A scientometric analysis of international collaboration and growth of literature at the macro level

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ABSTRACT
The aim of this study is to analyze international collaboration and growth of literature at the macro level using the two new indices, Relative International Collaboration Rate (RICR) and Relative Growth Index (RGI). To illustrate these indices, literature on the field of tribology covered in SCOPUS during 1998 – 2012 is used. As tribology is highly interdisciplinary in nature, which can be demonstrated by the indices, both indices can be used for other subject disciplines.

Keywords: Scientometrics; Bibliometrics; International Collaboratio;, Literature Growth; Tribology.

INTRODUCTION

According to van Raan (2005), scientometric methods have been used in many disciplines of science and engineering to measure scientific progress. Scientometric indicators are useful to help scientists and decision makers to obtain valuable information on science (Jin and Rousseau 2004). There are three levels of bibliometric studies: macro (countries, scientific disciplines), meso (research centers, university departments, scientific sub-disciplines) and micro (single papers, individual researchers) (Vinkler 1988; Glänzel and Moed 2002; Fiala 2014). Macro-indicators, especially national science indicators (a database of summary publication and citation statistics that reflect research performance in over 180 countries) are standard tools in scientometrics and provide a comprehensive picture of national research output (Moed, Glänzel and Schmoch 2004).

In recent years, the analysis of growth rates in terms of articles or patents is of interest by the researchers around the world (Elango, Rajendran and Manickaraj 2013; Milanez, et al. 2013; Zhou and Bornmann 2015). Collaborative research has become the norm, and collaboration across national boundaries has generally increased, as reflected in international co-authorship of research articles (National Science Board 2012). To the best of our knowledge, there has been no indicator to compare the growth rate and share of international collaborative papers of a specific country during a certain time period with the average over all countries. To substitute this, two new relative indicators called

Relative Growth Index (RGI) and Relative International Collaboration Rate (RICR) are introduced in this study.

OBJECTIVES

The objective of this paper is to analyze international collaboration and growth of literature using two new indices, Relative International Collaboration Rate (RICR) and Relative Growth Index (RGI). Further, the present study is designed to answer the following research question: How can growth rate (or share of international collaborative papers) of a country be compared with average of a data set?

To illustrate the indices, literature on the field of tribology covered in SCOPUS during 1998 – 2012 is used as an example. Tribology is defined as the science and engineering of surface phenomena such as friction, wear, lubrication, adhesion, surface fatigue, and erosion. (www.engineeringmaterials.org/tribology). It is multidisciplinary in nature, and includes mechanical engineering (especially machine elements such as journal and roller bearings and gears), materials science, with research into wear resistance, surface technology with surface topography analysis and coatings, and the chemistry of lubricants and additives (Mang, Bobzin and Bartel 2011).

METHODOLOGY

The SCOPUS database is used to retrieve the bibliographic records related to tribology research for the period of 15 years from 1998 to 2012. The following keywords are used in the combined fields of title, abstract and keywords: **tribolog* OR "tribosyst*" OR "tribo-syst*" OR "tribo-chem*" OR "tribochem*" OR "tribotechn*" OR "tribo-physi*" OR "tribophysi*".* Similar to Elango, Rajendran and Bornmann (2013), the search is refined to restrict the literature to articles, conference papers and reviews. Examples of the procedure to count the author's country of origin is provided in Table 1. The whole counting method is applied to give credit to all the contributing countries.

Table 1: Detailed Data Cleaning Procedure (examples)

Author	Affiliation	Remarks
Maalekian, M.	Institute for Materials Science and Welding, Graz University of Technology, Graz, **Austria**, Department of Materials Engineering, University of British Columbia, Vancouver, Canada	Only primary affiliation is considered and others discarded.
Lovell, M.R.	Department of Industrial Engineering, University of Wisconsin-Milwaukee, Milwaukee, WI 53201, **India**	Country of affiliation is corrected.
Sasaki, S.	National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8564, Japan, **American Ceramic Society, United States**	Author's professional associations are discarded.
Nakamura, E.	Toyota Motor Corporation	Internet is used to confirm the country of affiliation where it is not available.

