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Unit 14

Collaborations in science

I. Objectives

- What is collaboration?
- What are the reasons for collaboration?
- Different measures of collaboration;
- Steps involved in the calculation of different measures; and
- What can be measured with data on collaboration?

II. Learning Outcome

Collaborative research is an important area of research in Scientometrics; you have learnt this topic in this module. You are now familiar with various indices of collaborative research -- that exists among the individual scientists, institutions and among countries; it may be at the regional, national or at the international levels.

III. Module Structure

1. Introduction

2. Types of collaboration

3. Reasons for collaboration

4. Different measures of collaboration

    4.1 Collaborative Index (CI)

    4.2 Degree of Collaboration (DC)

    4.3 Collaborative Coefficient (CC)

    4.4 Co-authorship Index

    4.5 Domestic Collaborative Index (DCI)

    4.6 International Collaborative Index (ICI)

    4.7 Salton’s Measure for computing collaborative strength

5. Steps involved in calculation of various measures

6. What can be measured with data on collaboration?

    6.1 Co-authorship and collaborative pattern according to countries

    6.2 Domestic and international collaboration profile of different nations

    6.3 Collaboration pattern according to agencies/institutions

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6.6 Change in the pattern of collaboration over a period of time

7. Summary

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1. Introduction

Science is no longer a pursuit of an individual. Collaborative research is an important feature of science. The question arises as to what is collaboration? In simple terms, collaboration can be defined as the working together of two or more researchers to achieve the common goal of producing new knowledge. Collaboration takes place not only in the immediate work environment of researchers, but also extends beyond institutional and national boundaries. Governments in different countries have taken initiatives to enhance contacts among scientists in science through collaborative research programs, both at the national and international levels. Such initiatives have resulted in increased collaborations at national and international levels.

Statistical data indicate that percentage of research produced by teamwork has been growing steadily for more than half acentury[1,2]. For instance, the share of papers written by authors located in two or more different institutions rose from about 33% in 1981 to 50% in 1995, while the total papers rose by about 20%. During the same period, the share of co-authored papers rose from about 6% to 15%. [3]

According to Beaver and Rosen[4] collaboration resulted in response to professionalization and increased knowledge in science. During the 20th century, professionalization of science had its greatest impact on the members of scientific community. And because of this, there has been an increasing trend towards collaboration in almost all fields of science and technology. However, the extent of collaboration and their rate of growth vary from one subject to another, branch to branch of the same subject and from one country to another country. Among all countries involved in collaboration, the US is the major hub which accounted for 17% of all internationally collaborative paper in 2008[5]. The major impact of collaboration on scholarly research is the increase in productivity associated with multiple authorships as well as shared resources and increased funding opportunities.

Articles written in collaboration are more important than those involving no collaboration and articles written in international collaboration receive more citations than articles written in domestic collaboration, which in turn receive more citations than articles written in local collaboration. This implies that internationally co-authored articles represent a more important segment of the world science[6].

2. Types of collaboration

Collaboration in research can take a variety of paths. Based upon the type of participants and the location etc, collaboration can be categorised into three broad categories. These are local collaboration, domestic collaboration and international collaboration. A local collaboration occurs when scientists of two departments of the same institute collaborate; a domestic collaboration takes place when scientists from two or more institutes within the country collaborate and an international collaboration occurs when institutions from two or more countries join hands together to solve a problem. Among all these types of collaborations, the international collaboration has received the maximum attention. International cooperation in science is becoming more frequent and more extensive and is playing a significant role in the production of scientific knowledge. The growth in international cooperation is accompanied by the increase in the number of participating research laboratories or institutions between several countries.

International cooperation in science is caused by two different mechanisms−formal and informal:

- Informal contacts among scientists from different countries like exchange of ideas through informal communication, participation in international conferences. In some cases, this may lead to research collaboration with foreign institutions resulting in the publication of co-authored articles.

- Formal contacts like bilateral or multilateral cooperation agreements among different countries which may lead to exchange of scientists as well as the setting up of joint cooperation programmes. This type of cooperation among nations occurs to resolve global challenges or for strategic reasons. Examples of such cooperation are megaprojects like Large Hadron Collider (Switzerland) and International Thermonuclear Experimental Reactor (France).

