, sectors and countries.[2,3] and it has become the norm in every field of scientific research.[4,5] Many studies have attempted to investigate various roles of collaborative research. Specifically, investigations have been made to ascertain whether scientific collaborations produce some of the best quality science.[6] Whether research collaborations have effects on publication productivity, i.e. do those who collaborate more tend to have more publications.[4] Also, if collaborations breed a transfer of knowledge among collaborators.[7] The effects of leadership styles on the impact collaborative work.[8] Etc. As a result, many services aimed at quantification of extent of collaboration are now available. These include the Collaboration Score of Nature Index.[6] Collaboration Metrics of Centre for Science and Technology Studies (CWTS), Leiden; etc. Measuring collaboration is now considered an indicator of research performance, as the Weighted Fractional Count (WFC) of Nature Index is widely applied, and can be used to identify the rising stars performers in the research world.[9,10]

Lee and Bozeman,[4] Bozeman *et al.*[11] Brew *et al.*,[12] and Katz and Martin.[3] Have all reported positive effects of collaboration on scientific productivity. The arguments are that: much collaboration is based on the joint use of expensive or unique equipment without which research would be, not only less productive but also impossible; some researches require collaboration to bring special expertise and knowledge not otherwise available but crucial to research outcomes. Often, tacit knowledge and knowledge of technique are best conveyed through collaboration; particularly for mentoring students and trainee researchers/scientists;[4] and to support innovation and address new and unmet needs, the value of cross-border collaboration and networking is important.[13] Sangam and Arali.[14] studied growth versus scientific collaboration in the field of genetics, using scientometric analysis. Their study found out that there is a relation between growth and scientific collaboration in the field of Genetics.

However, despite these good reasons to expect positive outcomes in scientific collaborations; equally, there are propositions as to why collaboration may undermine productivity. Landry and Amara.[15] Cautioned that transaction costs are

usually an unavoidable consequence of working with others. Staying in touch by various media, engaging in social ingratiation, waiting for others to comment, respond, or do their part of the research – these are just some of the factors taking time and energy even in the best collaborative relationships[4].

While it is researchers rather than institutions/countries who make arrangements to work together, these collaborations are aggregated and scaled-up with the focus of most collaboration evaluation on institutional/national levels.[16, 11] Some studies have attempted to establish links between collaboration and research productivity. Studies focusing on measuring and evaluating collaborative performance/strength of individual researchers are scarce. The prominent methods of evaluating individual researchers include: g-Index;[17] h-Index;[18] i10 – Index,[19] The individual scientist ranking scheme of Webometric, developed by CSIC – the Spanish National Research Council.[20] All these schemes measure research indices which are different from collaboration. The conceptual frameworks used by many of the available collaboration metric services are also grossly in error and unsuitable for evaluating individual researchers. For example, the scheme used by collaboration metrics of CWTS, Leiden is abstrusive. Information on operational principles of the methodology is not made public. The Nature Index/ Collaboration Score dwells on three measures to evaluate collaborations. These are: Article Count (AC), Fractional Count (FC); and Weighted Fractional Count (WFC). The flaw here is that, for AC, a publication is given a score of 1 unit irrespective of the number of authors listed on the publications [6]. The argument is that, if the number of authors listed does not affect the score attributed to a publication, then, of what value is collaboration? The proper conceptual thought line should be that quality of publication improves with the number of listed authors; this because the input of every contributing author should add to the quality of the publication. Where an author has not added to the quality of a publication, then what is he/her contribution to justify being listed? It is a widely known adage that two heads are better than one. This adage is widespread, cross-cultural, and equally supported by the Holy Bible (Ecclesiastes 4: 9-12). Definitely, the output is bound to be of higher quality where there is more quality inputs.