SCIENTOMETRIC INDICES

Growth Rate

Compound Annual Growth Rate (CAGR) is used to give an indication of yearly growth (Choi, Lee and Sung 2011):

$$CAGR = \frac{End\ Value}{Beginning\ Value}^{\frac{1}{n-1}} - 1$$

Share of International Collaborative Papers

The Share of International Collaborative Papers (SICP) measures the internationally co-authored publications in the national total as well as the strength of co-publication links between countries (Glänzel 2000).

Relative Growth Index

Relative Growth Index (RGI) is obtained by dividing the growth rate of a specific country during a period by a corresponding growth rate of all countries during the same period:

$$\text{RGI} = \frac{\text{Growth Rate of a Country}}{\text{Growth of all Countries}}$$

RGI = 1 indicates that a country's growth rate is equal to the global average; RGI > 1 indicates that a country's growth rate is greater than the world average and RGI < 1 indicates a lower growth rate.

Relative International Collaboration Rate

The Relative International Collaboration Rate (RICR) is obtained by dividing the percentage of international collaborative papers of a country by the percentage of international collaborative papers of all countries. It is a simplified version of the International Collaboration Index (ICI) suggested by Garg and Padhi (2001):

$$\text{RICR} = \frac{\text{Share of ICP of a country}}{\text{Share of ICP in the data set}}$$

RICR = 1 indicates that a country's international collaboration rate is equal to the global rate; RICR > 1 (or RICR < 1) indicates that a country's international collaboration rate is greater (or lower) than the world average.

RESULTS AND DISCUSSION

A total of 27 952 articles published research on tribology during the study period (1998-2012). There is no country information for 700 articles. Thus, the final sample consists of 27 252 articles from 108 countries.

The share of international collaborative papers has increased from 10% in the first five year period to almost 15% in the last five year period (Table 2). Almost 14% of all papers were published with international collaboration during the study period.

Table 2: Share of International Collaborative Papers in Five Year Block Periods

Block Period	ICP	TP	SICP
1998-2002	481	4794	10.03
2003-2007	993	6800	14.60
2008-2012	2315	15658	14.78
Total	3789	27252	13.90

ICP = International Collaborative Papers, TP = Total Papers, SICP = Share of International Collaborative Papers

Almost 8% of annual growth rate has been observed in the production of research articles during the study period. Among the 108 contributing countries, there is no article produced either in 1998 or in 2012 for 55 countries. Only a single article was produced by two countries (Morocco and Senegal) both in 1998 and in 2012. So, the growth rate for these two countries is zero. The information on growth of articles and the corresponding RGI for the remaining 51 countries is provided in Table 3 and illustrated in Figure 1. Among these 51 countries, RGI is greater than 1 for 33 countries which states that the growth of publications for these countries is higher than the average of 8%. RGI for the remaining countries is lower than 1 which indicates that the growth of publications of these countries is lower than the average of 8%.

Table 3**:** Growth Rate & Relative Growth Index of Countries

Country	CAGR	RGI
Austria	28	3.51
Malaysia	25	3.14
Spain	21	2.65
Portugal	20	2.55
Brazil	20	2.54
Turkey	20	2.51
India	19	2.44
Romania	17	2.12
Slovakia	17	2.12
Tunisia	17	2.12
Croatia	16	2.00
South Korea	16	2.00
Argentina	15	1.86
Norway	15	1.86
China	15	1.86
Canada	14	1.71
Slovenia	14	1.71
Taiwan	13	1.65

CAGR = Compound Annual Growth Rate, RGI = Relative Growth Index

Country	CAGR	RGI
Poland	13	1.62
Greece	13	1.59
Algeria	12	1.52
South Africa	12	1.52
Netherlands	11	1.43
Bulgaria	10	1.30
Hungary	10	1.30
Italy	10	1.28
Switzerland	10	1.27
Czech Republic	10	1.20
Hong Kong	10	1.20
Serbia	10	1.20
Australia	8	1.02
Egypt	8	1.02
Sweden	8	1.00
Israel	8	0.95
United Kingdom	7	0.91
Thailand	7	0.91
Singapore	6	0.81
Germany	6	0.70
France	5	0.67
Denmark	5	0.63
Ukraine	5	0.63
Finland	4	0.51
Russian Federation	4	0.50
Belgium	3	0.39
United States	3	0.37
Venezuela	3	0.37
Belarus	3	0.34
Japan	2	0.28
Jordan	-5	-0.60
Kuwait	-5	-0.60
Armenia	-8	-0.94

CAGR = Compound Annual Growth Rate, RGI = Relative Growth Index

It is observed from Figure 1 that the countries having RGI score more than 1 are mapped above the average line and remaining countries are mapped below the average line.

