

S & T COLLABORATION: A QUANTITATIVE STUDY

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Abstract

Collaboration pattern amongst the Scientists have been already consented as a major indicator of scientific progress. Many studies have been reported on collaborative issues in different disciplines across the world. All these reports have established the fact that there is an increasing tendency of collaborative writing, especially among the Scientists. It is a complex social phenomenon in research which needs to be analyzed quantitatively and qualitatively. This warrants regular evaluation of research inputs and outputs.

Collaborative research is reflected through authorship pattern and co-authorship is an established form of research collaboration. Collaboration, generally, involves intra- & inter-cooperation. Consequently, these two approaches can involve intra- and inter-personal as well as intra- and inter-institutional collaborations. This approach of evaluation also reflects national and international collaboration which is a significant reflection of a country's scientific status.

Co-authorship has undergone several changes over the years, due to various determining factors such as national policies, size of the country and its scientific population, political and economical reasons, historical, cultural, linguistic and geopolitical influences.

Increased collaborative efforts and activities, motivations, affiliations, aggregation and evaluation not only imply 'big science' and globalization process in scientific research, but also support the hypothesis that 'R & D output seem to be increasing'.

On this ground, this paper aims at identifying S&T collaboration amongst the scientist spread over the world. To accomplish this objective, it is decided to analyze the S& T journals. As the journals base is voluminous, an attempt has been made to confine this study to evaluate only a selective set of S&T journals. Hence, the S & T journals subscribed at Anna University, Chennai, India has been chosen for the study. It is one of the premier S&T academic institutions in the country and of world repute. The selected samples of S&T journals include a total number of about 50 journals in English. These journals are identified to browse each issue to collect all the relevant details regarding authorship. This is estimated to yield around 3000 articles. On completion of the data collection of the authorship alone from each of the articles, quantitative analysis will be carried over to find out the authorship and co-authorship pattern amongst the S& T experts at the global level. Based on the analysis, inferences and interpretations will be drawn.

1 Introduction

Collaboration pattern amongst the Scientists have been already consented as a major indicator of scientific progress. Many studies have been reported on collaborative issues in different disciplines across the world. All these reports have established the fact, that there is an increasing

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tendency of collaborative writing, especially among the Scientists. It is a complex social phenomenon in research which needs to be analyzed quantitatively and qualitatively. This warrants regular evaluation of research inputs and outputs.

Collaborative research is reflected through authorship and co-authorship pattern is an established form of research collaboration. Collaboration, generally, involves intra- & inter-collaboration. Consequently, these two approaches can involve intra- and inter-personal as well as intra- and inter-institutional collaborations. This approach of evaluation also reflects national and international collaboration which is a significant reflection of a country's scientific status.

Co-authorship has undergone several changes over the years, due to various determining factors such as national policies, size of the country and its scientific population, political and economical reasons, historical, cultural, linguistic and geopolitical influences.

Increased collaborative efforts and activities, motivations, affiliations, aggregation and evaluation not only imply 'big science' and globalization process in scientific research, but also support the hypothesis that 'R & D output seem to be increasing'.

2 Means & Methods

This paper seeks to examine the pattern of collaboration amongst the scientists across the world. To accomplish this objective, it is decided to analyze the S&T journals. As the journals base is voluminous, an attempt has been made to confine this study to evaluate only a selective set of S&T journals. Hence, the S & T journals subscribed at Anna University, Chennai, India (one of the premier S&T academic institutions in the country and of world repute) has been chosen for the study.

