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efficiency and productivity in healthcare?
A Systematic Review and Bibliometric Analysis

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What do we know from the vast literature on efficiency and productivity in healthcare? A Systematic Review and Bibliometric Analysis

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Abstract

Not only does healthcare play a key role in a country's economy, but it is also one of the fastest-growing sectors for most countries, resulting in rising expenditures. In turn, efficiency and productivity analyses of the healthcare industry have attracted attention from a wide variety of interested parties, including academics, hospital administrators, and policy makers. As a result, a very large number of studies of efficiency and productivity in the healthcare industry have appeared over the past three decades in a variety of outlets. In this paper, we conduct a comprehensive and systematic review of these studies with the aid of modern machine technology learning methods for bibliometric analysis. This approach facilitated our identification and analysis and allowed us to reveal patterns and clusters in the data from 477 efficiency and productivity articles associated with the healthcare industry from 1983 to 2019, produced by nearly 1000 authors and published in a multitude of academic journals. Leveraging on such 'biblioanalytics', combined with our own understanding of the field, we then highlight the trends and possible future of efficiency and productivity studies in healthcare.

1. Introduction

Health care is an important aspect of well-being worldwide for all individuals, organizations, and countries. Health care has always been vital to the economy and the population, although it is especially relevant during the current COVID-19 pandemic. However, even before the pandemic, the healthcare sectors of both developed and developing countries have been growing rapidly: European countries averaged 3% growth per year in per capita health spending from 2013 to 2019 (OECD, 2019), while Asia Pacific countries achieved a growth rate of 4.7% per year between 2010 to 2017 (OECD, 2020). North American countries such as the United States and Canada experienced annual per capita health spending growth rates of 2.8% and 1.6%, respectively, from 2013 to 2018 (WHO, 2020). Health spending is expected to continue increasing due to aging populations, advances in medical technology, unhealthy lifestyles and the inefficient use of health care resources. From 2000 to 2017, global spending on health (in real terms) increased 3.9% a year, which is faster than the global economic growth rate of 3.0% per year between 2000 and 2017 (WHO, 2019).

Improving the efficiency of health care delivery is one of the most important management challenges, and health care managers need to respond to this challenge with sound performance evaluation and decision making. One of the most difficult tasks in performance evaluation is identifying the key combinations of inputs and outputs. Parametric (e.g., stochastic frontier analysis) and non-parametric (e.g., data envelopment analysis) methods, as well as their variations and innovative quantitative approaches (i.e., Malmquist measures, cost efficiency when prices are available, among others), have been used to measure and examine the efficiency and productivity of medical care among many countries. In the last four decades, it has been one of the most intensely explored areas of health services research. Nunamaker (1983), Sherman (1984), Banker et al. (1986) and Grosskopf and Valdmanis (1987) were among the earliest studies that measured efficiency and productivity in the healthcare sector. A myriad of other studies followed from many countries across the world that elaborated and improved upon these.

Overall, during the last four decades, a large number of efficiency and productivity studies have been conducted for several types of healthcare facilities, such as hospitals, pharmacies, nursing homes, clinics, and health programs. The objectives of these studies vary greatly. Some studies focus on benchmarking healthcare facilities within a country or with similar healthcare systems, others investigate the development and application of new methodologies or illustrate methodologies with healthcare data, and still others focus on issues in hospital management, healthcare reform and hospital resource allocation.

Altogether, this research has generated a wide range of literature on healthcare efficiency, particularly in developed countries, but the number of studies has also been growing rapidly in developing countries over the last decade. Several studies, including Hollingsworth (2003, 2008), Hollingsworth et al. (1999), O'Neill et al. (2008), Pelone et al. (2015), and Kohl et al. (2018), provide a comprehensive overview of this literature from various perspectives. For example, Hollingsworth et al. (1999) and O'Neill (2008) surveyed data envelopment analysis (DEA) and healthcare efficiency studies, whereas Hollingsworth (2003, 2008) reviewed related studies using either DEA or stochastic frontier analysis (SFA) models.

The use of DEA models, especially in the study of hospital productivity, has increased over the past decade. This approach is widely adopted due to findings that hospital spending has consistently been much higher than that for other healthcare services. Pelone et al. (2015) and Kohl et al. (2018) conducted systematic literature reviews on DEA model applications in primary care and hospitals, respectively.

Most of these survey papers on healthcare efficiency and productivity analysis investigate research focus, authorship, methodology, selection of input and output measures, research findings, and potential future research. We aim to complement this literature by reinforcing this literature with machine learning approaches for bibliometric analysis. In general, there are several advantages to using bibliometric analysis when reviewing previous studies with large amounts of information. Bibliometric analysis is a quantitative approach that can be used to analyze research impact, and it is considered more readily accessible than peer reviews. All the literature information is scalable, and the bibliometric method can be organized into different levels, from the author and affiliation levels to the country level. In this paper, we focus on healthcare efficiency studies from 1983 to 2019.

2. Literature search using the PRISMA procedure

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) is a useful procedure for bibliometric studies. This procedure provides a checklist of each step—identification, screening, eligibility and inclusion—that must be followed to ensure the quality of the literature data (Moher et al., 2009). In this study, we apply the PRISMA procedure to our data collection for the bibliometric and network analyses. Its steps are illustrated in Figure 1 and discussed below.

2.1 PRISMA procedure

To determine the publications for bibliometric analysis in the field of healthcare benchmarking analysis, several keywords are searched in the Scopus database on May 1-31, 2020. A total of 21,950 peer-reviewed journal titles are indexed by Scopus, and the coverage period is from 1970 onwards. The Scopus database is recognized by Mongeon and Paul-Hus (2016) as an essential tool in interdisciplinary field coverage. Since healthcare benchmarking analysis is considered an interdisciplinary research area that covers economics, operations research, and health care, the Scopus database is appropriate for use in the literature search. To capture the literature collection effectively, a search strategy with abstract-title-author keywords including "benchmarking analysis of the healthcare industry" [1], "efficiency of the healthcare industry", and "productivity of the healthcare industry" was employed.[2] In the initial stage, a total of 1693 publications were found based on our search strategy. To meet our literature search criteria, a total of 110 publications that were either redundant or published in or after 2020 were removed.

In the screening phase, we manually evaluated the publications carefully to ensure that the literature collection was relevant to the research in this field, using the following criteria:

(i) fully available through access by subscription or open access;
(ii) published in an English-language journal;
(iii) involving the healthcare industry (i.e., hospitals, clinics, pharmacies, nursing homes, health systems, healthcare programs); and
(iv) journal article only.[3]

As a result, a total of 452 publications were collected for the next phase, the eligibility and inclusion process. Additional relevant records that did not appear in our initial stages but were included in the

[1] Benchmarking is an exercise comparing firm performance metrics to the observed best in the industry. Studies using cost effectiveness or cost-benefit analysis are outside of the scope of our study.

[2] In basic terms, productivity is defined as the output per unit of input, while efficiency describes performance relative to some benchmark or target (e.g., the frontier or best practice). In the case of production (or productive) efficiency, it can be understood as a comparative perspective of productivity relative to some benchmark; hence 'benchmarking analysis' is often used to describe 'efficiency analysis'.

[3] Other publications such as review article, editorial article, book series, book, chapter in book, handbook, conference proceeding, trade publication are outside of the scope in our literature collection.

reference list of the existing systematic review studies (e.g., Kohl et al., 2018) were reconsidered in the final literature collection. Ultimately, 477 publications were included as our literature data for the bibliometric and network analyses.