3. Reasons for collaboration

Beaver[7] have enumerated the following purposes for which people collaborate:

- Access to expertise.
- Access to equipment, resources, or “staff” one doesn’t have.
- Improved access to funds.
- To obtain prestige or visibility for professional advancement.
- Efficiency: multiplies hands and minds; helps to learn the tacit knowledge that goes with a technique.
- To make progress more rapidly.
- To tackle more important, more comprehensive, and more difficult problems that are global in nature.
- To enhance productivity.
- To get to know people, to create a network, like an “invisible college”.
- To learn new skills or techniques, usually to break into a new field, subfield, or problems.
- To satisfy curiosity, intellectual interest.
- To share the excitement of an area with other people.
- To find flaws more efficiently, reduce errors and mistakes.
- To keep one more focused on research, because others are counting on one to do so.
- To reduce isolation, and to recharge one’s energy and excitement.
- To educate [a student, graduate student, or, oneself]
- To advance knowledge and learning.
- For fun, amusement, and pleasure.

4. Different measures of collaboration

To measure the extent of co-authorship or collaboration, different authors have suggested different methods for computing it. These are described in the following paragraphs.

4.1 Collaborative Index (CI)

The measure was suggested by Lawani[8] and is expressed as follows:

$$CI = \sum_{j=1}^{k} \frac{jf_j}{N}$$

Where f_j denotes the number of j authored research papers published in a discipline in a certain period of time; N denotes total number of research papers published in the same discipline during the same period of time and k is the greatest number of authors per paper in that discipline.

4.2 Degree of Collaboration (DC)

The measure was suggested by Subramanyam[9] and is expressed as follows:

$$DC = 1 - \frac{f_1}{N}$$

Where f_1 is the number of single author papers.

4.3 Collaborative Coefficient (CC)

Ajiferuke[10] pointed out that the above two measures were inadequate and suggested a single measure, which incorporates some of the merits of both and calls it collaborative coefficient. The method is based on fractional productivity defined by Price and Beaver[11]. It is given by the following formula and the symbols used in the formula have been explained above under collaborative index.

$$CC = 1 - \frac{\sum_{j=1}^{k} (1/j) f_j}{N}$$

According to Ajiferuke, CC tends to zero as single authored papers dominate and to 1-1/j as j-authored papers dominate. This implies that higher the value of CC, higher the probability of papers with multi or mega authors. Here multi authors imply papers with 3 or 4 authors and mega authors with more than 4 authors. However, inclusion of authors as multi or mega can be changed according to data to be analyzed.

4.4 Co-authorship Index

The above measures do not indicate which type of authors dominates the collaboration. To overcome this problem, Garg and Padhi[12] suggested Co-authorship Index (CAI) which indicates the type of co-authorship that dominates the authorship pattern.
Co-authorship Index is obtained by calculating proportional output of single, two, multi and mega-authored papers for different nations and for different disciplines or sub-disciplines in

science and technology. The methodology is similar to one suggested by Price[13] and used to calculate Activity Index (AI) suggested by Frame[14] and elaborated by Schubert and Braun[15].

Here $CAI = \{(N_{ij} / N_{io}) / (N_{oj} / N_{oo})\}x100$ where
N_{ij} = Number of papers having j-authors from country i,
N_{io} = Total output of country i,
N_{oj} = Number of papers having j-authors from all countries,
N_{oo} = Total output for all countries included in the study, and
j = 1,2,(3,4) and (>5)

CAI = 100 implies that a country's co-authorship effort for a particular type of authorship corresponds to the world average, CAI > 100 reflects higher than average co-authorship effort, and CAI < 100 lower than average co-authorship effort by that country for a given type of authorship pattern.

Other measures suggested by Garg and Padhi are used to compute domestic and international collaboration as the above indicators do not indicate the nature of collaboration i.e. domestic or international. These are domestic collaborative index and international collaborative index and have been described below.

4.5 Domestic Collaborative Index (DCI)

Domestic collaborative index is obtained by calculating proportional output of domestically co-authored papers. For calculating DCI papers written in local and domestic collaboration are to be added together.

Here $DCI = \{(D_i / D_{io}) / (D_o / D_{oo})\}x\ 100$ where
D_i= Number of domestically co-authored papers for country i,
D_{io} = Total output for country i,
D_o = Number of domestically co-authored papers from all countries,
D_{oo} = Total output for all countries included in the study.

4.6 International Collaborative Index (ICI)

The value of ICI is obtained by calculating proportional output of internationally co-authored papers.