As regards FC, all contributing authors are attributed with a uniform count, which is determined by diving 1 unit with the number of contributing author. For instance, where a publication has 10 authors.[6,16] then it means that each author receives an FC of 0.1. This idea is equally flawed, because it is a fact, generally known in scientific publishing that the order of author listing is indicative of the extent of contribution/ influence of the authors as per the published research. If order of author listing is irrelevant, author listing would rather follow an alphabetic order, which is not the case in real time publishing. Weighted Fractional Count (WFC) is a normalization of overrepresentation of paper, and it applies to the field of Astronomy. [6, 16]

In the light of foregoing observations, another approach to evaluating scientific collaborations of individual scientists is presented. In this present study, the collaborative strength of scientists at the Centre for Science and Technology Studies (CWTS), Leiden is investigated. The approach in the new scheme introduces a new feature which considers the position of scientists in the author list of their published works. With this perspective, the study is original, and has great potentials. Herein, the justification for the study is identified.

Methodology

Co-authorship pattern of academic staff at the CWTS, Leiden in Netherlands was studied. Only published academic staffs at the CWTS were investigated. The information on co-authorship pattern of these scientists was as obtained at the following link: https://www.cwts.nl/people as at 25th November, 2016. In all, there were about twenty eight academic staff at the CWTS, Leiden; however only twenty-one academic staffs have records of publication history.

The co-authorship of each publication as recorded against the scientist at the website is obtained. A simple count of the total number of authors listed on a particular publication is counted and recorded as n; the position of the scientist in the author list is recorded in ascending order as r; starting with the first author listed. A record of distribution of n and r was obtained for the academic staff of CWTS who had publication records. The collaborative strength of individual researchers is determined using the relationship expressed as follows.

$$C_S = \sqrt[4]{\sum_{i=1}^{P}(n_i - r_i + 1)} \quad (1)$$

Where C_S is the collaborative strength, P is the total number of publications of the scientist and i is indicative of a particular publication of a scientist. The mean of the number of persons collaborating per paper (n_{mean}) and mean of the positions of a specific research staff (r_{mean}) were calculated using the following expressions

$$n_{mean} = \frac{\sum_{i=1}^{P} n_i}{P} \quad (2)$$

$$r_{mean} = \frac{\sum_{i=1}^{P} r_i}{P} \quad (3)$$

The adoption of co-authorship for measuring collaboration was informed from the premise laid by Katz and Martin,[3] which was similarly adopted by Gal *et al*.[13] Bozeman *et al*.[11]

Table 1: Distribution of number of persons (n) collaborating per publication.

S/N	CCM	RC	NJE	JK	TL	IM	EN	TR	SR	AR	CT	RT	VT	MV	LW	IW	EW	JW	PW	AY	ZZ
1.	4	3	2	10	4	3	5	3	5	5	4	3	1	4	4	2	2	2	5	3	3
2.	2	3	3	4	5	4	10	3	2	2	1	2	3	4	4	4	3	3	3	3	3
3	10	2	4	10	3	4	3	2	5	1	3	3	8	10	2	4	4	2	3	2	4
4	2	3	2		3	3	3	3	2	2	7	2	3	3	2		2	2	5	2	3
5	2	3	5		3		4	5	2			3	3	5	2	3	2		3	3	3
6	4	3	2		5		3	1	1			3	2	5	4	3	2		3	3	3
7	4	3	2		1		5	1	1			4	2	5	2	3	3		5	2	4
8	4	5	2		1		2	10	2			6		5	2	4			10	3	4
9	2	4	3		4		2	3	2			1		3	2	3			2	3	1
10	3	2	4		4		4	2	2			10		4	3	3			2	3	2
11	4	2	4		2		4	3				3		3	5	4			3	2	3
12	4	3	2		2		2	3				3		5	2	3			3	3	3
13	10	3	2		3		1	3				3		4	2	3			4		3
14	2	3	2		3		3	3				3		5	2	4			3		3
15	3	4	10		1		3	5				3		5	2				2		3
16		2	3		2		3	5				1		3	3				9		
17		2	3		2		2	5				1		4	4				2		
18		3	4		10		2	3				3		4	4				2		
19		2	3		3		3	3				2		10	1				2		
20		3	2		3		2	3				6		3	2				1		
21		3	3		3		2	5				1			2				1		
22		3	3		5		10	4				3			2				1		
23		3	3		5		3	1				1			10				2		
24		4	3		5		3	1				1			3				2		
25		2	5		2		5	1				2			3				2		

Table 2: Distribution of number of persons (n) collaborating per publication (Annex).