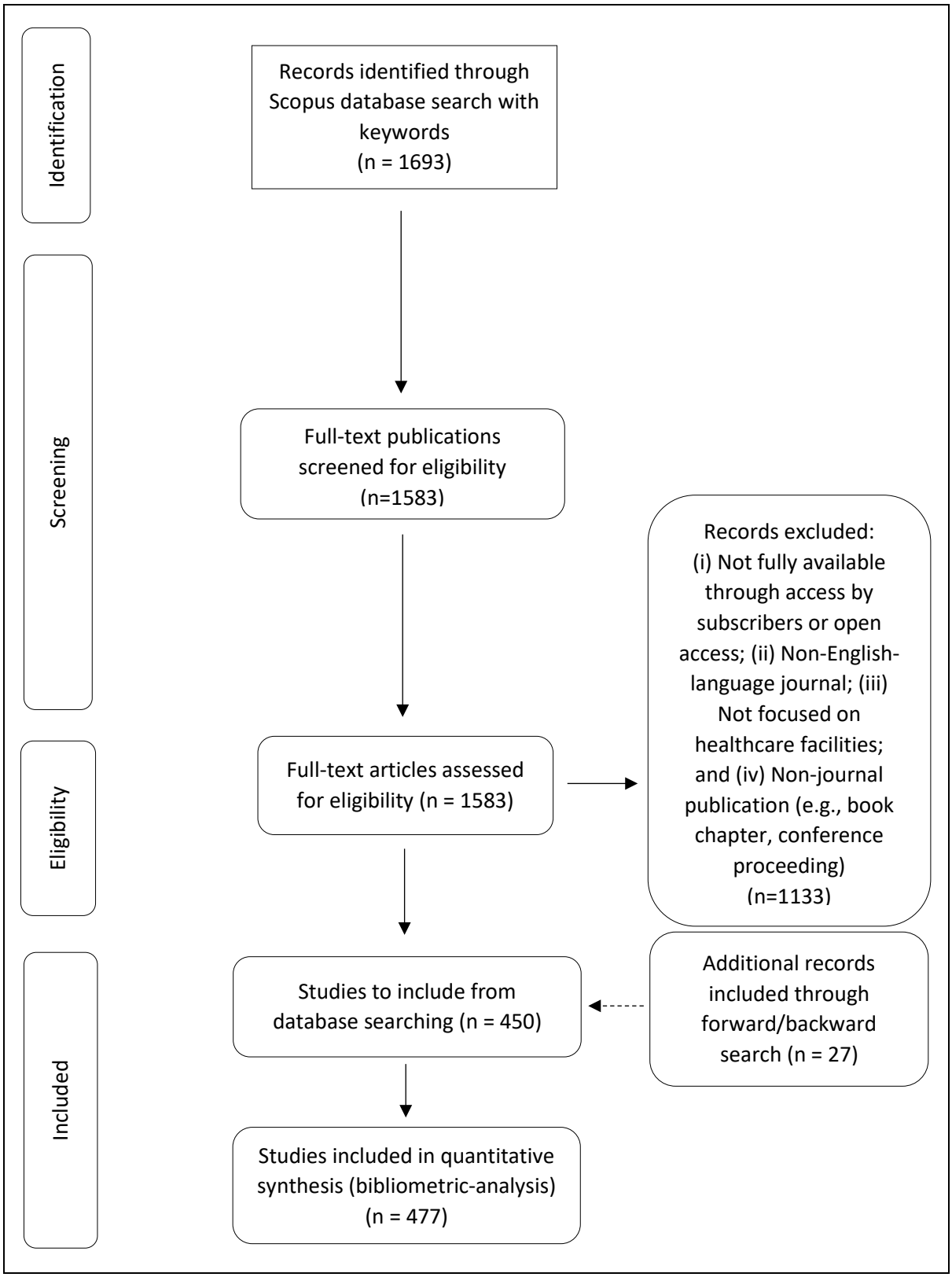


Fig. 1 Literature search using the PRISMA procedure.

To prepare our literature data, we organized information using different characteristics of the publications, including author name, year of publication, affiliation, country, journal, funding information, keywords, etc., for the bibliometric analysis. However, some of this information is inconsistent in our literature collection. For instance, author name might appear differently in two publications but reference the same author. Therefore, a data cleaning process was required before the literature data could be used for bibliometric analysis.[4]

2.2 Bibliometric analysis and network analysis

The data analysis was performed through bibliometric analysis and network analysis. Bibliometric analysis uses quantitative and statistical techniques to manage a large number of publications in specific fields (Mishra et al., 2017). Several bibliometric tools, such as geographic mapping, identify the publication distribution, collaboration flow, and country analysis (Zupic and Cater, 2015; Feng et al., 2017). Network analysis, as applied to the bibliometric approach, can identify the popularity and emerging relevance of different characteristics (e.g., authors, affiliations, and countries) of publications in a particular research area. It can also be used to determine the clusters for each of the characteristics in the existing studies, showing the collaborative relationship between two subjects in the group of clusters. Keyword analysis can be used to assess research hotspots to gain a deeper understanding of this field. Overall, bibliometric analysis can provide a comprehensive review of the existing efficiency and productivity studies of the health care industry.

The fractional counting and full counting approaches are popular when conducting bibliometric analysis (Waltman and Van Eck, 2015). The fractional counting method assigns coauthored publications to a single author with a fractional weight, whereas full counting assigns coauthored publications to a single author with the full weight count. Since fractional counting provides useful information based on the theoretical consideration presented by Perianes-Rodriguez et al. (2016), we use fractional counting to calculate the coauthors, affiliations, and countries of the publications. To conduct the bibliometric and network analyses, all literature data was analyzed using VOSviewer (Van Eck and Waltman, 2010) and R Bibliometrix package (Aria and Cuccurullo, 2017).

3. Results and discussion

In general, several elements of the publications, such as publication trends, most productive authors and affiliations, most influential journals, and most cited articles, can be analyzed through bibliometric analysis. We summarize these in turn.

3.1 Publication trends

Figure 2 illustrates the publication trends in the research on health care benchmarking analysis during the study period from 1983 to 2019. We observe an increasing trend with an annual growth rate of 8.36% over the years. The increasing trend in the number of publications reflects the importance of research on efficiency and productivity analysis in the healthcare industry.

[4] Data cleaning involved the correction of literature information that was extracted directly from the journal. Author name, affiliation, and reference lists used for the articles were edited to ensure consistency throughout the literature data.

Fig. 2 Publication trends in healthcare benchmarking studies, 1983-2019.

Based on our observations, Nunamaker (1983), Sherman (1984) and Grosskopf and Valdmanis (1987) were the first three papers in healthcare studies estimating health care efficiency published in international journals. From 1983 to 2000, more than 100 articles on this topic were accepted for publication in Scopus-indexed journals, and the publications were mostly contributed by authors in developed countries. Since then, this research has attracted attention from researchers from developing countries (especially research on health care reforms), who have contributed a growing number of publications since 2005.

We further identified the geographical distribution for research contributions from the corresponding authors through science mapping during the years 1983 to 2019, as illustrated in Figure 3.[5] A total of 45 countries have contributed to the research in this field, and a high concentration of the corresponding authors are located in the United States, with 172 publications. Many leading authors, including Ozcan, Valdmanis, and Grosskopf, have produced a significant number of both methodology- and application-oriented healthcare benchmarking studies. Corresponding authors from the United Kingdom, Spain, and Germany also have a number of publications, with 39, 23, and 22, respectively. Benchmarking analysis of the healthcare sector has also attracted researchers from developing countries such as Iran (21) and China (18).

[5] The corresponding author is often the senior author who contributed the intellectual input and design to the study. To simplify research contribution across countries, the corresponding author is used for the mapping.

