Original Research

A Systematic Review of Scientific Collaboration Studies by Iranian Authors

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Abstract

Scientific collaboration indicates active teamwork between researchers beyond the simple exchange of material or information. This study is a systematic review of the papers published by Iranian researchers, aiming to provide comprehensive indicators, methodologies, and software used for evaluating scientific collaboration. According to guidelines of the Cochrane Handbook, the national and international databases were used for searching by English and Persian keywords without any time limitations. The retrieved articles were managed using EndNote software. By applying the inclusion and exclusion criteria, 201 articles remained for this review. These articles were selected from 93 domestic and foreign journals between 2000 and 2019. The studies used 16 software to extract and analyze scientific collaboration indicators. Systematic review shows that bibliometric and network analysis methods were the main approaches used in scientific collaboration studies among papers published by Iranian researchers (93.5%). More than 25 indicators were extracted from these studies, and they were categorized into patterns of collaboration and co-authorship network analysis. Researchers have revealed an increasing interest in the factors affecting scientific collaboration in recent years. The present study provides comprehensive information on the articles published by Iranian researchers on scientific collaboration. The methodologies and software were identified that are most often used to evaluate scientific collaboration and adapted to direct future research. Still, a variety of indicators situates them in heterogeneous methods of research. This analytical perspective does not locate the evaluation of scientific collaboration at a single spot. Future scientific collaboration studies will continue to evolve to offer more powerful indicators for assessing the knowledge flow status quo.

Introduction

Scientific collaboration is fast becoming a key strategy in the world of science. The problems of conducting research studies, such as complexity, specialty, and high cost, have led to the scientific collaboration between countries, universities, research centers, and researchers. Besides, recent evidence suggests that ICT innovations such as social-science networks effectively promote scientific collaboration (Bornmann, 2015; Ebrahimi, Asemi, Shabani & Nezarat, 2021; Jamali, Russell, Nicholas & Watkinson, 2014; Ramezani-Pakpour-Langeroudi, Okhovati & Talebian, 2018). Co-authorship in research is the most formal manifestation of the authors' intellectual, social, and scientific collaboration (Galyani-Moghaddam, 2019; Lu, Zhang, Ahn, Ding, Zhang & Ma, 2019). Through co-authorship, the flow of knowledge will be increased in scientific collaboration networks (Galyani-Moghaddam, 2019). Authorship shows active collaboration amongst participants beyond the simple exchange of data or material (Sampaio, Fonseca & Zicker, 2016). However, patterns of scholarly participation can be determined by identifying various co-authorship or multi-authorship indicators (Gazni, Sugimoto & Didegah, 2012). Combining many authors from different geographical areas is a complex authorship pattern (Ghane, 2011; Lima & Farias, 2020).

Recently, Web of Science, PubMed, and Scopus – as the largest bibliographic databases, have indexed new articles by more than 1000 authors (Craig, 2018; Marušić, Bošnjak & Jerončić, 2011). According to the National Library of Medicine (2019), the average number of authors per article on MEDLINE®/PubMed® was estimated to be 4.01. The average of 1.68 authors per article in 1975 increased to 5.81 in 2019. It indicates the importance of expanding scientific collaborations in the research fields. Evidence suggests that scientific collaboration is among the most significant factors in increased researchers' productivity and citations (Abbasi, Jalili & Sadeghi-Niaraki, 2018; Adams, Pendlebury, Potter & Szomszor, 2019; Ahn, Oh & Lee, 2014; Bornmann, 2015; Gazni & Didegah, 2011; Jamali et al., 2014; Ramezani-Pakpour-Langeroudi et al., 2018). On the other hand, the tendency for scientific collaboration and co-authorship in groups and diverse scientific fields is different (Ghane, 2011; Henriksen, 2016; Nikzad, Hariri, Babalhavaeji & Nooshinfard, 2017; Osareh & Wilson, 2000). Sustainable development is one of the most significant current discussions in scientific and political meetings regarding the impact of scientific collaborations on national and international research (Khosravi & Pournaghi, 2019). Researchers have used various indicators to measure the pattern of scientific collaboration (Boyack & Klavans, 2019; Galyani-Moghaddam, Momeni & Sttarzadeh, 2015; Jaafarzadeh, Khodapanah & Zareh Gavgani, 2016; Liao & Yen, 2012). However, few studies have done systematic reviews of scientific collaboration research among Iranian researchers. The study of Galyani-Moghaddam et al. (2015) searched five Persian databases, and then forty articles were collected between 2000 and 2014. Only co-authoring dimensions with methodology and typology were studied in their work. However, a comprehensive evaluation of the approaches and software used in the Iranian scientific collaboration studies has not yet been undertaken. The specific objective of this study is to present a historical overview of the assessment of scientific collaboration studies in Iran. To our knowledge, this research is the first attempt to characterize this literature systematically. It will provide a foundation for describing evaluation in this domain. In addition, this study systematically reviews the data categories and classification, aiming to provide complete indicators of scientific collaboration research.