The selected samples of S&T journals include the following five premier journals in the field of Engineering. Details of the chosen journals are as follows:

Table 1 Select S&T journals - Details

SOURCE JOURNAL	COUNTRY	FREQUENCY	YEAR OF ORIGIN	SUBSCRIPTION SINCE
ASCE-CEM	U.S.A	Bi-Monthly	1875	1966-Till Date
ASCE-JHE	U.S.A	Monthly	1875	1956-Till Date
ASME-JT	U.S.A	Quarterly	1879	1983-Till Date
PICE	U.K	Quarterly	1836	1997-Till Date
TRJ	U.K	Monthly	1931	1980-Till Date

ASCE-JCEM – ASCE- Journal of Construction Engineering & Management

ASCE-JHE - ASCE-Journal of Hydraulic Engineering

ASME-JT – ASME -Journal of Tribology

PICE – Proceedings of Institute of Civil Engineers (Transport)

TRJ - Textile Research Journal

The period chosen for this study spans for a period of five years, 2001-2005. The authorship data – names of the author/s and the country of the author/s were collected from each of the issues of the above stated primary journals for the chosen period. No secondary database was used for this purpose.

The collected data has been analyzed quantitatively to identify the authorship and co-authorship pattern amongst the S& T experts at the global level. A working database was developed using MS- Excel. A further analysis was carried out using FoxPro to identify the authorship and co-authorship pattern. Using SPSS, cluster analysis was carried out to identify the collaboration pattern amongst the authors both at the Intra- and Inter level. Based on the analysis, inferences and interpretations are drawn.

3. Results

Co-authorship has been used as an indicator of linkages and communication networks amongst the experts in this study, as has been reported in several earlier such studies.

3.1. Authorship Pattern

Table 2 shows the quantum of papers of the selected sample set of journals.

YEAR	ASCE-CEM	ASCE-JHE	ASME-JT	PICE	TRJ	TOTAL
2001	67	89	118	28	162	464
2002	73	158	113	26	169	539
2003	93	150	109	21	170	543
2004	111	166	109	23	172	581
2005	155	155	110	21	122	563
TOTAL	499	718	559	119	795	2690

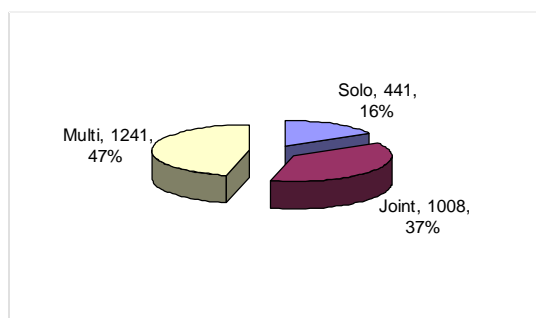
This raw data was examined for the authorship pattern as reflected in the following table:

Table 3 – Authorship Pattern

AUTHORSHIP PATTERN	2001	2002	2003	2004	2005	TOTAL
SOLO	82	109	77	80	93	441
JOINT	187	191	227	198	205	1008
MULTIPLE (More than Two Authors)	195	239	239	303	265	1241
TOTAL	464	539	543	581	563	2690

It is found that solo authorship is very low and negligible compared to collaborated authorship. In the collaborative authorship, works by more than two authors (multiple) seem to be more than even by those of two authors (joint). This is observed clearly through the following figure.

Figure 1 – Authorship Pattern



3.2. Collaboration Pattern

The authorship data obtained was grouped under two headings, viz. Intra-collaboration and Inter-collaboration. Intra-collaboration refers to items found with the collaborative authors within a country and the inter-collaboration includes those items for which the authors were from more than one country.

The findings for each of the journal under study are as given in the following tables. Tables 4 A-E indicate the intra-collaborative pattern of the study sample.

Table 4 A - E - INTRA-COLLBARATIVE PATTERN

Table 4 A - ASCE - CEM

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Australia	1			1		2
Brazil			1			1
Canada	9	4	7	3	8	31
China			1	4		5
Egypt	1			1		2
Florida	1					1
Germany					1	1
Greece					1	1
Honk Kong	5	2	7	6	6	26
India	1					1
Israel	1		2	2	5	10
Japan					1	1
Korea	1	1		3	3	8
Malaysia		1	1			2
Nigeria	2					2
Saudi Arabia					1	5
Singapore	2	1	8	4	5	20
Spain				1		1
Stanford			1			1
Taiwan	1		4	2	1	8
Turkey				1	2	3
UK	4		1	1	2	8
USA	8	8	13	1	18	56