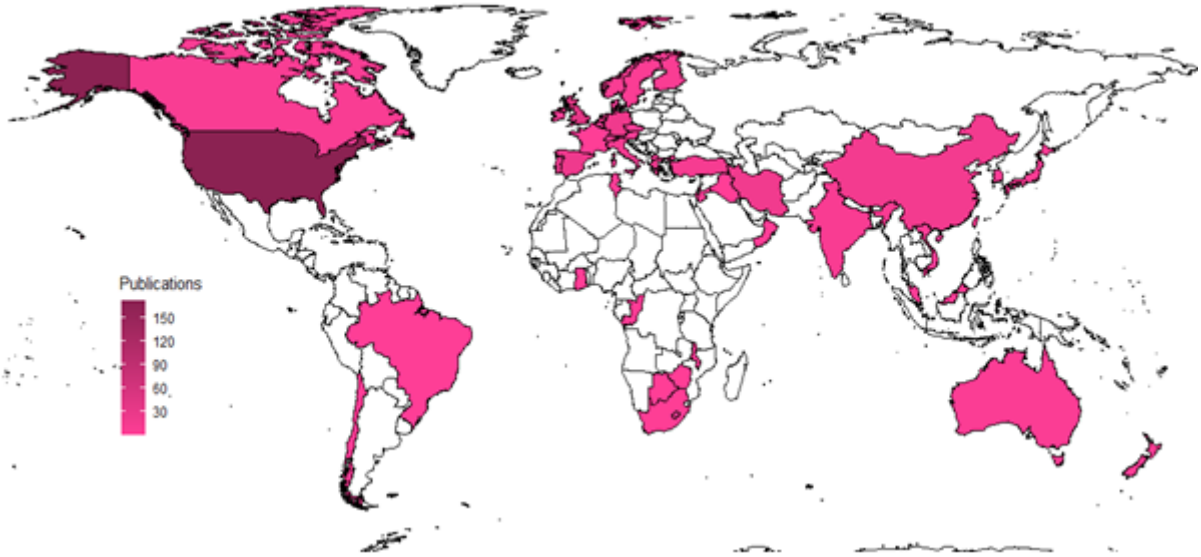


Fig. 3 Geographical contribution to publications based on the corresponding author from 1983 to 2019.

3.2 Most productive authors

A total of 921 authors contributed to publications on efficiency and productivity analysis in the healthcare industry during the study period. Table 1 presents the 16 most productive authors from 1983 to 2019; the majority of them are affiliated with institutions from developed countries. To normalize the author publication, fractional accounting is used to reflect the author's publication performance.

We observe that Ozcan played a leading role in 18.85 (3.95%) fractionalized publications, followed by Valdmanis and Rosko, with 10.33 (2.17%) and 6.17 (1.29%) fractionalized publications in this research field, respectively. As we observed in the literature data, Ozcan has a wide range of collaborative networks that produce a large number of publications. While the majority of his papers are focused on DEA applications for healthcare in the United States, they also involve OECD countries (Ozcan and Khushalani, 2017), Brazil (Ozcan et al., 2010; Lobo et al., 2010; Lobo et al; 2014), and Turkey (Ersoy et al., 1997; Sahin and Ozcan, 2000; Sahin et al., 2011; Kacak et al., 2014; Ozgen et al., 2015). Valdmanis also focused her healthcare studies in the United States, and she has strong collaborations with Rosko and Grosskopf, with Leleu and Ferrier.

The total fractionalized citations for the most productive authors are also presented in Table 1. The fractionalized number of citations can be obtained by multiplying the proportional contribution of an author with the number of citations in a particular publication. As shown in Table 1, 10 authors obtained more than 100 citations for their publications in the field of study. For instance, Ozcan (577.73) attracted the highest number of total citations, followed by Valdmanis (544.67) and Grosskopf (393.00).

Table 1: The 16 most productive authors during 1983-2019.

Author	Country	FP	WFP(%)	FC	*h*-index
Ozcan YA	USA	18.85 (1)	3.95	577.73 (1)	27
Valdmanis V	USA	10.33 (2)	2.17	544.67 (2)	24
Rosko MD	USA	6.17 (3)	1.29	331.83 (4)	24
Schreyogg J	Germany	3.75 (4)	0.79	135.92 (9)	23
Grosskopf S	USA	3.50 (5)	0.73	393.00 (3)	50
Ozgen H	Turkey	3.37 (6)	0.71	95.07 (11)	7

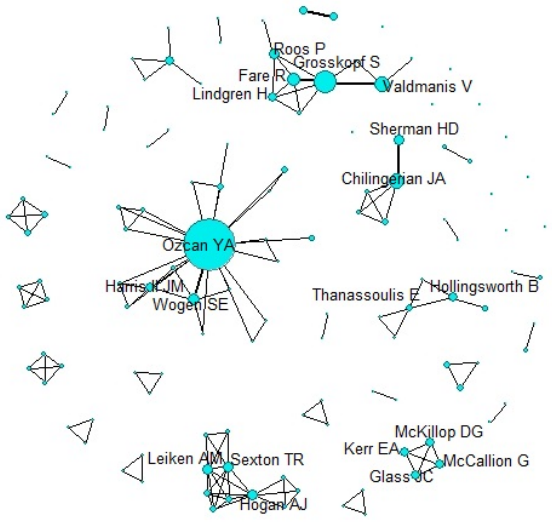
Magnussen J	Norway	3.26 (7)	0.68	164.20 (7)	16
Chilingerian JA	USA	3.08 (8)	0.65	252.58 (6)	13
Prior D	Spain	3.08 (8)	0.65	87.08 (12)	22
Harrison JP	United Kingdom	2.92 (10)	0.61	61.25 (15)	29
Hollingsworth B	United Kingdom	2.67 (11)	0.56	125.50 (10)	22
Street A	United Kingdom	2.67 (11)	0.56	77.58 (13)	25
Linna M	Finland	2.6 (13)	0.55	158.70 (8)	25
Blank JLT	Netherlands	2.5 (14)	0.52	36.00 (16)	9
Sherman HD	USA	2.5 (14)	0.52	280.50 (5)	57
Staat M	Germany	2.5 (14)	0.52	76.50 (14)	10

Note: FP is fractionalized publications; WFP is the ratio of fractionalized publications of an author to all authors for all publications during 1983 to 2019; FC is the fractionalized citations; the *h*-index for all relevant authors is obtained from the Scopus database; the number in parentheses represents the ranking for each author by publications and citations.

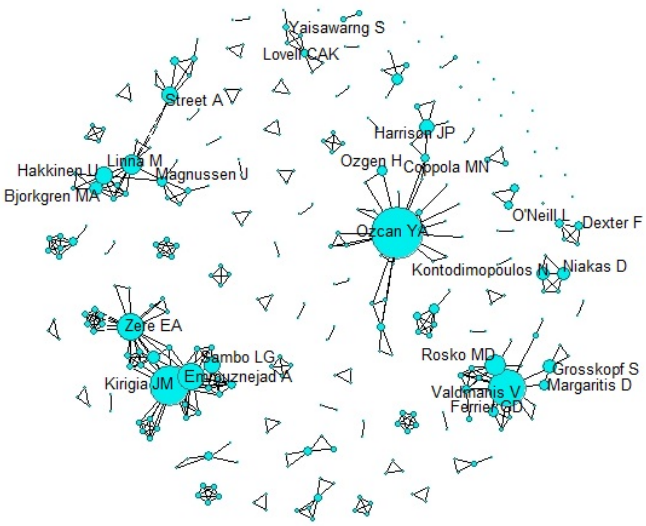
The collaborative relationship between authors in the publications is depicted in Figures 4(a)-(d). Each node represents an author, and the node size reflects the total number of publications for that author. The edge connecting two nodes is the collaboration link between those authors. During the 1983-2019 period, a few distinctive clusters were formed by the joining of several clusters, and many new and small clusters arose in the network.

As we discussed in the previous section, an upward publishing trend was observed for the research in this field over the study period. One interesting observation in Figure 4(a)-(c) is that there are a growing number of researchers who conducted benchmarking analyses of the healthcare sector. Domestic and international collaborations are important in conducting research, and the network size continued expanding over the study period. From the perspective of the collaborative links, 123, 316, and 484 nodes are found for the years 1983-2000, 2000-2009, and 2010-2019, respectively.