Research Question

1. What are the methodological approaches of Iranian researchers in the field of collaborative scientific studies?
2. What software has been used to extract and determine parameters from Iranian researchers in the field of scientific collaboration?
3. What are Iranian researchers' evaluation indicators for evaluating scientific collaboration?

Materials and Methods

Design / Explanation of methods

According to the Cochrane Handbook, this study was planned and conducted systematically (Ke & Cheng, 2015; Higgins, Higgins, Thomas, Chandler, Cumpston, Li, Page & Welch, 2020). A systematic review's significant advantage is the predetermined rules and regulations applied in a structured search to identify the literature (Ke & Cheng, 2015; Xu, Kang & Song. Multiple search strategies were formulated to identify studies in scientific collaboration by Iranian researchers. Accordingly, the search terms were determined by reviewing a random sample of publications (Table 1). The thesaurus in Persian and English was used, and then the search was run in the primary databases. We used the Boolean operator "OR" between the search terms.

Table 1

The search terms by reviewing a random sample of publications

Item No.	Keywords	Compound vocabulary
1	Collaboration	Scholar Collaboration, Scientific Collaboration, Network Collaborations, Collaboration Rate, Research Collaboration, Collaborative Research
2	Authorship	Authorship Network, Co-authorship, Scientific Co-authorship, Number of Author, Co-authorship Patterns
3	Centrality	social network analyses, collaborative network, Centrality measures
4	Publication	Patterns of co-writing, Co-publication, Collaboration patterns
5	Partnership	Scientific participation
6	Cooperation	International cooperation
7	Communication	Scientific communication

The initial query keywords were broad. Thus, after reviewing the results, the search query was narrowed to return precise numbers of relevant research and increase the results' specificity.

Inclusion and exclusion criteria of primary study

The inclusion criteria warranted the authorship of Iranian researchers in the papers investigating scientific collaboration in both Persian and English without time limitation. Mainly, the types of articles included peer-reviewed studies. Essential aspects of the research question were used to define the exclusion criteria. The exclusion criteria were as follows. The main perspective of the research question was used. References were excluded, such as book reviews, books, dissertations or theses, national and international proceedings, conference papers, personal comments on blogs or web pages, the reduplicated publication of bilingual articles, and resources by no access to the full-text document. Besides, studies with a

scientometrics approach did not report the patterns and criteria of scientific collaboration. In formulating the query, gray literature was not included.

Information Sources and Search strategy

According to Cochrane's handbook method, identification, screening, eligibility, and inclusion were performed for sampling (Higgins et al., 2020). The selected databases were searched to identify the literature related to the research topic. These are summarized in the results (Figure 1) and inform the discussion of the results. Databases with a high level of credibility in the scientific community were selected. Five international databases were searched: Library, Information Science & Technology Abstracts (LISTA), Web of Science, Scopus, PubMed, Google Scholar, and several Persian-language databases such as SID, Marigans, Irandoc, Islamic World Science Citation Center (ISC), Ensani, and Noormgs. The appropriate syntax was run for all searches between 21-29 April 2020. Preliminary search results in English and Persian databases were recorded in EndNote citation management software.

According to the search strategy and the identified characteristics, qualitative and quantitative synthesis of the determined studies was performed to begin this process. Collectively, the review team gained a shared understanding of the inclusion and exclusion criteria; almost 40% of the results were filtered by title/abstract. During the full-text screening, one hundred and one studies were excluded. After selecting the relevant papers by systematic review and determining the sample size, the full texts that passed the evaluation phase were thoroughly studied. Then these were reviewed according to frequencies to simplify the interpretation of data.