RC		NJE				TL						TR						RT				LW				PW	
S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n	S/N	n
26	2	26	5	51	2	26	3	51	3	76	3	101	3	26	1	51	1	76	3	26	4	51	4	26	2	51	2	26	3
27	3	27	5	52	2	27	3	52	2	77	4	102	4	27	1	52	2	77	10	27	5	52	2	27	2	52	2	27	3
28	2	28	2	53	3	28	3	53	2	78	4	103		28	1	53	2	78	3	28	1	53	4	28	3	53	4	28	3
29	2	29	2	54	3	29	3	54	5	79	2	104		29	1	54	4	79	3	29	1	54	2	29	2	54	2	29	3
30	2	30	4	55	2	30	5	55	4	80	3	105		30	1	55	1	80	4	30	1	55	3	30	3	55	2	30	3
31	2	31	4	56	10	31	6	56	2	81	2			31	1	56	1	81	5	31	3	56	3	31	3	56	4	31	4
32	2	32	5	57	3	32	5	57	5	82	2			32	1	57	1	82	4	32	1	57	10	32	3	57	2	32	2
33	2	33	3	58	3	33	4	58	3	83	3			33	1	58	1	83		33	5	58	3	33	5	58	3	33	3
34	2	34	2	59	3	34	3	59	3	84	2			34	5	59	1	84		34	3	59	3	34	5	59	3	34	3
35	3	35	3	60	2	35	1	60	2	85	4			35	1	60	2	85		35	2	60	2	35	5	60	2	35	3
36	3	36	2	61	2	36	1	61	2	86	10			36	4	61	1	86		36	5	61	2	36	2	61	10	36	10
37	3	37	2	62	3	37	6	62	5	87	3			37	3	62	1	87		37	2	62	2	37	4	62	3	37	1
38	3	38	2	63	3	38	1	63	3	88	2			38	5	63	1	88		38	3	63	3	38	4	63	2	38	1
39	2	39	2	64	3	39	3	64	3	89	3			39	2	64	1	89		39	1	64	5	39	5	64	2	39	
40	4	40	2	65	4	40	1	65	3	90	3			40	5	65	2	90		40	2	65	3	40	2	65	2	40	
41	2	41	2	66	3	41	1	66	3	91	2			41	4	66	2	91		41	2	66		41	3	66	2	41	
42	3	42	2	67	4	42	3	67	4	92	2			42	5	67	4	92		42	3	67		42	2	67	4	42	
43	2	43	2	68		43	2	68	2	93	2			43	3	68	2	93		43	2	68		43	2	68	3	43	
44	4	44	2	69		44	4	69	3	94	3			44	1	69	2	94		44	2	69		44	2	69	3	44	
45	3	45	2	70		45	5	70	2	95	5			45	1	70	2	95		45	4	70		45	2	70	4	45	
46	3	46	2	71		46	2	71	2	96	4			46	1	71	2	96		46	1	71		46	2	71		46	
47	3	47	2	72		47	5	72	3	97	5			47	1	72	2	97		47	2	72		47	2	72		47	
48		48	2	73		48	4	73	2	98	4			48	1	73	1	98		48	2	73		48	2	73		48	
49		49	2	74		49	3	74	2	99	3			49	1	74	2	99		49	1	74		49	2	74		49	
50		50	2	75		50	5	75	4	100	2			50	3	75	2	100		50	4	75		50	2	75		50	

Table 3: Distribution of position (r) of authors listed in a publication.