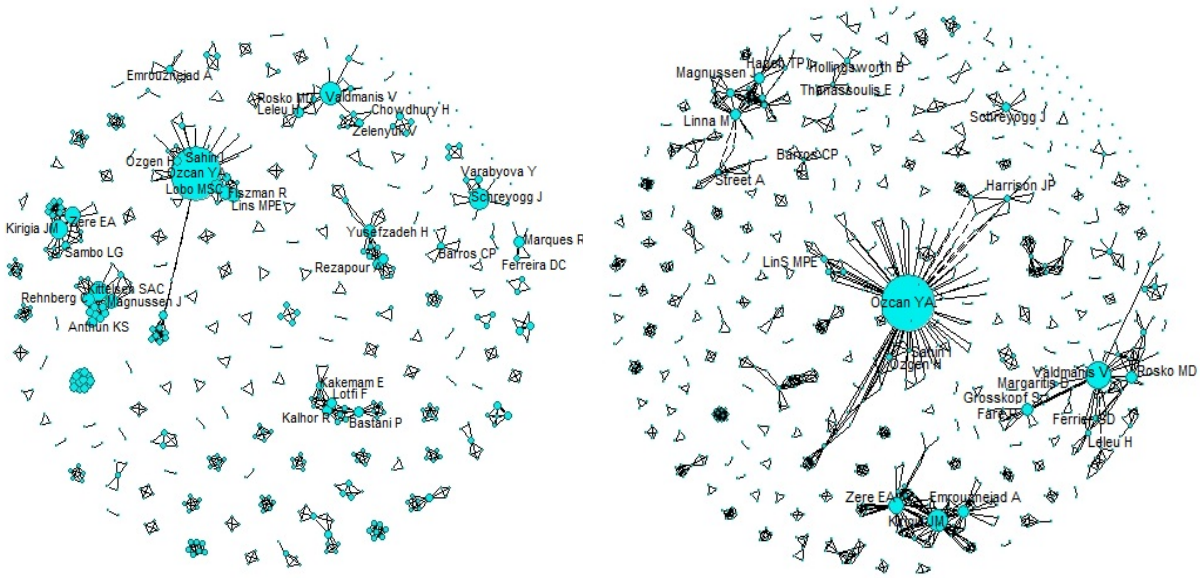
From Figure 4(d) we observe that Ozcan, Valdmanis, Kirigia, and Linna are the leading authors in the distinct clusters. These leading authors have a broad collaborative relationship with many authors in this research field. From 1983 to 2019, the distinctive clusters continued growing, and the largest node with the most coauthors in the network was Ozcan. Many new authors emerged in this research, but these authors are bounded by a limited number of publications and are more likely to have a limited number of coauthors in the network.



(a) Author collaboration network: 1983 – 1999.



(b) Author collaboration network: 2000 – 2009.



(c) Author collaboration network: 2010 – 2019. (d) Author collaboration network: 1983 – 2019.

Fig. 4 Author collaboration over 4 decades.

3.3 Most productive institutions

The contribution of institutions in healthcare benchmarking studies was analyzed through the full affiliation address of the authors in the publications. Table 2 shows the 15 most productive institutions based on the fractionalized number of publications from 1983 to 2019. The results indicate that Virginia Commonwealth University was ranked at the top, contributing the most (39.08, 8.19%) publications, followed by University of York (9.33, 1.95%) and Widener University (6.88, 1.44%). This implies that Virginia Commonwealth University started contributing to this field in 1992 because Ozcan was one of the authors affiliated with this university and had been the editor of Health Care Management Science. It is remarkable that most of the affiliations come from developed countries, except for the Tehran University of Medical Sciences, which has 3.67 (0.77%) publications. Examining the total number of citations, we find that 13 affiliations have more than 100 citations, as shown in Table 2.

Table 2: The 15 most productive institutions during 1983-2019.

Affiliation	Country	FP	WFP (%)	FC
Virginia Commonwealth University	USA	39.08 (1)	8.19	1156.25 (1)
University of York	UK	9.33 (2)	1.95	397.17 (2)
Widener University	USA	6.88 (3)	1.44	352.29 (3)
Hacettepe University	Turkey	5.75 (4)	1.21	136.75 (10)
University of North Florida	USA	5.17 (5)	1.08	103.17 (13)
Hellenic Open University	Greece	5.00 (6)	1.05	158.50 (9)
University of Hamburg	Germany	4.83 (7)	1.01	179.83 (7)
University of Oslo	Norway	4.33 (8)	0.91	165.17 (8)
Washington State University	USA	4.33 (8)	0.91	219.83 (5)
Tulane University	USA	4.03 (10)	0.84	211.93 (6)
Aston University	UK	3.92 (11)	0.82	113.17 (12)
Technical University of Lisbon	Portugal	3.83 (12)	0.80	96.83 (14)

University of Iowa	USA	3.83 (12)	0.80	127.67 (11)
Brandeis University	USA	3.67 (14)	0.77	270.83 (4)
Tehran University of Medical Sciences	Iran	3.67 (14)	0.77	35.67 (15)

Note: FP is the fractionalized publications; WFP is the ratio of fractionalized publications of an insitution to all institutions for all publications during 1983 to 2019; FC is the fractionalized citations; the number in parentheses represents the ranking of institutions by publications and citations.

The collaborative relationship among the affiliations for all publications was analyzed using network analysis, as depicted in Figure 5. The node represents the affiliation, and the size of the node is directly proportional to the number of publications. The edge shows a collaborative link between the affiliations. The findings in the network are as follows: (i) The Virginia Commonwealth University was dominant in this research field since it has the largest size of the node. (ii) There are a total of 154 clusters in this field consisting of independent and interconnected affiliations.

As seen in Figure 5, several distinctive clusters were established with a leading contributor to this field, including the Virginia Commonwealth University, the World Health Organization regional office for Africa, and University of the Sciences in Philadelphia.

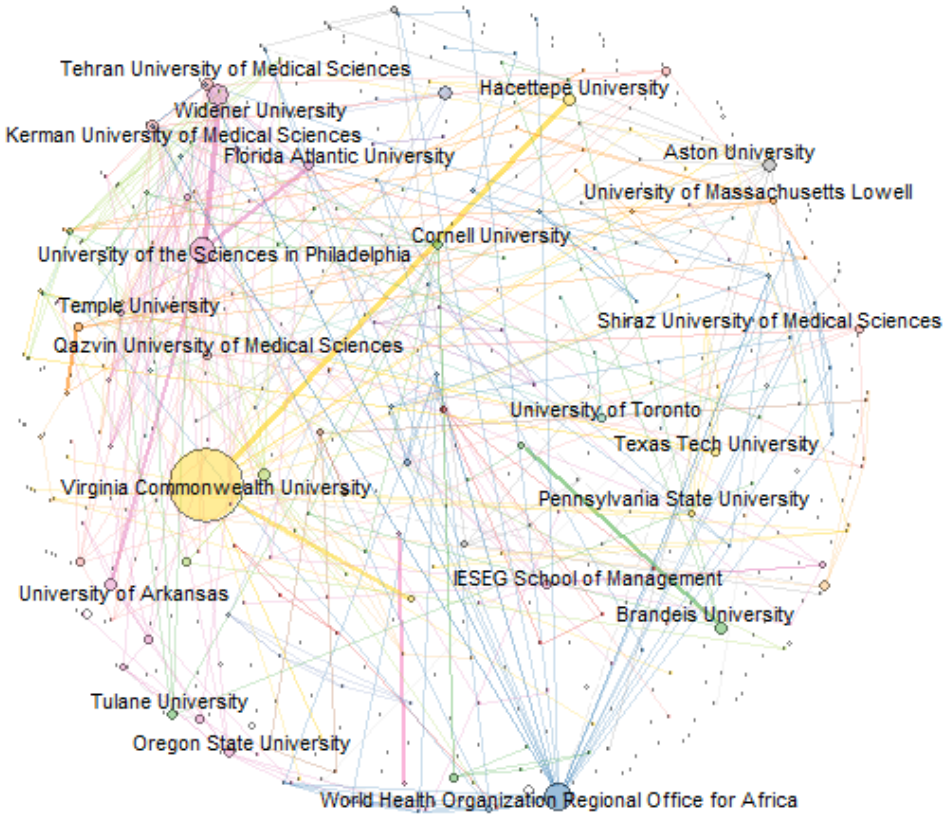


Fig. 5: Collaborative network for institutions, 1983-2019

3.4 Most productive countries

It is interesting to note the contribution of countries to the research in this field relevant to their different research interests and different healthcare systems (Kohl et al., 2018). Table 3 reports the 15 most productive countries by their contributions to efficiency and productivity analyses of the healthcare sector during the 37-year study period. From Table 3, we can observe that researchers

from the USA have produced 161.17 publications (33.79%) related to healthcare benchmarking studies. Researchers from the United Kingdom and Spain also show significant contributions to the research in this field, with 37.87 (7.94%) and 22.00 (4.61%), respectively. The results also revealed that the USA has attracted the highest number of total citations (6728.00), followed by the United Kingdom (1446.95) and Germany (700.33).