Data analysis

Two investigators carried out the selection of the papers independently. The main objective of this step was to extract the information on methodology, software, and indicators of scientific collaboration from articles and finally to answer the research questions. Two independent researchers (AR and FS) applied the review checklist to the research sample, and a third reviewer (LS) checked the process for agreement and precision. Whenever both researchers discussed differences, a final decision was made through consensus with the third reviewer.
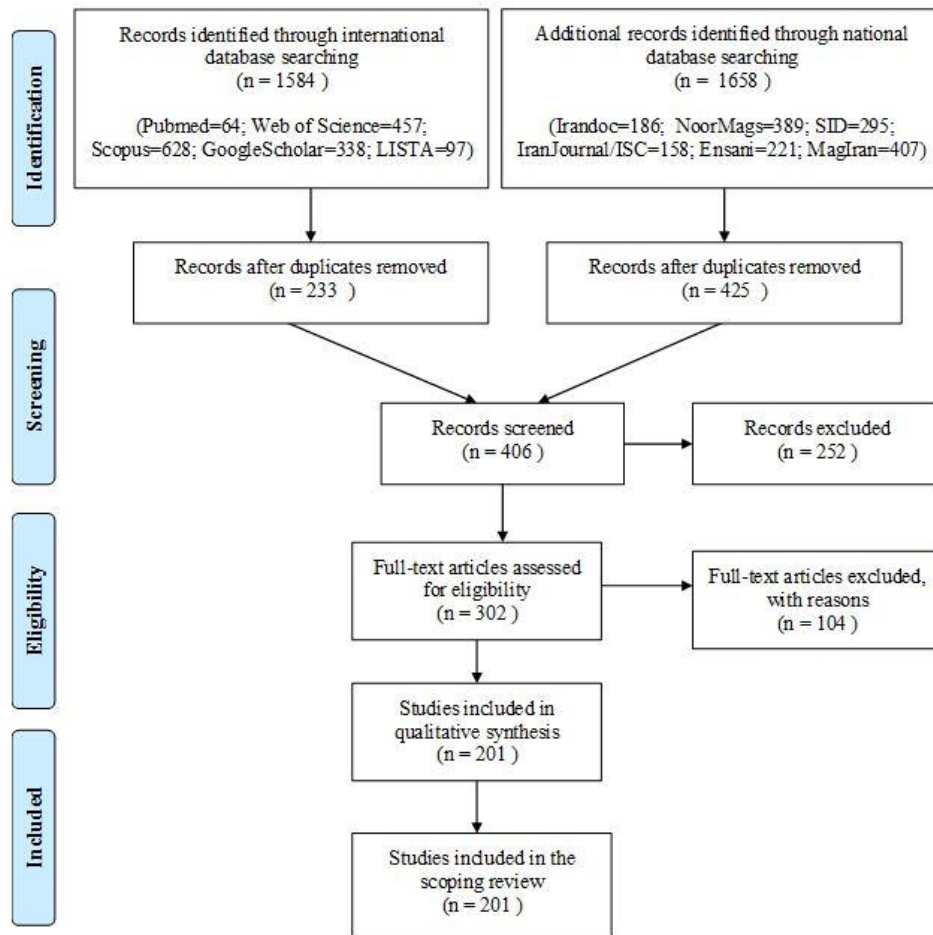
Figure 1. Flowchart of Literature Search and Study Selection for Iranian Scientific Collaboration Studies (Source: Moher, Liberati, Tetzlaff & Altman (2010).

The information of the articles included the Author(s), year, journal's name, the main objective of the study, subject of the study (Medical, Non-medical, and All Topics), methodological approaches, the population and sample size, the software used, dimensions, and the unit of analysis mentioned in the content of the paper. For this purpose, a checklist was prepared based on which information was recorded in different fields. At first, to confirm the validity of a checklist, the data of ten articles were obtained. After the data were collected, some fields and definitions changed. Therefore, the checklist was redesigned to fit the data fields required. Finally, the information was extracted and categorized from all articles.

Results

Based on the results, out of 201 articles, 137 were in Persian (68.2%), and 64 were in English (31.8%). These articles were published in 93 international and national accredited journals. According to the results for 19 years, publication in scientific collaboration research in Iran started in 2000 and peaked in 2017. The findings of this study show a significant increase in the publication on scientific collaboration. Systematic review shows that most scientific collaboration research in Iran occurs in the medical field. Interestingly, this observation could be attributed to this study area (See Appendix (A).

Methodological approach

Seven methodological approaches emerged from the analysis (Table 2). Scientometrics was the primary approach of scientific collaboration studies in Iran (90.6%). Almost half of the studies used the network analysis approach (49.3%). According to the findings, the network analysis approach in co-authorship studies has grown over the last ten years.