S/N	CCM	RC	NJE	JK	TL	IM	EN	TR	SR	AR	CT	RT	VT	MV	LW	IW	EW	JW	PW	AY	ZZ
1.	3	1	2	3	2	1	3	3	1	3	3	2	1	4	4	2	2	1	2	3	2
2.	2	1	2	2	2	1	4	2	1	2	1	2	1	4	3	1	3	2	3	1	2
3	2	2	2	3	2	4	2	2	4	1	2	3	3	9	2	1	4	1	3	2	3
4	2	2	1		2	1	2	3	2	1	7	2	1	3	1	4	2	1	2	1	1
5	1	2	1		2		3	3	1			3	2	4	2	2	2		3	3	1
6	1	2	2		3		3	1	1			3	1	4	3	2	2		3	2	2
7	1	1	2		1		2	1	1			4	1	4	2	2	2		3	2	2
8	2	2	2		1		1	8	2			4		3	1	3			10	3	2
9	2	4	2		1		2	3	2			1		3	1	3			2	3	1
10	2	2	2		3		2	2	2			5		3	2	1			2	3	1
11	3	2	2		2		4	3				3		1	2	1			2	1	1
12	3	2	2		2		2	3				1		2	1	2			3	2	1
13	2	3	2		2		1	1				2		2	1	3			4		1
14	2	1	2		2		2	1				3		4	1	1			3		1
15	1	2	6		1		1	5				2		4	1				2		1
16		1	3		1		1	5				1		3	1				9		
17		1	2		1		1	5				1		4	1				1		
18		2	3		7		1	3				1		4	1				2		
19		1	3		2		1	3				2		9	1				2		
20		1	1		2		2	3				3		2	1				1		
21		1	3		2		2	1				1			1				1		
22		1	3		3		4	4				3			1				1		
23		1	2		3		2	1				1			1				1		
24		1	2		3		2	1				1			1				2		
25		1	2		2		5	1				1			1				1		

Table 4: Distribution of position (r) of authors listed in a publication (Annex).

RC		NJE		TL								TR						RT				LW		PW	
S/N	r	S/N	R	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r	S/N	r
26	1	26	2	51	2	26	2	51	3	76	1	101	2	26	1	51	1	76	3	26	1	51	4	26	2	51	2	26	3
27	1	27	2	52	2	27	2	52	1	77	3	102	3	27	1	52	2	77	8	27	4	52	1	27	2	52	1	27	3
28	1	28	2	53	3	28	2	53	2	78	3	103		28	1	53	2	78	3	28	1	53	1	28	2	53	2	28	3
29	1	29	1	54	3	29	2	54	2	79	1	104		29	1	54	4	79	3	29	1	54	1	29	2	54	1	29	3
30	1	30	1	55	2	30	2	55	2	80	2	105		30	1	55	1	80	4	30	1	55	1	30	1	55	2	30	3
31	1	31	1	56	6	31	3	56	1	81	2			31	1	56	1	81	5	31	1	56	1	31	1	56	3	31	4
32	1	32	4	57	3	32	2	57	1	82	1			32	1	57	1	82	4	32	1	57	5	32	1	57	1	32	2
33	1	33	3	58	1	33	3	58	1	83	1			33	1	58	1	83		33	3	58	2	33	1	58	1	33	3
34	1	34	2	59	1	34	2	59	3	84	2			34	5	59	1	84		34	1	59	3	34	1	59	2	34	2
35	2	35	2	60	1	35	1	60	1	85	1			35	1	60	2	85		35	2	60	2	35	1	60	1	35	3
36	1	36	1	61	2	36	1	61	1	86	7			36	1	61	1	86		36	3	61	1	36	2	61	1	36	10
37	2	37	1	62	1	37	4	62	1	87	2			37	3	62	1	87		37	1	62	2	37	2	62	2	37	1
38	3	38	2	63	2	38	1	63	2	88	2			38	5	63	1	88		38	3	63	3	38	2	63	1	38	1
39	1	39	2	64	1	39	2	64	2	89	2			39	1	64	1	89		39	1	64	4	39	5	64	2	39	
40	1	40	2	65	1	40	1	65	1	90	2			40	5	65	2	90		40	1	65	1	40	1	65	1	40	
41	2	41	1	66	1	41	1	66	2	91	1			41	4	66	2	91		41	1	66		41	1	66	1	41	
42	2	42	1	67	2	42	1	67	2	92	2			42	5	67	4	92		42	1	67		42	2	67	2	42	
43	1	43	1	68		43	2	68	2	93	1			43	3	68	1	93		43	1	68		43	2	68	2	43	
44	2	44	2	69		44	3	69	2	94	2			44	1	69	2	94		44	1	69		44	1	69	1	44	
45	1	45	1	70		45	5	70	2	95	5			45	1	70	2	95		45	2	70		45	1	70	3	45	
46	1	46	2	71		46	1	71	2	96	2			46	1	71	2	96		46	1	71		46	1	71		46	
47	1	47	1	72		47	1	72	3	97	2			47	1	72	2	97		47	2	72		47	2	72		47	
48		48	2	73		48	3	73	2	98	2			48	1	73	1	98		48	2	73		48	2	73		48	
49		49	2	74		49	2	74	1	99	3			49	1	74	2	99		49	1	74		49	1	74		49	
50		50	1	75		50	2	75	3	100	1			50	3	75	2	100		50	4	75		50	1	75		50	