Table 3: The 15 most productive countries during 1983-2019.

Country	FP	WFP(%)	FC
USA	161.17 (1)	33.79	6728.00 (1)
United Kingdom	37.87 (2)	7.94	1446.95 (2)
Spain	22.00 (3)	4.61	496.50 (5)
Iran	21.00 (4)	4.40	232.50 (11)
Germany	19.17 (5)	4.02	700.33 (3)
Greece	18.83 (6)	3.95	550.17 (4)
Turkey	17.50 (7)	3.67	363.50 (7)
Taiwan	15.33 (8)	3.21	363.67 (6)
China	15.00 (9)	3.14	212.50 (12)
Italy	14.33 (10)	3.00	280.67 (9)
Portugal	11.50 (11)	2.41	196.00 (13)
Norway	11.25 (12)	2.36	358.00 (8)
Canada	9.33 (13)	1.96	241.83 (10)
India	9.00 (14)	1.89	87.50 (15)
Netherlands	8.03 (15)	1.68	151.03 (14)

Note: European countries include the United Kingdom (37.87), Spain (22.00), Germany (19.17), Greece (18.83), Italy (14.33), Portugal (11.50), Norway (11.25), and the Netherlands (8.03). FP is the fractionalized publications; WFP is the ratio of fractionalized publications of a country to all countries for all publications during 1983 to 2019; FC is the fractionalized citations; the number in parentheses represents the ranking for the total number of publications and total number of citations as shown for each country.

There are several important academic collaborations across countries. Research collaborations can develop innovative solutions and improve the quality of work, and researchers from developing countries seek research experience by conducting healthcare benchmarking analysis with prominent researchers from developed countries through coauthored collaborations. Three different chord diagrams, Figures 6(a)-(c), are used to visualize country collaborations providing new insights and approaches such as resource involvement, direction, contribution, and abstraction.

In Figure 6(a), the nodes are the countries, and the chords show the collaborative links connecting the nodes. The thickness of the chord connecting two nodes indicates the extent of the collaboration. We observe that the USA, the United Kingdom, Germany, Turkey, and Greece are the 5 most active countries in international collaborations.

To illustrate international cooperation through authoring journal articles in detail, the research collaborations of two countries, the USA and the United Kingdom, are presented in Figures 6(b)-(c), respectively. Specifically, in Figure 6(b), we observe that three countries, France, China and Turkey, have relatively stronger collaborations than other countries with the USA. By contrast, the United Kingdom has attracted the highest number of collaborative countries, as illustrated in Figure 6(c). Developing countries such as South Africa, Nigeria, and India have shown an interest in healthcare efficiency and productivity studies in recent years, but they seem to have developed a limited number of international collaborative relationships with other countries.

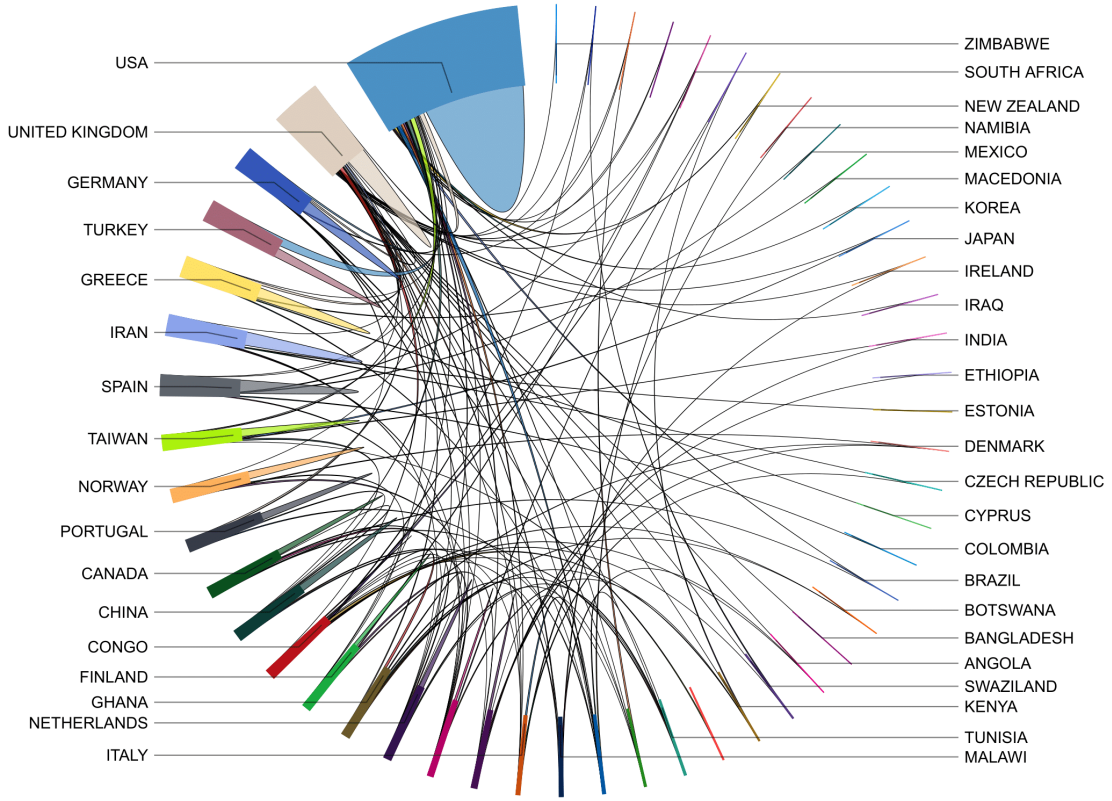


Fig. 6(a): Country collaboration flow in healthcare benchmarking studies

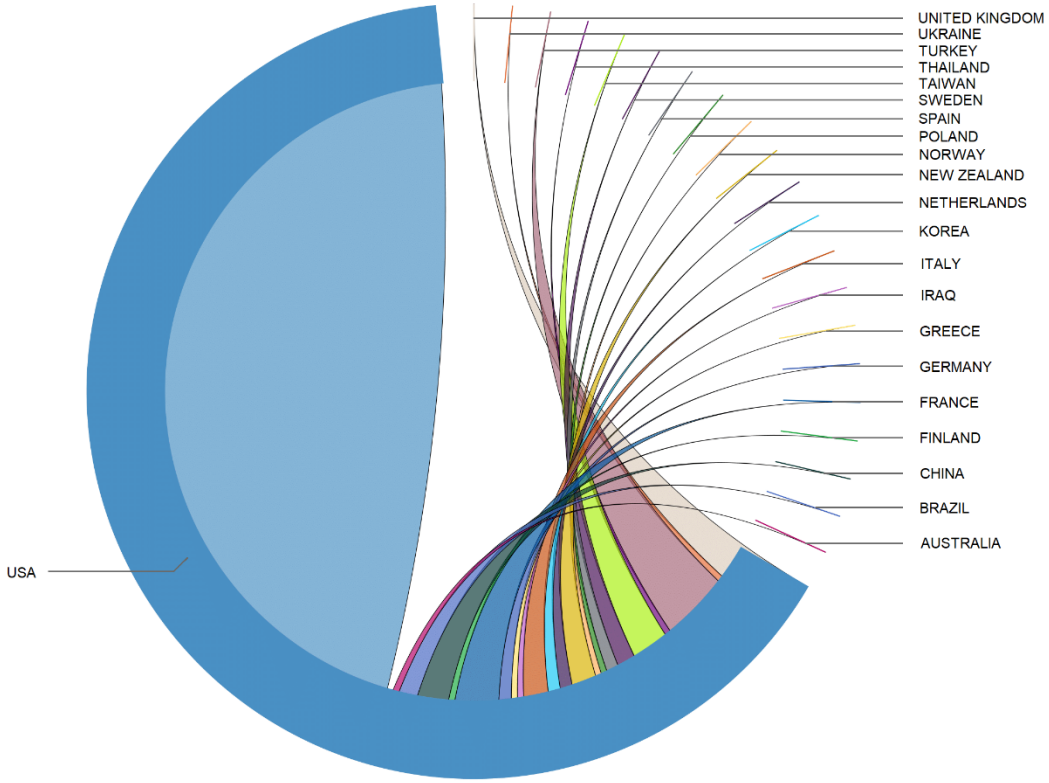


Fig. 6(b): International cooperation through authoring journal articles between the USA and other countries.