Table 4 B – ASCE-JHE

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Argentina		1				1
Australia	1		1	2		4
Austria				1		1
Belgium		2	1	1	1	5
Canada	1	10	3	8	5	27
Chile		1				1
China	1	3	1	2	2	9
Denmark	2					2
Egypt				1		1
France					1	1
Germany		2		4		6
Greece				1	1	2
Honk Kong	3	3	1	2		9
India	3	5	5	3	6	22
Iran		1	2			3
Israel		1				1
Italy	3	6	5	9	11	34
Japan	1	4	4	4	4	13
Korea		2	2		2	6
Mexico					1	1
Netherlands		1			2	3
New Zealand	2	6	2	1	1	12
Portugal		2	1		5	8
Singapore	1	1	2	2	2	8
South Africa			2			2
Spain				4	3	7
Sweden	1			1		2
Switzerland	3	4	3	2	4	16
Taiwan	2	7	3	5	2	19
Turkey		1		2	3	5
UK	1	5	13	4	6	29
USA	17	19	28	34	30	128
Venezuela				2		2

Table 4 C – ASME-JT

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Argentina				1	1	2
Argonne			1			1
Australia		2			1	3
China	2		3	1	4	10
France		1		3	3	7
Honk Kong	1	1				2
India				1	1	2
Japan	2	2	3		1	8
Korea						
Mexico			1			1
Netherlands				1		1
Romania	1	1				2
Russia	1					
Sweden		1				1
UK	1		2	1		4
USA	4	2	6	6	3	21
Venezuela	1					
West Greenwich		1				

Table 4 D - PICE

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Brunei Darussalam		1				1
China		1				1
Honk Kong			2		4	6
New Zealand	1					1
Singapore			2			2
Spain				1	1	2
Turkey				1		1
UK	7	12	9	7	8	43
USA			1		1	2

Table 4 E – TRJ

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Australia	7	2	5	9	1	24
Austria	1	1	1		2	5
Belgium	1	2	1		2	6
Canada	1		1	1		3
China	15	16	25	32	15	103
Croatia	2		2			4
Denmark		2				2
Finland	3	1	1			5
France	14	5	2	2	1	24
Germany		3	2	3		8
Greece					1	1
Honk Kong	8	10	12	10	5	45
Hungary					1	1
India	2	1	1	6	2	12
Iran					1	1
Italy	1	1		3		5
Japan	15	17	17	13	5	67
Korea	17	12	11	11	11	62
Lithuania			1			1
Netherlands		1	3			4
New Zealand		5		3	1	9
Poland	1	3	2	1		7
Portugal	1	1				2
Slovenia	1	2	1	3	1	8
Spain	3	1	1	1		6
Sweden					1	1
Switzerland			1	1		2
Thailand		1	1	1		3
Turkey	3	2	5	7	8	25
UK	2	7	10	3	1	23
USA	35	30	30	29	32	156

The results of the analysis of the inter-collaborative pattern of the same sample are as given in the following tables. Tables 5A-E indicate the inter-collaborative pattern of the study sample

Tables 5 A-E INTER-COLLBARATIVE PATTERN**Table 5A – ASCE- JCEM**

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Australia	1	1	1	1	1	5
Beaumont	-	-	1	-	-	1
Blooming Glen	-	-	-	1	-	1
Brazil	-	1	-	-	-	1
California	-	-	-	1	-	1
Canada	1	1	2	5	8	17
China	3	2	4	5	2	16
Colombia	-	-	-	1	-	1
Egypt	-	-	1	4	3	8
Honk Kong	2	2	2	2	5	13
Houghton	-	-	-	2	-	2
Iran	-	-	1	-	-	1
Japan	-	-	1	-	1	2
Ketchum	-	-	-	1	-	1
Korea	2	-	2	2	6	12
Lebanon	1	-	-	-	-	1
Malawi	1	1	-	-	1	3
Mexico	-	-	-	1	-	1
New Zealand	-	-	-	-	1	1
Norman	-	-	-	1	-	1
Pal ha(India)	-	-	1	-	-	1
Platteville	-	-	-	1	-	1
Qatar	1	-	-	2	-	3
Saudi Arabia	-	-	-	-	2	2
Singapore	-	1	-	3	2	6
Switzerland	-	-	-	1	-	1
Taiwan	-	-	1	2	1	4
Texas	-	1	1	2	-	4
Thailand	-	-	1	1	-	2
Turkey	-	1	1	2	2	6
UK	3	1	1	1	4	10
USA	3	5	4	5	6	23
Villanova	1	-	-	-	-	1
West Lafayette	-	-	-	2	-	2
Worcester	-	-	-	1	-	1
éclair	-	-	1	-	-	1