Table 5: Full names of CWTS Scientists Investigated.

S/N	Names	Initials	Number of Papers	n_{mean}	r_{mean}	C_s
1.	Clara Calero-Medina	CCM	15	4.00	1.93	2.60
2.	Rodrigo Costas	RC	47	2.77	1.47	3.22
3.	Nees Jan van Eck	NJE	67	3.00	1.97	3.41
4.	Joost Kosten	JK	3	8.00	2.67	2.09
5.	Thed van Leeuwen	TL	102	3.02	2.04	3.86
6.	Ingeborg Meijer	IM	4	3.50	1.75	1.82
7.	Ed Noyons	EN	26	3.54	2.19	2.79
8.	Tong van Raan	TR	82	2.56	2.32	3.18
9.	Sarah de Rijcke	SR	10	2.40	1.70	2.03
10.	Alex Rushforth	AR	4	2.50	1.75	1.63
11.	Clifford Tatum	CT	4	3.75	3.25	1.57
12.	Robert Tijssen	RT	65	2.86	1.97	3.33
13.	Vincent Traag	VT	7	3.14	1.43	2.09
14.	Martijn Visser	MV	20	4.70	3.80	2.48
15.	Ludo Waltman	LW	70	2.94	1.56	3.59
16.	Inge van der Weijden	IW	14	3.43	2.00	2.41
17.	Erik van Wijk	EW	7	2.57	2.43	1.68
18.	Jos Winnink	JW	4	2.25	1.25	1.68
19.	Paul Wouters	PW	38	2.97	2.63	2.67
20.	Alfredo Yegros	AY	12	2.67	2.17	2.06
21.	Zohreh Zahedi	ZZ	15	3.67	1.47	2.48

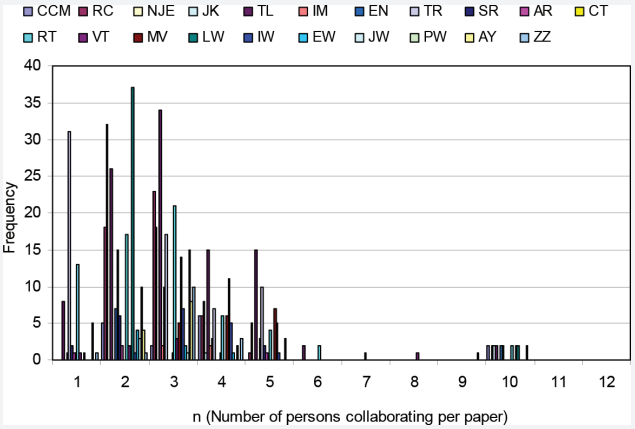

Figure 1: Frequency distribution of n for the study.