Here $ICI = \{(I_i / I_{Io}) / (I_o /I_{oo})\}\ x100$ where
I_i= Number of internationally co-authored papers for country i,
I_{Io} = Total output for country i,
I_o = Number of internationally co-authored papers for all countries,
I_{oo} = Total output for all countries included in the study.

The value of DCI or ICI = 100 indicate that a country’s collaborative effort corresponds to world average. DCI or ICI > 100 reflects collaboration higher than world average and DCI or ICI < 100 reflects collaboration less than world average.

4.7 Salton’s Measure for computing collaborative strength

The measure was suggested by Salton and Bergmark[16]. It measures collaborative strength between various pair of countries or regions. It is expressed by the following formula.

$$r_{ij} = \frac{P_{ij}}{\sqrt{P_i P_j}}$$

Where entities i and j represent pair of countries or regions to be compared, P_{ij} are the number of collaborated publications between countries/regions i and j, P_i and P_j are publications of countries/regions i and j and r_{ij} is the mutual collaborative strength between countries/regions i and j.

5. Steps involved in calculation of various measures

Following steps are involved in the calculation of the above mentioned measures. Downloading of data from an appropriate database like Web of Science or Scopus;

- Identification of single, two, multi and mega authored papers; (For calculating CC each type of authorship is to be counted separately, while for calculating CAI co-authored papers can be clubbed as multi and mega authored papers as has been mentioned above in the definition of CAI).
- Identification of domestically and internationally co-authored papers to calculate DCI and ICI;
- Identification of different countries with which a country has collaboration to calculate Salon's measure.

Calculation of the above mentioned measures using the suitable data is given in Appendix.

6. What can be measured with data on collaboration?

The following can be computed with the help of data on co-authorship/collaboration.

- Pattern of co-authorship/collaboration of different nations, agencies and institutions.
- Pattern of co-authorship/collaboration of different sub-disciplines of science and technology as well as of sub-specialities of a discipline.
- Pattern and type of collaboration whether local, domestic or international.
- Change in the pattern of co-authorship/collaboration over a period of time.
- Volume of collaboration and change in it over a period of time.
- Type of collaboration like bilateral or multilateral.
- Disciplines where collaboration occurs most.

It has been illustrated with the help of data on international and domestic output in the field of laser science and technology, a sub-field of physics.

6.1 Co-authorship and collaborative pattern according to countries

Table 1 presents the distribution of output by single, two, multi and mega-authored papers besides the values of the CAI and CC for each country. The average value of CC for laser science and technology is 0.58. This implies that the collaborative pattern in the field of laser science and technology is mainly characterized by co-authored papers and not by single authored papers. It also indicates that Japan, France, Italy, Netherlands, and Switzerland had more than average value of CC (0.58), which implies that these countries must have higher values of CAI either for multi or mega-authored papers. An examination of data (Table 1) indicates that except Switzerland all other above named countries had the highest values of CAI for mega-authored papers. For Switzerland the reason for the higher value of CC is the absence of single authored papers. The value of CAI for mega-authored papers is higher for France and Japan, because these two countries pay more attention on application oriented laser research. Canada, China, and Australia had emphasized more on theoretical laser research[17] hence these countries have low values of CC and higher values of CAI for single author papers.

Country	Single authored papers	Two authored papers	Multi-authored papers	Mega authored papers	Total papers	Collaborative Coefficient (CC)
USA	202 (114)	352 (98)	540 (95)	310 (104)	1404	0.58
Japan	31 (55)	85 (75)	204 (114)	123 (131)	443	0.65
USSR	51 (102)	94 (99)	158 (104)	68 (86)	371	0.58
UK	19 (65)	81 (136)	97 (103)	35 (71)	232	0.59
Germany	17 (92)	43 (115)	58 (98)	28 (90)	146	0.58
France	8 (45)	19 (52)	64 (111)	51 (169)	142	0.67
Canada	17 (160)	37 (172)	23 (68)	7 (39)	84	0.48
Italy	4 (69)	13(110)	17 (91)	12 (123)	46	0.61
China	20 (220)	13 (70)	28 (96)	11 (72)	72	0.48
India	6 (78)	25 (160)	25 (101)	5 (39)	61	0.55
Israel	9 (142)	9 (70)	29 (143)	3 (28)	50	0.54
Netherlands	4 (70)	9 (78)	19(104)	13(136)	45	0.64
Switzerland	--	18 (184)	12(78)	8(99)	38	0.63
Australia	13(52)	17 (166)	10 (62)	--	40	0.39
Total	401	815	1284	674	3174	0.58

Multi-authored: Papers with 3/4 authors, Mega-authored: Papers with 5 or more authors, (CAI) Co-authorship Index for different countries.