Table 2
Methodological approaches of the Iranian researchers in studies of scientific collaboration

Item No.	Approaches	Number	Percentage
1	Scientometrics	87	43.3
2	Social Network Analysis	7	3.5
3	Scientometrics & Social Network Analysis	92	45.8
4	Scientometrics and Survey	1	0.5
5	Scientometrics by Mixed Method	2	1
6	Survey	5	2.5
7	Review	7	3.5
	Total	201	100

As Table 2 shows, survey and review methods were selected in only 12 studies for identifying collaboration and knowledge-sharing factors among researchers. Furthermore, in these studies, the concepts of scientific collaboration were reviewed, and co-authorship indices were introduced. The systematic review showed that the researchers used various methodologies based on the need and approach of the research. Scientometrics and network analysis methods are the two main approaches to collaborative studies. Another important finding was that each researcher focused on co-authorship patterns and social network analysis.

The software used

The second question in this systematic review sought to determine the software used to extract and analyze scientific collaboration indicators. 16 software were used in 201 scientific collaboration studies (Table 3). Some studies applied the software to the collaborative scientific evaluation, but 67 studies did not mention software use. In these researches, the total frequencies of software use were 253.

Table 3
 The software and parameters in scientific collaboration in Iranian studies

Item No.	Software Name	Usage times
Indicators Calculation & Visualization		
1	Visone	1
2	Sci2 Tool	4
3	Network Workbench	3
4	Pajek	26
5	Gephi	5
6	HistCite	19
7	CiteSpace	9

Item No.	Software Name	Usage times
8	VOSviewer	28
9	AuthorMap	1
10	R-Project (I-graph)	1
11	Ucinet 6/NetDraw	49
12	NodeXL	6
Data Extraction & Description		
1	leydesdorff	12
2	Microsoft Excel	61
3	Ravar Matrix	6
4	BibExcel	22

All of the software is conceived at least in two significant respects. From one aspect, some fields, such as the authors' names and the author's address, have components that are difficult to extract and investigate manually. On the other hand, the network's adjacency matrix is needed to analyze the co-authorship. Manually preparing this matrix is a time-consuming task. Therefore, the software is used to extract and describe data and to calculate and map co-authorship indices. It can be seen from the data in Table 3 that the software was categorized into two groups: one extracting and describing the data; and the other computing and plotting the co-authorship indices. These studies used the most commonly used software (Ucinet / NetDraw, VOSviewer, and Pajek) to calculate and plot the co-authorship indices. Also, Microsoft Excel and BibExcel software were used to extract and describe the data. In their studies, the researchers used other software based on their capabilities.

Classification of indicators

After studying the full text of the scientific collaboration articles, the initial analysis identified more than 25 indices. The results obtained from the checklist are categorized in Table 4.

Table 4
Indicators from evaluation of scientific collaboration studies by Iranian authors

A: Patterns and Indicators of Scientific Collaboration		Frequency (%)
1	Price model	2(1.0)
2	Lotka's law	8(4.0)
3	Bradford's Law	4(2.0)
4	P =NI/INI	12(6.0)
5	Collaboration Index (CI)	55 (27.4)
6	Collaboration Degree (CD)	47(23.4)
7	Collaboration Coefficient (CC)	66(32.8)

B: Macro-Level Metrics Social Network Analysis		Frequency (%)
1	Density	50(24.9)
2	Clustering Coefficient	30(14.9)
3	Mean Distance	15(7.5)
4	Diameter	10(5.0)
5	Components	14(7.0)
6	Modularity Q	4(2.0)
7	Structural Holes	5(2.5)
8	Theory of Six Degrees of Separation	2(1.0)
9	Small World	7(3.5)
10	Connectedness	3(1.5)
11	Fragmentation	3(1.5)
12	Sigma	5(2.5)
13	Centralization	2(1.0)
C: Micro-Level Metrics Social Network Analysis		Frequency (%)
1	Closeness centrality	57(28.4)
2	Betweenness centrality	67(33.3)
3	Degree centrality	69(34.3)
4	Eigenvector centrality	25(12.4)
5	Beta centrality	6(3.0)

These indices were classified into two levels through a brief review: collaborative scientific patterns (Collaboration Index; Collaboration Degree) and co-authorship network (its scope is broader than previous levels such as centrality and density). The co-authorship of network analysis in collaborative scientific research is also divided into macro and micro levels. The co-authorship network at the macro level is structurally examined. The micro co-authorship network compares the features of authors with other authors in the network (Table 4).