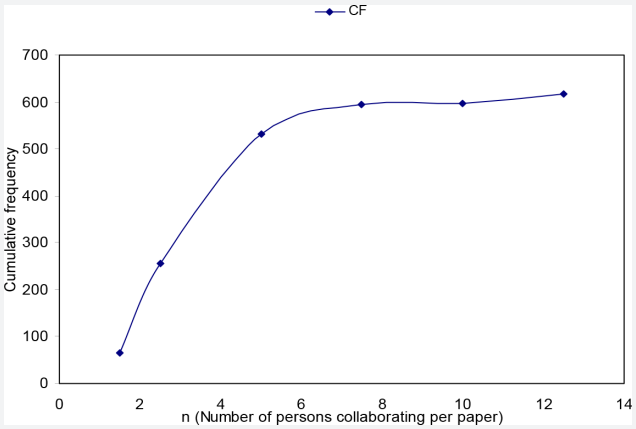

Figure 2: Cumulative frequency of n for the study.

and Voutilainen and Kangasniem.[2] Count of number of listed authors and total number of publications have also been used in Nature Index.[6,9,10,16]

RESULTS AND DISCUSSION

Tables 1 and 2 present the distribution of number of persons (n); collaborating per publication. These Tables give the overview of n distribution for the study. Similarly, Tables 3 and 4 present the distribution of position (r) of authors listed in a publication. The Tables provide overview of distribution of r of listed authors in a publication. In Table 5, the full names of the initials of CWTS scientists investigated in this study are presented. In this Table, the total number of publications, n_{mean}, r_{mean} and C_S for each staff is indicated.

The frequency distribution and cumulative frequency of number of persons (n) collaborating per publication for the study are presented in Figure 1 and 2 respectively. From these Figure, it can be seen that, CWTS scientists collaborate mostly

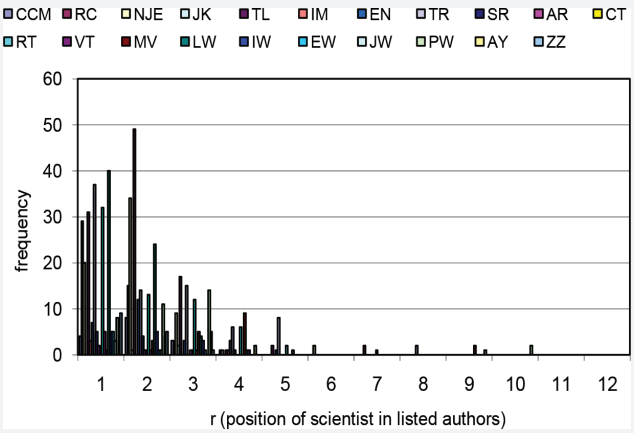

Figure 3: Frequency distribution of r for the study.

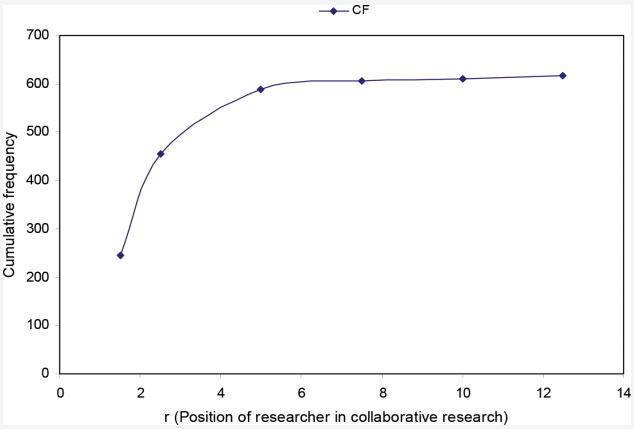

Figure 4: Cumulative frequency of r for the study.

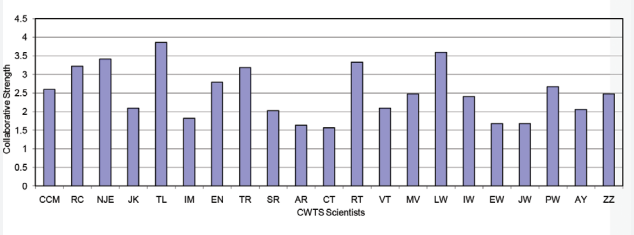

Figure 5: Distribution of collaborative strength.

in groups ranging from 1 to about 5 persons in a group. Specifically, the lower quartile from Figure 2 shows that about 25% of the papers are published by groups consisting of 1 or 2 persons; while the upper quartile from Figure 2 shows that about 75% of the papers are published by groups consisting of 1 to 4 persons.