Table 5 B – ASCE-JHE

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Australia	-	2	1	3	4	10
Austria	-	1	2	-	2	5
Belgium	-	-	2	1	1	4
Brazil	-	1	1	1	-	3
Canada	1	2	3	2	1	9
China	2	3	5	4	7	21
Denmark	2	-	2	-	-	4
Egypt	-	2	-	1	-	3
Germany	-	1	1	-	-	2
India	-	-	2	1	2	5
Iran	-	1	1	1	3	6
Israel	-	-	-	-	-	-
Italy	-	3	-	1	1	5
Japan	-	1	1	1	1	4
Jordan	-	-	1	-	-	1
Korea	1	2	1	2	2	8
Kuwait	-	-	1	-	1	2
Mexico	-	-	1	-	1	2
Netherlands	1	1	-	1	-	3
New Zealand	1	-	2	2	2	7
Puerto rice	1	-	-	-	-	1
Singapore	1	-	1	2	1	5
South Africa	1	-	-	-	-	1
Sweden	-	-	1	-	-	1
Switzerland	1	1	1	1	-	4
Taiwan	1	-	-	-	-	1
Turkey	1	-	1	1	2	5
UK	1	2	7	4	4	18
USA	3	8	5	4	4	24
Venezuela	-	-	-	1	-	1

Table 5C - ASME-JT

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Argentina				1	1	2
Argonne			1			1
Australia	1	2	1	1	1	6
Canada	-	-	-	1	-	1
China	2	3	5	4	4	18
France		1		3	3	7
Honk Kong	1	1	1	2	1	6
India				1	1	2
Japan	2	2	3	1	1	9
Korea	1	1	2	1	2	7
Mexico			1			1
Netherlands				1		1
New Zealand	1	-	2	-	2	5
Romania	1	1				2
Russia	1					1
Sweden		1				1
Troy				2		2
Turkey	-	1	1	-	1	3
UK	1	2	1	1	2	7
USA	4	2	6	4	3	19
Venezuela	1					1
West Greenwich		1				1

Table 5 D - PICE (Transport)

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Honk Kong	-	-	1	-	-	1
France	-	1	-	-	-	1
Ireland	-	-	-	-	1	1
New Zealand	-	-	-	-	1	1
China	1	2	1	2	1	7
Singapore	-	-	1	-	-	1
UK	1	1	2	1	1	7
USA	2	2	3	2	2	11

Table 5 E- TRJ

COUNTRY	2001	2002	2003	2004	2005	TOTAL
Australia	1	2	1	1	3	8
Algeria	-	-	-	1	-	1
Belgium	-	1	-	-	-	1
Canada	1	-	-	1	-	2
China	4	2	6	6	8	26
Croatia	-	-	1	-	-	1
Denmark	-	2	-	-	-	2
Finland	-	-	-	1	-	1
France	2	1	-	-	1	4
Germany	-	-	-	1	-	1
Honk Kong	2	9	3	2	2	18
Hungary	-	-	1	1	-	2
Iran	1	-	-	-	-	1
Italy	-	1	-	-	-	1
Japan	-	1	1	1	2	5
Korea	3	5	2	3	3	16
Lebanon	-	-	-	1	-	1
Netherlands	-	-	1	-	-	1
New Zealand	1	-	-	1	2	4
Portugal	1	-	-	1	-	2
Slovenia	-	1	-	1	-	2
Spain	1	-	2	-	-	3
Sweden	-	-	1	-	-	1
Tunisia	-	-	-	-	1	1
Turkey	-	1	-	3	2	6
UK	1	1	1	2	2	7
USA	7	5	2	2	2	18
Yugoslavia	1	-	-	-	-	1