Table 1: Pattern of authorship among different countries in Laser S&T during May 1991- April 1990

6.2 Domestic and international collaboration profile of different nations

Domestic and international collaborative profile has been calculated by using domestic collaborative index and international collaborative index mentioned above. The results of Domestic Collaborative Index (DCI) and International Collaborative Index (ICI), besides, the number of papers for each country written in local, domestic and international collaboration are given in Table 2. The number of papers written in domestic collaboration is much more as compared to papers written in international collaboration.

Among the countries listed in Table 2 only four countries, viz. USA, Japan, France and India have more than average value of DCI. The reason for the higher value of DCI for USA and Japan are mainly due to the links of AT&T Bell Labs (USA) and NTT (Japan) with their sister concerns scattered in different regions of USA and Japan respectively. The value of DCI for

India is higher because of the concentration of resources and equipments at Bhabha Atomic Research Centre, which has large links with other institutions in India.

Regarding ICI it is observed that China, Israel, Netherlands and Switzerland have very high values of ICI. This can be explained on the basis of the argument provided by Frame and Carpenter[18] that “international collaboration is inversely proportional to the size of the scientific enterprise in a country and more basic the field, greater the probability of international co-authorship". In the case of these four countries, the total output in mainstream science journals in laser science and technology is about 6.5% of the world output and all the four countries emphasised on theoretical laser research. In case of Italy also, the same argument holds good. For China the open door policy of the post-Mao leadership led by Deng Xiaoping[19] seems to be working. Switzerland in general has high international links in physics[20].

The value of ICI for USA, Japan and the erstwhile USSR is less than world average. These countries are the major producers of scientific output in laser science and technology, which leads to the conclusion that laser science and technology in these countries are well developed. Hence these countries do not require a higher magnitude of international collaboration. Other reason for low ICI for the erstwhile USSR was their political relations with other developed countries as well as the language of communication. For Japan the low value of ICI is because of its emphasis on application oriented laser technology as well as the language. India, Australia and Canada have to improve their international collaboration as the values of ICI for these countries are low.

Further analysis of the raw data indicate that USA had the largest number (39%) of the internationally co-authored articles followed by UK, Germany, and France, which constituted about 12.5%, 8% and 6% of the internationally co-authored articles. However, European countries together constituted about 37% of the internationally co-authored articles. The three Asian countries namely Japan, India and China constituted 12.5% of the internationally co-authored articles. Among these three countries, India had the lowest number of internationally co-authored articles. The findings support the fact that OECD countries are the major collaborators and the countries from Asia constitute a small fraction of internationally co-authored publications[21]. It is also observed that expect six papers; all papers had only bilateral collaboration. USA is the most important partner country for all the countries listed in Table below.

Country	**Local Collaborative papers**	**Domestic Collaborative papers**	**Total**	**DCI**	**International collaborative papers**	**ICI**	**Total papers**
USA	43	241	284	122	63	89	1404
Japan	22	75	97	132	8	36	443
USSR	-	6	6	10	8	43	371
UK	2	32	34	88	20	171	232
Germany	2	19	21	87	13	177	146
France	5	24	29	123	10	140	142
Canada	1	9	10	72	2	47	84
Italy	-	8	8	105	4	173	46
China	1	6	7	59	9	248	72
India	7	9	16	158	3	98	61

Israel	1	5	6	72	6	238	50
Netherlands	2	6	8	107	5	220	45
Switzerland	-	1	1	16	7	365	38
Australia	-	-	-	-	2	99	40
Total	86	441	527	-	160		3174

Table 2: Local, domestic and international collaboration among different nations in Laser S&T during May 1991-April 1990

6.3 Collaboration pattern according to agencies/institutions

Table 3 provides data on the number of collaborative papers published by different type of agencies like academic institutes, research institutes, industrial houses, and the government organizations. It indicates that most of the collaborations have resulted from academic institutions followed by industrial houses and research institutions. Further analysis of raw data indicates that most of the collaborations from industrial houses and government organizations are from USA and Japan. Using similar methodology one can identify institutions that are involved in collaboration in different countries. Analysis of the distribution of the total output of the papers by number of institutions indicates that most of the collaborative papers have resulted by bilateral collaboration of the institutions.