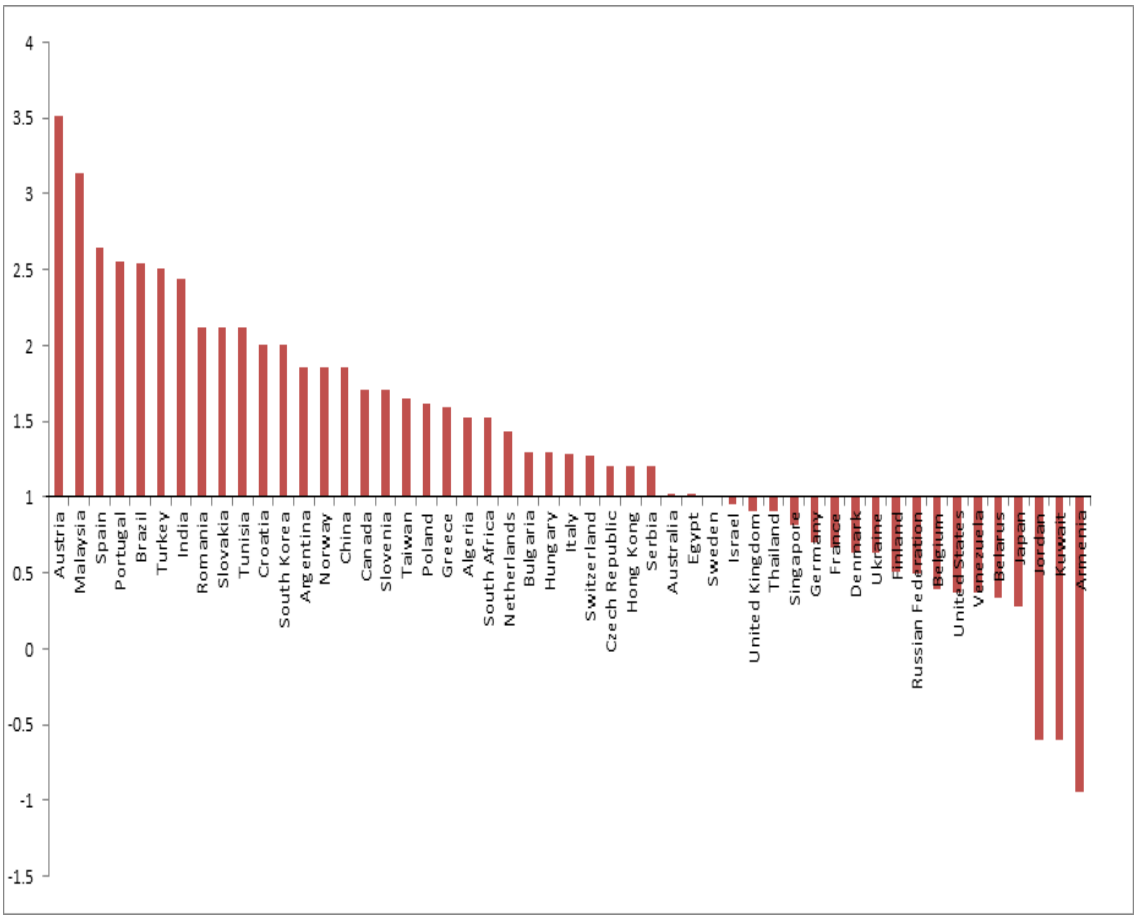

Figure 1: Relative Growth Index and its Associated Countries

There is no article in international collaboration for six countries (Azerbaijan, Kenya, Botswana, Cameroon, Jamaica and Puerto Rico). Therefore, the share of international collaborative papers is zero for these six countries. The share of international collaborative papers and corresponding RICR for the remaining 102 countries is provided in Table 4. Among these countries, RICR is lower than 1 for two countries (China and Taiwan) which states that the share of international collaborative papers of these countries is below the average of 13.9%. RICR is greater than 1 for remaining countries which states that the share of international collaborative papers is higher than the average of 13.9%.