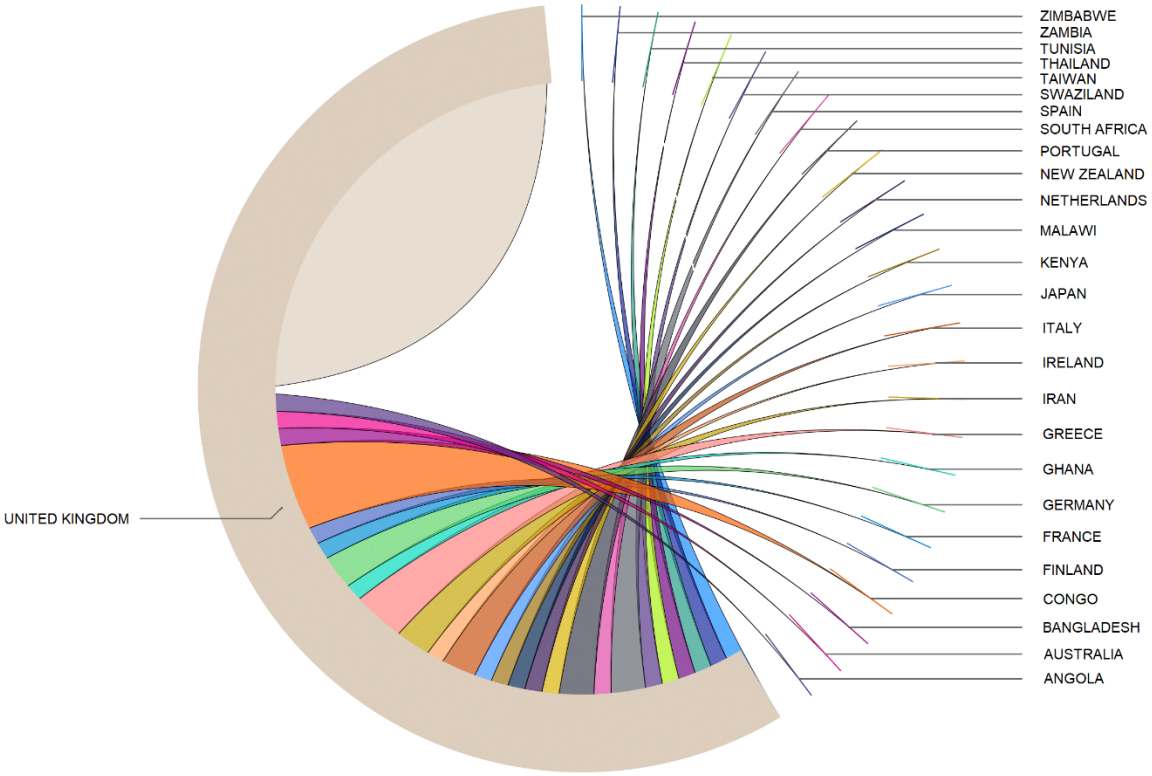


Fig. 6(c): International cooperation through authoring journal articles between the United Kingdom and other countries.

3.5 Most influential journals

Table 4 lists the distribution of the publications in peer-reviewed journals of studies offering efficiency and productivity analysis of the healthcare sector from 1983 to 2019. A total of 477 articles were published in 148 journals. Health Care Management Science (11.53%), Journal of Medical Systems (7.13%) and Health Economics (4.82%) are the most common publication outlets considered by researchers when submitting their research efforts in this area of study. There are also four journals (i.e., European Journal of Operational Research, Annals of Operations Research, Socio-Economic Planning Sciences and Journal of Productivty Analysis) that are not specific to health but that typically publish more recent and innovative approaches used in the health care applications.

Similar to the results for citations, Health Care Management Science gained the highest number of citations (1599.00), followed by Journal of Medical Systems (1070.00) and Journal of Productivity Analysis (1061.00). Although there might be different perspectives from the researchers when assessing the performance of these core journals, such as publications, impact factor, or total number of citations, the journal list reported in Table 4 presents the core journals considered when researchers search for literature on healthcare benchmarking studies. Such information can be useful for researchers by helping them to submit their research to the most appropriate publication outlets.

Table 4. The 14 most influential journals in healthcare benchmarking studies

Source	P	WP(%)	IF	C
Health Care Management Science	55 (1)	11.53	2.150 (11)	1599.00 (1)
Journal of Medical Systems	34 (2)	7.13	3.058 (4)	1070.00 (2)
Health Economics	23 (3)	4.82	2.250 (9)	1015.00 (4)
Applied Economics	19 (4)	3.98	1.103 (13)	695.00 (6)
Health Policy	18 (5)	3.77	2.212 (10)	618.00 (9)
European Journal of Operational Research	17 (6)	3.56	4.213 (1)	939.00 (5)
European Journal of Health Economics	13 (7)	2.73	2.367 (7)	296.00 (11)
Annals of Operations Research	12 (8)	2.52	2.583 (6)	361.00 (10)
Health Services Research	11 (9)	2.31	2.351 (8)	666.00 (8)
Health Services Management Research	10 (10)	2.10	n/a (14)	260.00 (12)
Medical Care	9 (11)	1.89	3.210 (3)	687.00 (7)
Socio-Economic Planning Sciences	9 (11)	1.89	4.149 (2)	250.00 (13)
Health Care Management Review	8 (13)	1.68	2.667 (5)	243.00 (14)
Journal of Productivity Analysis	8 (13)	1.68	1.375 (12)	1061.00 (3)

Note: P is the total number of publications; WP is the ratio of publications of a source to all sources for all publications during 1983 to 2019; IF is the impact factor in 2019 obtained from Incites Journal Citation Reports, Clarivate Analytics; C is the total number of citations; n/a indicates that the information is not available in Incites Journal Citation Reports; Number of parentheses represent the ranking for the total number of publications, impact factor, and total number of citations as shown for each source.

3.6 Most cited articles

The number of total citations for an article is indicative (although not perfectly) of the significance of its impact and the spread of its influence in the specific field (Celayir et al., 2008). Table 5 presents the most globally cited publications on benchmarking analysis of the healthcare sector from 1983 to 2019. “Local citation” represents the total number of articles cited within the collection of 477 articles in the field, whereas "global citation" refers to the cumulative Scopus citations for an article. We observe that there is a significant gap between local citations and global citations, as reported in Table 5(a), which reveals that these healthcare benchmarking studies also attract attention from researchers in other disciplines. Meanwhile, the summary of key finding(s) in the most cited articles are presented in Table 5(b) and briefly described below.

As shown in Table 5, “Productivity changes in Swedish pharmacies 1980-1989: a non-parametric Malmquist approach” and “Accounting for environment effects and statistical noise in data envelopment analysis” published by Journal of Productivity Analysis were ranked first and second for the highest number of global citations, with 564 and 313 citations, respectively. The most globally cited paper, Färe et al. (1992), proposed the input-oriented Malmquist productivity index and its decompositions in assessing the productivity growth of 42 pharmacies in Sweden. The results revealed that technical change contributes the most to productivity growth over the study period. The second-most globally cited paper, Fried et al. (2002), developed a three-stage analysis that integrated environmental variables and statistical noise to evaluate the performance of 990 hospital-affiliated nursing homes in the United States. Both papers are examples of a manuscript that developed a new methodology or made some novel improvement to the existing methods. However, these papers only attracted a small number of local citations because both were focused on developing new methods to evaluate the performance of the healthcare sector.