The results of the analysis of the inter-collaborative pattern of the same sample was too large but low in value. Hence, decided to present the top ten of the collaboration only (Table 6)

Table 6 – Quantum of Inter Collaboration - Top Ten Countries

COUNTRY	ASCE-CEM	ASCE-JHE	ASME-JT	PICE	TRJ	TOTAL
USA	23	24	19	11	18	95
China	16	21	18	7	26	88
UK	10	18	7	7	7	49
Korea	12	8	7	0	16	43
Honk Kong	13	0	6	1	18	38
Canada	17	9	1	0	2	29
Australia	5	10	6	0	8	29
Japan	2	4	9	0	5	20
Turkey	6	5	3	0	6	20
New Zealand	1	7	5	1	4	18

Other than USA, most of the top ten countries are interestingly from the Asian continent. Of which, China ranks high, followed by Korea, Hong Kong, and Japan.

3.3 Degree of Collaboration

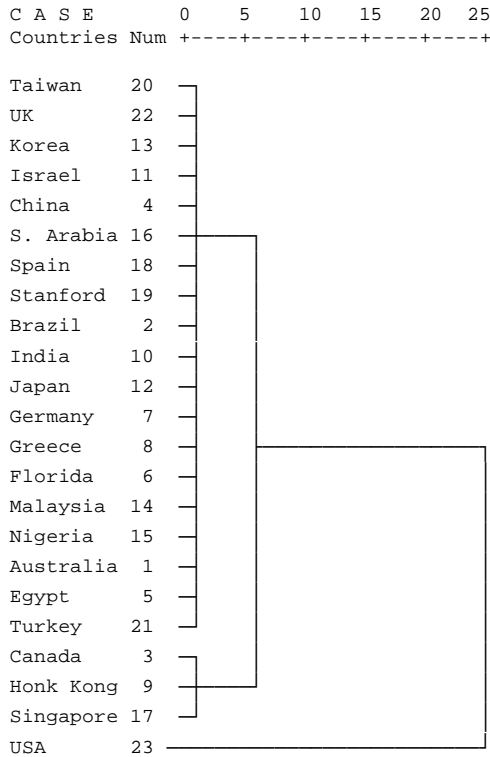
Further analysis was carried out to examine the degree of collaboration at the intra and inter level network amongst the S&T authors (Figures 2 A-E)

3.3.1. Intra-Collaboration

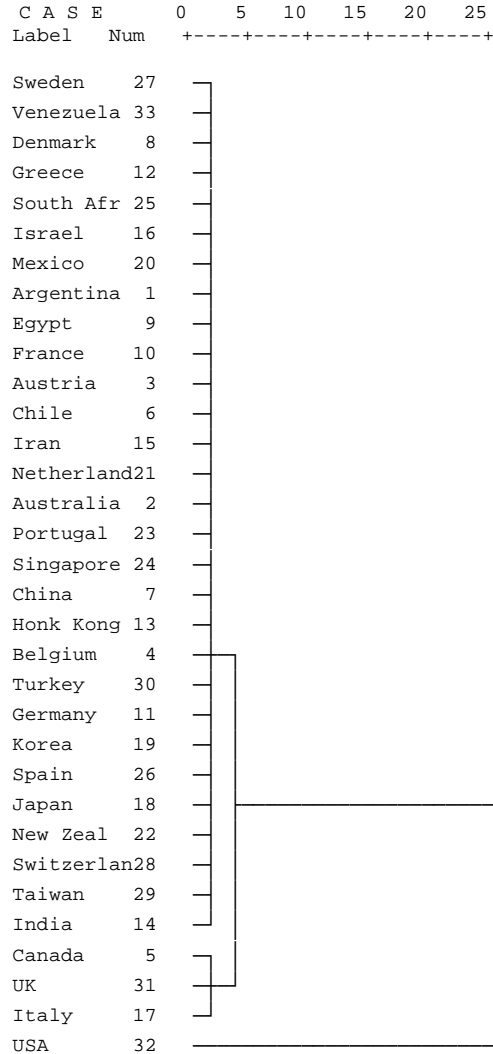
It is seen from the dendrogram (Figure 2) that at 8% level three clusters have been formed. Cluster-I is exclusively within USA. Cluster-II includes three countries namely Singapore, Hong Kong and Canada and the rest forms the third cluster. It is inferred from above analysis that the research productivity on Intra-Collaborative Pattern of authors/contributors to *ASCE Journal of Construction Engineering & Management* is within the four countries (Cluster-I & II) which has been corroborated with the data given in Table 4A.