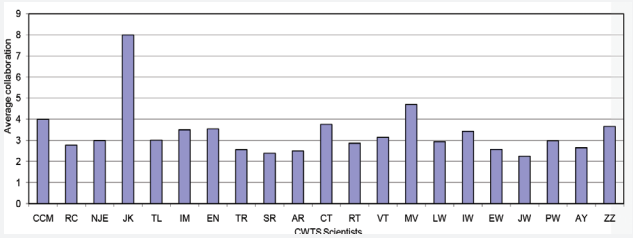

Figure 6: Distribution of average collaborations.

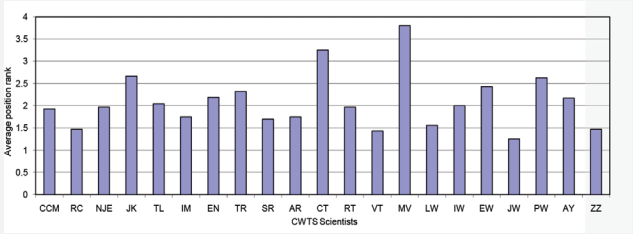

Figure 7: Distribution of average position ranks.

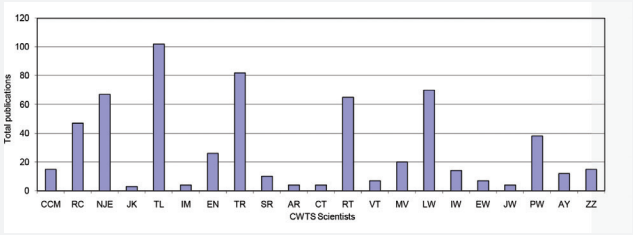

Figure 8: Distribution of total number of publications by each scientists.

Similarly, Figure 3 and 4 illustrate the frequency distribution and cumulative frequency of the positions of CWTS scientists in collaborative researches. From Figure 3, it is clear that these scientists are mostly listed between the first and third authors listed on the publications studied. It is in about 40% of the collaborations that CWTS staffs have been listed as first author.

Table 5 and Figure 5 to 8; present information on collaborative strength, average collaborations, average position ranks, and total number of publication per scientist. Overall, Thed van Leuween has the highest collaborative strength. He has published about 102 scientific articles, which translates to the fact that he has utilized about 102 opportunities for scientific collaborations. His average collaborations per publication (n_{mean}) and average position rank (r_{mean}) are 3.02 and 2.04 respectively. This implies that ordinarily, Thed van Leuween

collaborates with about three persons per publication and is mostly either the first or the second author listed. Although in Figure 6 and 7; Joost Kosten has the highest average collaborations per publication while Jos Winnink has the strongest position rank, however, the total number of publications by these staffs is rather very small, and the reason for their observed weak collaborative strength.

Comparing Tong van Raan and Ludo Waltman, overall, Ludo Waltman has better collaborative strength despite that Tong van Raan has published more. Ludo Waltman published a total of 70 papers, while Tong van Raan published 82 papers. However, overall, Ludo Waltman has better collaborative strength because on the average, Ludo collaborates with about 3 persons per publication and is mostly the first listed author, where as Tong van Raan collaborates with about 2 persons per publication and mostly listed as the second author.

Ingeborg Meijer; Alex Rushforth; Clifford Tatum and Jos Winnink have all published the same number of publication which is 4. Ingeborg Meijer has the highest collaborative strength because he publishes with 3 or 4 persons per publication, and is mostly listed as the second author. Jos Winnink is next to Ingeborg Meijer. Although, Jos Winnink collaborates mostly with 2 persons, however, he is mostly listed as the first author in publications. Alex Rushforth is in third place. He collaborates mostly with 2 persons and is mostly listed as the second author. Clifford Tatum is last in this set. Although he collaborates mostly with 3 or 4 persons, however, his collaborative strength is weak because he is mostly the last or second last author listed.