The third most cited article is entitled “Measuring hospital performance: a non-parametric approach”, coauthored by Grosskopf and Valdmanis (1987) and published by the Journal of Health Economics, with 248 global citations and 76 local citations. The purpose of the paper was to examine the efficiency of 22 public and 60 not-for-profit hospitals in California using a DEA model. The results of the study

confirmed that public hospitals are more efficient than not-for-profit hospitals. This article was considered a good application of DEA models and was well-received by researchers from both within and outside the discipline.

From the total number of articles collected, a total of 49 articles with more than 70 global citations were selected for citation network mapping. Based on the content analysis, 49 highly cited articles were examined, and the key literature of this research was reviewed. As illustrated in Figure 7, six main themes are detected by the citation network within this research area:

(i) Articles in the red shaded cluster, including Färe et al. (1992), Färe et al. (1995), Burgess and Wilson (1996), Chang et al. (2004), Chang et al. (2011), Maniadakis and Thanassoulis (2004), Nyman and Bricker (1989), Chang (1998), Ferrier and Valdmanis (1996), are mainly involved in developing a new modelling framework for efficiency analysis with an application (or an empirical illustration) in the healthcare sector;

(ii) Articles in the green shaded clusters are more focused on studying technical efficiency using either the DEA or SFA model. Biorn et al. (2003), Rosko (2001), Tiemann and Schreyogg (2012), Herr (2008), Ozcan et al. (1992), Varabyova and Schreyogg (2013), Retzlaff-Roberts et al. (2004), Nayar and Ozcan (2008), and Jacobs (2001) are examples of interest of this type of performance study;

(iii) Articles in the blue shaded cluster examine the determinants of efficiency in various healthcare facilities, i.e., Chen et al. (2005), Chirikos and Sear (2000), Ozcan and Luke (1993), Harris et al. (2000), Chilingerian and Sherman (1990), Magnussen (1996), Nunamaker (1983).

(iv) Articles in the orange shaded cluster, including Zuckerman et al. (1994), Linna (1998), Koop et al. (1997), Barbetta et al. (2007), examine hospital performance considering different types of hospital ownership, including public and private hospitals.

(v) Articles in the yellow shaded cluster are examples of technical efficiency studies of hospitals using a DEA model. including Grosskopf and Valdmanis (1987), Parkin and Hollingsworth (1997), Kirigia et al. (2002, 2004), Osei et al. (2005) and Zere et al. (2006).

(vi) Articles in the purple shaded cluster are focused on primary care services, such as nursing homes (Rosko et al., 1995), physicians (Chilingerian, 1995), individual specialties of National Health Services Trusts in the United Kingdom (Tsai and Molinero, 2002), and Family Health Service Authorities in the United Kingdom (Salinas-Jimenez and Smith, 1996).

Table 5(a). The 10 most cited articles in efficiency and productivity analysis in healthcare, 1983-2019.

Title	Author(s)	Year	Journal	Local Citations	Global Citations
Productivity changes in Swedish pharmacies 1980-1989: a non-parametric Malmquist approach	Färe R; Grosskopf S; Lindgren B; Roos P	1992	Journal of Productivity Analysis	18 (8)	564 (1)
Accounting for environment effects and statistical noise in data envelopment analysis	Fried HO; Lovell CAK; Schmidt SS; Yaisawarng S	2002	Journal of Productivity Analysis	5 (9)	313 (2)
Measuring hospital performance: a non-parametric approach	Grosskopf S; Valdmanis V	1987	Journal of Health Economics	76 (1)	248 (3)
Measuring hospital efficiency with frontier cost functions	Zuckerman S; Hadley J; Iezzoni L	1994	Journal of Health Economics	59 (2)	234 (4)
Hospital efficiency measurement and evaluation: empirical test of a view technique	Sherman HD	1984	Medical Care	54 (4)	208 (5)
Alternative methods to examine hospital efficiency: data envelopment analysis and stochastic frontier analysis	Jacobs R	2001	Health Care Management Science	37 (5)	163 (6)
Evaluating physician efficiency in hospitals: a multivariate analysis of best practices	Chilingerian JA	1995	European Journal of Operational Research	27 (7)	155 (7)
Bayesian efficiency analysis through individual effects: hospital cost frontiers	Koop G; Osiewalski J; Steel MFJ	1997	Journal of Econometrics	4 (10)	142 (8)
Measuring routine nursing service efficiency: a comparison of cost per patient day and data envelopment analysis models	Nunamaker TR	1983	Health Services Research	33 (6)	134 (9)
Ownership and organizational performance: a comparison of technical efficiency across hospital types.	Ozcan YA; Luke RD; Haksever C	1992	Medical Care	56 (3)	128 (10)

Note: The number in parentheses represents the ranking for the article citations.

Table 5. Summary of key finding(s) based on the 10 most cited articles in efficiency and productivity analysis in healthcare.

Author(s)	Year	Data	Paper Orientation	Method	Key Finding(s)
Färe R; Grosskopf S; Lindgren B; Roos P	1992	42 Swedish pharmacies, 1980 to 1989.	Methodology	DEA Malmquist Productivity Index	Technological progress contributes the most to the productivity growth over the study period.
Fried HO; Lovell CAK; Schmidt SS; Yaisawarng S	2002	990 US hospital-affiliated nursing homes, 1993	Methodology	Three stages DEA model	Small scale hospital-affiliated nursing homes are more favorable in the existing operating environment after the DEA score is adjusted with enviromental variables.
Grosskopf S; Valdmanis V	1987	22 public and 60 not-for-profit hospitals in California, 1982	Application	VRS input oriented DEA model	Public hospitals are more technically efficient than not-for-profit hospitals as they use fewer input sources for hospital services.
Zuckerman S; Hadley J; Iezzoni L	1994	5322 US hospitals, 1986-87	Application	Stochastic cost frontier model	Eliminating hospital inefficiency can save 13.6% of total hospital costs.
Sherman HD	1984	7 hospitals in Massachusettes, 1976	Application	CRS input oriented DEA model	The results confirm that DEA is an alternative for hospital performance measurement and is compared to the ratio or econometric approach.
Jacobs R	2001	232 NHS hospitals in the UK, 1995/96	Application	DEA and SFA models	Random “noise” and data deficiencies explain the variations between DEA and SFA models.
Chilingerian JA	1995	36 physicians in a single hospital	Application	DEA model and tobit regression	Physicians are efficient if they are working at health maintenance organizations and specialize by diagnostic related groups.
Koop G; Osiewalski J; Steel MFJ	1997	382 nonteaching hospitals in the US, 1987-1991	Methodology	Bayesian SFA cost frontier model	Public hospitals are more cost efficient than for-profit hospitals.
Nunamaker TR	1983	17 hospitals from Wilcosin group, 1978-79	Application	CRS input oriented DEA model	A total of 60% of hospitals experienced managerial inefficiency, while case mix differences should be taken into consideration for potential savings.
Ozcan YA; Luke RD; Haksever C	1992	3000 US hospitals, 1987	Application	CRS output oriented DEA model	Public hospitals are more technically efficient than for-profit hospitals.