Figure - 2 A - ASCE JCE

**Average Linkage Method)
Rescaled Distance Cluster Combine**

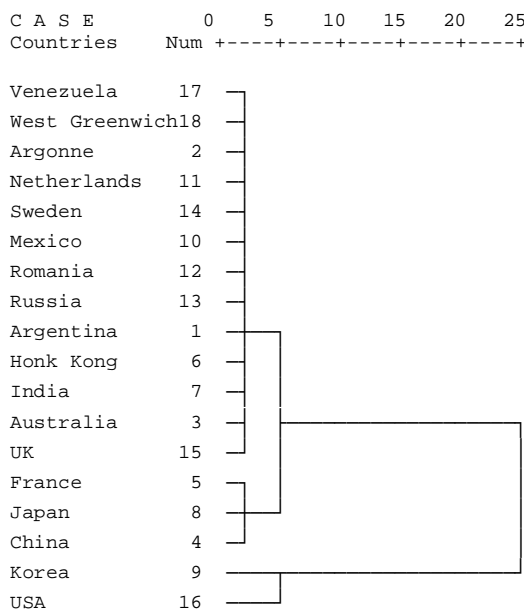


**Figure- 2B ASCE-JHE
Average Linkage Method - Rescaled Distance
Cluster Combine**



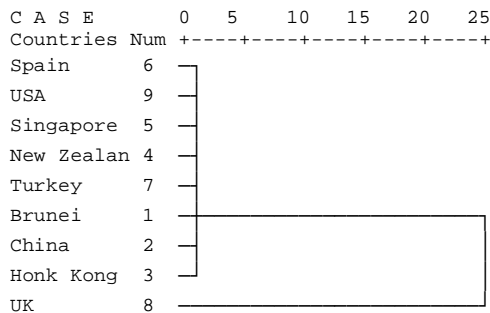
It is seen from the dendrogram(Figure 2 B) that at 4% level three clusters have been formed. Cluster-I is of USA. Cluster-II includes three countries namely Italy, UK and Canada and the rest are formed in the third cluster. It is inferred from above analysis that the research productivity on Intra Collaborative Pattern of countries of Journal of Hydraulic Engineering is highly concentrated within the four countries(Cluster-I & II) which has been corroborated with the data given in Tables 4– B