CONCLUSION

Two new relative indices, Relative International Collaboration Rate (RICR) and Relative Growth Index (RGI) have been introduced in this study. These two indices have been illustrated with a sample of literature on the field of tribology covered in SCOPUS bibliographic database during 1998 – 2012. It is believed that the indicators illustrated in this study could be useful to the general scientometrics and bibliometrics community for research assessment on international collaboration at the macro level.

Table 4: Share of International Collaborative Papers and Relative International Collaborative Rate of Countries

Country	SICP	RICR
Cyprus	100	7.19
Viet Nam	100	7.19
Uzbekistan	100	7.19
Qatar	100	7.19
Kazakhstan	100	7.19
Syrian Arab Republic	100	7.19
Tajikistan	100	7.19
Uganda	100	7.19
Montenegro	100	7.19
Benin	100	7.19
Cote d'Ivoire	100	7.19
Ecuador	100	7.19
Ghana	100	7.19
Malta	100	7.19
Mauritius	100	7.19
Myanmar	100	7.19
Sri Lanka	100	7.19
Trinidad and Tobago	100	7.19
Libyan Arab Jamahiriya	100	7.19
Tanzania	100	7.19
El Salvador	100	7.19
Luxembourg	94.44	6.79
Indonesia	90.91	6.54
Latvia	87.50	6.29
Morocco	85.71	6.16
Algeria	83.33	5.99
Liechtenstein	83.33	5.99
United Arab Emirates	80.00	5.75
Bosnia and Herzegovina	77.78	5.59
Pakistan	76.92	5.53
Venezuela	71.11	5.11
Iraq	66.67	4.79
Iceland	66.67	4.79
Hong Kong	62.69	4.51
Tunisia	62.22	4.48
Colombia	60.94	4.38
Moldova	60.00	4.32

SICP = Share of International Collaborative Papers, RICR = Relative International Collaboration Rate

Country	SICP	RICR
Jordan	57.89	4.16
Saudi Arabia	57.50	4.14
Hungary	56.52	4.07
Cuba	55.56	4.00
Czech Republic	54.74	3.94
Switzerland	52.45	3.77
Bangladesh	52.17	3.75
Mexico	52.13	3.75
Slovakia	51.16	3.68
New Zealand	50.00	3.60
Oman	50.00	3.60
Georgia	50.00	3.60
Senegal	50.00	3.60
Zimbabwe	50.00	3.60
Belgium	49.41	3.55
Austria	48.75	3.51
Norway	48.28	3.47
Argentina	48.15	3.46
Croatia	47.92	3.45
Chile	47.06	3.38
Ireland	45.65	3.28
Canada	45.17	3.25
Australia	45.12	3.25
Kuwait	44.44	3.20
Spain	43.95	3.16
Lebanon	42.86	3.08
Portugal	42.26	3.04
Macedonia	41.94	3.02
Bulgaria	41.38	2.98
Denmark	41.30	2.97
Estonia	40.54	2.92
France	38.75	2.79
Armenia	38.46	2.77
United Kingdom	38.43	2.76
Netherlands	38.35	2.76
South Africa	34.09	2.45
Brazil	33.43	2.40
Thailand	33.33	2.40
Bahrain	33.33	2.40

SICP = Share of International Collaborative Papers, RICR = Relative International Collaboration Rate

Country	SICP	RICR
Israel	32.96	2.37
Italy	32.46	2.33
Slovenia	32.45	2.33
Finland	31.25	2.25
Greece	30.58	2.20
Germany	30.48	2.19
Egypt	30.11	2.17
Singapore	29.96	2.16
Poland	29.24	2.10
Sweden	29.21	2.10
Malaysia	28.57	2.05
Ukraine	28.09	2.02
Romania	28.06	2.02
South Korea	27.20	1.96
United States	26.76	1.92
Belarus	26.03	1.87
Lithuania	25.00	1.80
Russian Federation	23.23	1.67
Serbia	22.06	1.59
Nigeria	20.00	1.44
Iran	18.27	1.31
Turkey	17.41	1.25
India	17.05	1.23
Japan	13.89	1.00
China	10.08	0.73
Taiwan	9.43	0.68

SICP = Share of International Collaborative Papers, RICR = Relative International Collaboration Rate

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