CONCLUSION

A new scheme for evaluation of scientific collaboration has been introduced. The importance of total number of publications on the measure of collaboration as reported in earlier studies is upheld by the study. The role of number of persons collaborating in a particular research, and the relative positions of the collaborators in their published research is also confirmed relevant and important to overall measure of scientific collaborations.

ACKNOWLEDGEMENT

None.

CONFLICT OF INTEREST

None

REFERENCES

1. Basu A, Kumar BSV. International Collaboration in Indian Scientific Papers; Scientometrics. 2000;48(3):381-402. doi:10.1023/A:1005692505687.
2. Voutilainen A, Kangasniemi M. Applying the ecological Shannon's diversity index to measure research collaboration based on co-authorship: A pilot study; Journal of Scientometric Research. 2015;4(3):172-7.
3. Katz JS, Martin BR. What is research collaboration? Research Policy. 1997;26(1):1-18.
4. Lee S, Bozeman B. The Impact of Research Collaboration on Scientific Productivity; Social Studies of Science. 2005;35(5):673-702.
5. Beaver D, Rosen R. Studies in Scientific Collaboration: Part III - Professionalization and the Natural History of Modern Scientific Co-authorship, Scientometrics. 1979;1(3):231-45.
6. Nature Index. A guide to the nature index, Nature Index. 2015;S83.
7. Perez OH. Collaborative Information Behaviour in Completely Online Groups: Exploring the Social Dimensions of Information in Virtual Environments; Qualitative and Quantitative Methods in Libraries (QQML) Journal. 2015;4(5):775-87.
8. Shah C. The blind leading the blind: Impromptu leaderships influenced by awareness in collaborative search, Aslib Journal of Information Management. 2016;68(2):212-26. DOI http://dx.doi.org/10.1108/AJIM-08-2015-0125.
9. Philips N. Nature Index 2016 – Rising Stars; Nature. 2016;535(7613):S49-S88.
10. Nature Index. Nature Index 2016 – Rising Stars. 2016;S49.
11. Bozeman B, Fay D, Slade CP. Research collaboration in universities and academic entrepreneurship: The state of the art; Journal of Technology Transfer. 2013;38(1):1-67
12. Brew A, Boud D, Lucas L, Crawford K. Reflexive deliberation in international research collaboration: Minimizing risk and maximizing opportunity. High Educ. 2013;66(1):93-104.
13. Gal D, Glanzel W, Sipido KR. Mapping cross-border collaboration and communication in cardiovascular research from 1992 to 2012; European Heart Journal (Special Article). 2016;(16)1249-58. doi:10.1093/eurheartj/ehw459.
14. Sangam SL, Arali U. Growth versus scientific collaboration in the field of genetics: A scientometrics analysis, COLLNET Journal of Scientometrics and Information Management. 2016;10(1)9-19. http://dx.doi.org/10.1080/09737766.2016.1177938.
15. Landry R, Amara N. The Impact of Transaction Costs on the Institutional Structuration of Collaborative Academic Research', Research Policy. 1998;27(9):901-13.
16. Grayson M, Pincock S. Nature Index 2015 – Collaborations; Nature. 2016: 527(7577):49.
17. Egghe L. Theory and practise of the g-index, Scientometrics. 2006:69(1):131-52. doi:10.1007/s11192-006-0144-7.
18. Hirsch JE. "An index to quantify an individual's scientific research output". Proceedings of the National academy of Science. 2005;102(46):16569-72.
19. Cornell University Library, Measuring your research impact: i10-Index; Retrieved August 18, 2016, from: http://guides.library.cornell.edu/c.php?g=32272andp=203393.
20. Webometric. (2016) Rankings based on Google Scholar Citations: Methodology, Retrieved January 23rd, 2017 from: http://www.webometrics.info/en/node/179.