Type of institution	Local	Domestic	International	Total	%
Acad. Institution	36	237	91	364	52.98
Res. Institution	9	83	35	127	18.49
Industrial Houses	39	83	25	147	21.40
Government Orgn.	2	38	9	49	7.13
Total	86	441	160	687	100

Table 3: Distribution of collaborative papers according to type of agencies in Laser S&T during May 1990-April 1991

6.4 Co-authorship pattern according to Sub-specialities

Table 4 shows the pattern of co-authorship for various sub-specialities. It indicates that theoretical laser research require less collaboration while the experimental and application oriented laser research requires more collaboration. The value of CC for theoretical laser research is lower than the values of CC for experimental and application oriented laser research. Similarly, the values of CAI for multi and mega authored papers are higher for experimental and application oriented laser research. Similarly, it can be applied for computing co-authorship pattern among broad disciplines of science and technology.

Code	Single authored papers	Two authored papers	Multi authored Papers	Mega authored papers	Total papers	Collaborative Coefficient(CC)
B	194 (195)	302 (150)	258 (81)	31 (18)	785	0.64

C	119 (61)	303 (76)	662 (106)	462 (141)	1546	0.60
D	88 (83)	210 (97)	364 (107)	181 (101)	843	0.58
Total	401	815	1284	674	3174	

B: Theoretical Laser Research, C: Experimental Laser Research, D: Applications of Lasers, (CAI) Co-authorship Index for different sub-specialities.

Table 4: Co-authorship pattern in different sub-specialties of Laser S&T during May 1990-April 1991

6.5 Collaborative profile according to sub-specialties

An analysis of the collaborative profile can also be made according to the sub-specialties of laser science and technology. Number of collaborative papers in different sub-specialties of laser science and technology are given in Table 5 which indicates that most of the collaborations are in experimental laser research followed by application oriented laser research. This is in accordance to what has been stated earlier under co-authorship index (Table 4) that theoretical laser research had a low value of CC and higher value of CAI for single author papers. However, proportion of internationally co-authored papers is higher for theoretical and experimental laser research as compared to application-oriented research.

Sub-specialty	**Local**	**Domestic**	**International**	**Total (%)**
Theoretical	14	82	61	157 (22.85)
Experimental	42	225	63	330 (48.03)
Application	30	134	36	200 (29.11)
Total	86	441	160	687 (99.99)

Table 5: Distribution of collaborative papers according to sub-specialties in Laser S&T during May 1990 –April 1991

6.6 Change in the pattern of collaboration over a period of time

Table 6 presented below indicates the values of CC and CAI for different periods in five blocks from 1970-1994 for Indian output in laser science and technology. It clearly shows that in the last block (1990-1994) the value of CC as well as CAI is highest. This implies that over a period of time the number of multi and mega authored papers have increased.

Year	**Single authored papers**	**Two authored papers**	**Multi authored papers**	**Mega authored papers**	**Total**	**Collaborative Coefficient (CC)**
1970-1974	17 (139)	42 (120)	25 (80)	00 (00)	84	0.45
1975-1979	34 (131)	78 (105)	66 (100)	1 (8)	179	0.48
1980-1984	32 (102)	97 (108)	81 (101)	6 (41)	216	0.50

1985-1989	34 (104)	82 (90)	91 (110)	16 (105)	223	0.52
1990-1994	22 (60)	95 (92)	91 (97)	42 (255)	250	0.57
Total	139	394	354	65	952	0.52

Table 6: Pattern of co-authorship during different blocks Of India in Laser S&T

7. Summary

Collaborative research is an important feature of science. Collaboration can be defined as the working together of two or more researchers to achieve the common goal of producing new knowledge. Governments in different countries have taken initiatives to enhance collaborative research programs and such initiatives have resulted in increased collaborations at national and international levels. Statistical data indicate that percentage of research produced by teamwork has been growing steadily for more than half a century. However, the extent of collaboration and their rate of growth vary from one subject to another. Based upon the type of participants and the location etc, collaboration can be categorised into three broad categories. These are local collaboration, domestic collaboration and international collaboration. Among all these types of collaborations, the international collaboration has received the maximum attention. Different measures of collaboration suggested in literature are Collaborative Index (CI), Degree of Collaboration (DC), Collaborative Coefficient (CC), Co-authorship Index (CAI), Domestic Collaborative Index (DCI), International Collaborative Index (ICI) and Salton's measure for computing collaborative strength between various pair of countries or regions.

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