Discussions

The innovation of this study was the comprehensive identification of methodology, software, and indicators of scientific collaboration obtained by the systematic review method. In previous studies, this method's potential has also been noted. (Xu et al., 2015; Khosravi & Pournaghi, 2019; Maden & Kotas, 2016). Co-authorship analytics achieves wide application in several fields due to its capability in uncovering hidden patterns for multi-authorship. Marušić et al. (2011) conducted a systematic review of authorship issues in the research process, and their meta-analysis on co-authorship issues revealed that it might potentially impact the research process. However, these scientific collaborative studies' interdependence and heterogeneity features pose a vital challenge, and these criteria support research analysis. Therefore, it can be assumed that the decision can usually be made with multiple perspectives and approaches (Ebrahimi et al., 2021). The findings of this study show a substantial increase in the publication on scientific collaboration. This observation could be attributed to the importance of this area of research. Scientometrics and network analysis methods are the two main approaches to collaborative studies. These findings were also reported by Galyani-Moghaddam et al. (2015).

This study classified the software indicators of scientific collaboration into two levels (Bales, Wright, Oxley & Wheeler, 2020). The first level of software is generally used to extract

matrices and describe co-authoring data (Microsoft Excel, Ravar Matrix, BibExcel). This software standardizes organizational affiliation or authors' names for reliable results. The second level of software calculates and visualizes co-authoring indicators (Ucinet 6/NetDraw, NodeXL) (Moral-Muñoz, Herrera-Viedma, Santisteban-Espejo & Cobo, 2020). This software has provided valuable information on presenting co-authorship and collaboration patterns for the past two decades (van Raan, 2019; Gazni et al., 2012; Liao & Yen, 2012).

It is interesting to note that sixteen software and applications are used independently of citation databases for extracting and preparing scientific collaboration data (Cobo et al., 2020). It was hypothesized that researchers were using the most popular and free software because they were accessible. Therefore, the frequency of their use in research of scientific collaboration was high in Iran. However, commercial software is also used to analyze such studies though much of this software has been used by individual researchers in limited research. It can, thus, be suggested that Iranian researchers use them for more extensive and deep analysis (Bales et al., 2020; Moral-Muñoz et al., 2020). The systematic review showed that the researchers used various collaboration indicators based on the need and approach of the research. The coefficient of cooperation (CC) is one of the important indicators that reveal the pattern of cooperation and provide a complete picture of the findings of the studies that examined the patterns of scientific cooperation in Iranian studies.

Another important finding was that each researcher focused on co-authorship patterns by social network analysis. Co-authorship network analysis is increasingly employed as a powerful method to assess collaboration trends and to classify leading scientists and organizations. The analysis uncovers the social structure of the networks by identifying actors and their connections. Prior studies on more than 1000 authors also noted the importance of this method of authorship patterns by showing complex co-authorship, so there need to be new evaluation indicators (Craig, 2018; Marušić et al., 2011). This study will help Iranian researchers compete with other international researchers in methodological research in this field by examining the diversity and continuous development of scientific cooperation evaluation indicators. Therefore, with these indicators, heterogeneity in the methodology of studies and diversity of reports can be avoided, and the indicators collected in this study can be used for a comprehensive evaluation of scientific collaboration in Iran.

The main contribution of this research is categorizing the method of heterogeneity in the criteria for evaluating collaborative studies. Instead, it situates them in heterogeneous methods of research. This analytical perspective does not locate the evaluation of scientific collaboration at a single spot. Future scientific collaboration studies will continue to evolve to offer more powerful indicators for assessing knowledge flow. To illustrate the effectiveness and potentials of this comprehensive approach, an illustrating example of applying this approach in the academic research community is needed in the future by a case study of top universities in Iran. In addition, another study is conducted to examine precisely the methodology of statistical findings in these studies.

Conclusion

A systematic review of Iranian scientific collaboration studies showed that network analysis and scientometrics were the main approaches of these studies. Concerning the software identified in Iranian scientific collaboration studies, it is recommended that scientometrics experts use them in future studies. Due to the variety of software capabilities, they are helpful

for in-deep and comprehensive evaluation of scientific collaboration. The main limitation of this study was incomplete reported data in the reviewed articles. Overall, these citations were searched systematically and limited to studies published by Iranian researchers. Because of all that has been mentioned so far, one may suppose that valuable sources may have gone undetected. The decision to limit the review to scientific collaboration in Iranian studies omitted potentially valuable literature from researchers in other countries; this was done to limit the research to a manageable size.

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