Figure- 2C ASME-JT
Average Linkage Method
Rescaled Distance Cluster Combine



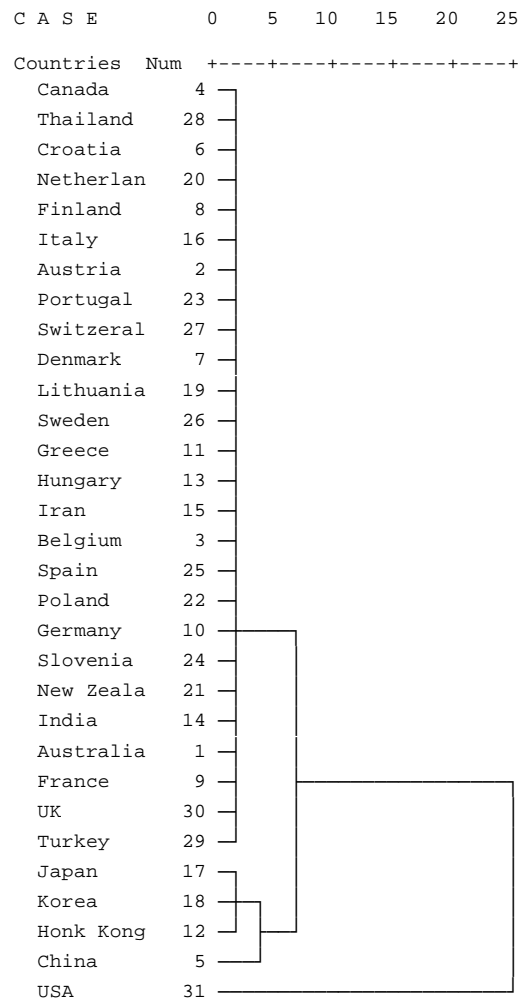
It is seen from the above Figure that at 8% level three clusters have been formed. Cluster-I is with two countries - USA and Korea. Cluster-II has formed with China, Japan and France and the remaining forms the third cluster. Authors are mostly working within these five countries found in cluster I and II (Table 4 B)

Figure 2D - PICE (Transport)
Average Linkage Method
Rescaled Distance Cluster Combine



It is seen from the Figure 2 D, that at 4% level only two clusters have been formed. Cluster-I is formed of and the other is with the rest of the countries. Unlike the authors of other journals, contributors to this journal are concentrating within UK.

Figure- 2E TRJ
Average Linkage Method
Rescaled Distance Cluster Combine



It is seen from the above figure that at 9% level four clusters have been formed. Cluster-I is formed with USA. Cluster-II is formed with China, Cluster-III is formed with three countries namely Hong Kong, Korea and Japan and the remaining is formed in the fourth cluster. Intra-collaboration of this journal is found to be within these five countries (Cluster I-III).

3.3.2. Inter-Collaboration

As the number of countries involved in inter-collaboration is very high, it was decided to present only the result of the analysis of the top ten

countries with reference to the degree of inter-collaboration (Table 7)

USA	Korea-16	UK-14	Turkey-14	Germany-10	China-15
CHINA	Japan-19	H. Kong-19	USA-15	UK-12	Singapore-8
U.K.	USA-14	China-12	Korea-5	New Zealand-5	Netherland-3
KOREA	USA-16	Japan-7	UK-5	Germany-5	Spain-4
HONG KONG	China-19	Australia-5	USA-4	Singapore-4	UK-2
CANADA	USA-5	Korea-3	Egypt-3	Spain-2	UK-1
AUSTRALIA	USA-4	Hongkong-5	UK-4	Spain-3	India-3
JAPAN	USA-7	China-12	Korea-7	Denmark-3	UK-2
TURKEY	USA-14	UK-2	Poland-2	Singapore-2	Germany-2
NEW ZEALAND	UK-6	USA-4	Hong Kong-3	Germany-3	Australia-1

The above table reflects the top ten countries versus their collaborative countries. It can be found that there is a high cross-country collaboration amongst the top ten countries

4. Summary

Like in most of the disciplines, in Science and technology also, multiple authorship seems to rank high than other patterns. An examination of the collaborative pattern of the Scientists based on the analysis of the select sample reveals that the intra-collaborative though in USA is high, it is true that it is similar in the case of other countries also such as that of both the developed and developing countries. With reference to inter-collaborative authorship pattern, Other than USA, those of the Asian countries like China, Korea, Hong Kong and Japan. China, interestingly, seem to be leading in collaborating with authors from other countries, which is a new trend, followed by Korea. This trend is viewed to be healthy and these two and Hong Kong or Japan are no more close worlds or isolates in S&T communication as they were earlier. More the scientific collaboration more will be the interaction, sharing and exchange of scientific knowledge towards the welfare global society.

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