Notes: CRS: Constant returns to scale; VRS: Variable returns to scale

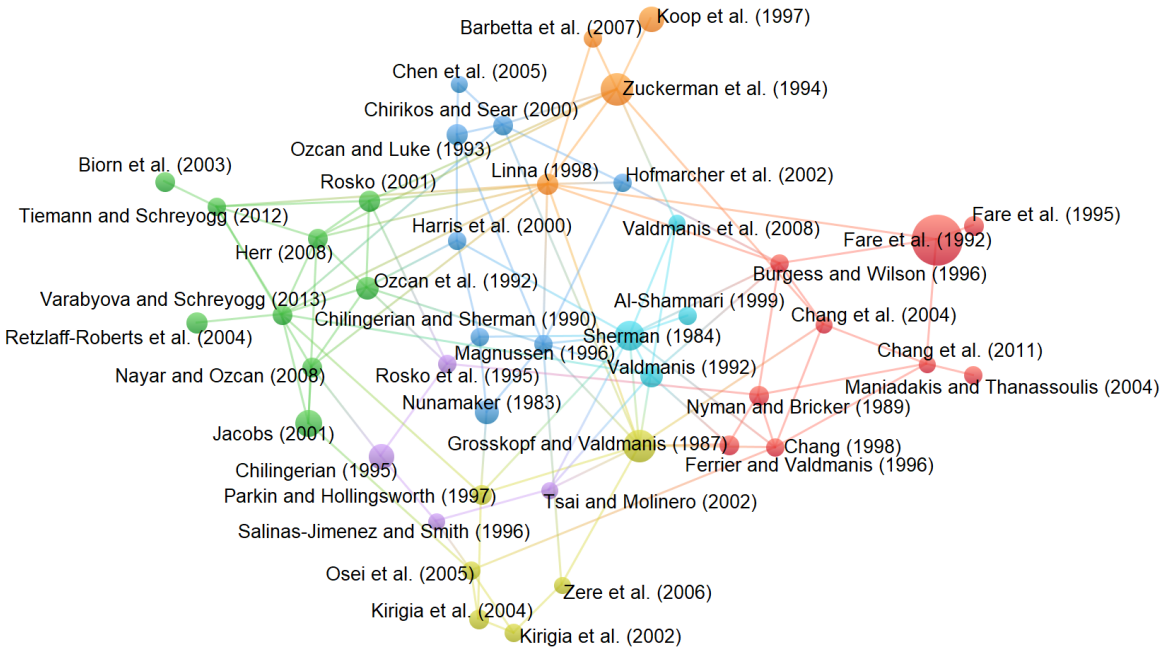


Fig. 7 Citation network of 49 related articles (threshold = 70 citations)

From Table 5, it was demonstrated that the DEA model and its variants were employed more often than either the SFA or stochastic cost frontier. One reason for the popularity of DEA in assessing performance in health care is that researchers are hard pressed to make a priori economic assumptions related to cost minimization or profit maximization. This is due to the substantial share of public and non-profit ownership forms in the industry, as well as other health care objectives such as charity care, treating uninsured patients, and teaching that would alter a strict cost-minimization/profit maximization approach.

3.7 Keyword analysis

This section analyzes the direction and hotspots of these studies using keyword analysis and visualization tools. Elements of the publications such as title, abstract, author keywords, and keywords plus[6] are often used to identify emerging issues and research trends. To some extent, the author keywords are preferred elements for bibliometric analysis. Therefore, we use the author keywords in this study to reveal the information for all publications. To capture the author keywords between developed and developing countries, Figures 8(a)-(e) summarize the keywords plus articles for the relevant studies. A total of 334 articles involved studies conducted in developed countries, whereas 137 articles were focused on developing countries.[7] Because the first article of healthcare benchmarking analysis in developing countries was accepted and published in 1997, the keyword cloud for developing countries is presented in two periods, i.e., 1997-2009 and 2010-2019.

[6] Keyword plus is generated by a computer algorithm and is usually based on the titles of an article's references. In many cases, keyword plus may be different than the author keywords of an article.

[7] A total of 7 articles involving developed and developing countries are excluded in the author keywords analysis.

(a) Developed countries, 1983 – 1999.

(b) Developed countries, 2000 – 2009.

(c) Developed countries, 2010 – 2019.

(d) Developing countries, 1997 – 2009.

(e) Developing countries, 2010 – 2019.

Fig. 8. Author keywords from healthcare benchmarking studies in developed and developing countries

In developed country studies, the most widely used author keywords over the study period are consistent: DEA (153), efficiency (83), hospitals (53), hospital efficiency (34). From Figures 8(a)-(c), we observe that the DEA model, compared to the SFA model, is a popular method employed in studies involving developed countries. To explore the determinants of efficiency, the bootstrapping method was adopted by studies, especially during the most recent 10 years of the study period. Furthermore, hospital quality has been considered an important focus in measuring healthcare performance in developed countries since 2000. There is a significant difference when one compares the author keywords used to reflect the content of the article between developed and developing countries. Prior to 2010, the most frequently used author keywords in developing countries, such as "DEA", "hospital efficiency", "hospital", "healthcare" and "productivity", were similar to the keywords from earlier studies in developed countries from 1983 to 1999. Other keywords, for instance, "the SFA model" and "hospital quality", appear in developing countries for efficiency and productivity analyses of the healthcare sector from 2010 to 2019.

We also examine the combined author network and keyword network, as illustrated in Figure 9. In these two mode networks, the edges represent relationships between the nodes, and the square boxes and circles represent the authors and author keywords, respectively. A few insights can be captured in these two mode networks. First, several productive authors are linked to methodologies and application-based keywords. For instance, Ozcan, Valdmanis, Harrison, and Grosskopf are the most prominent researchers developing and using DEA models, while Rosko and Schreyogg are the most prominent researchers applying the SFA model in healthcare publications. Second, several author keywords, such as "DEA", "technical efficiency", "hospitals", and "quality", are located at the center of the network. For example, DEA model, technical efficiency measurement and hospitals are the main focus of studies conducting an efficiency evaluation of the healthcare sector and covering diverse issues.

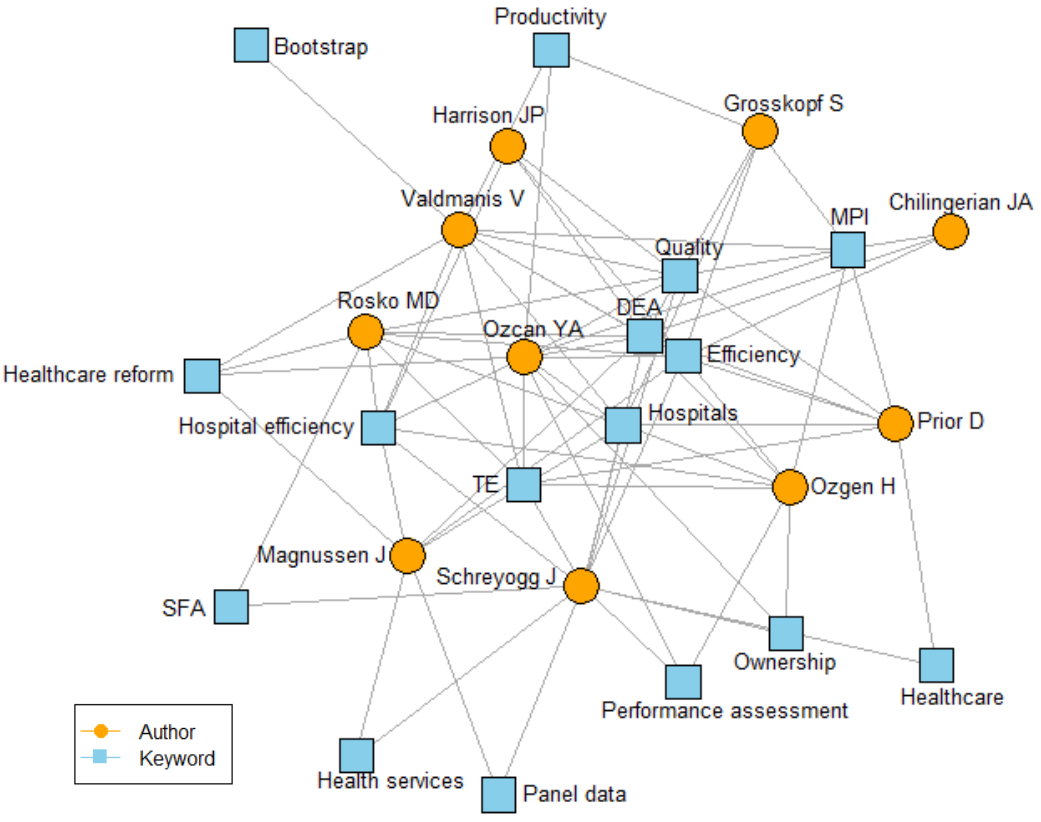
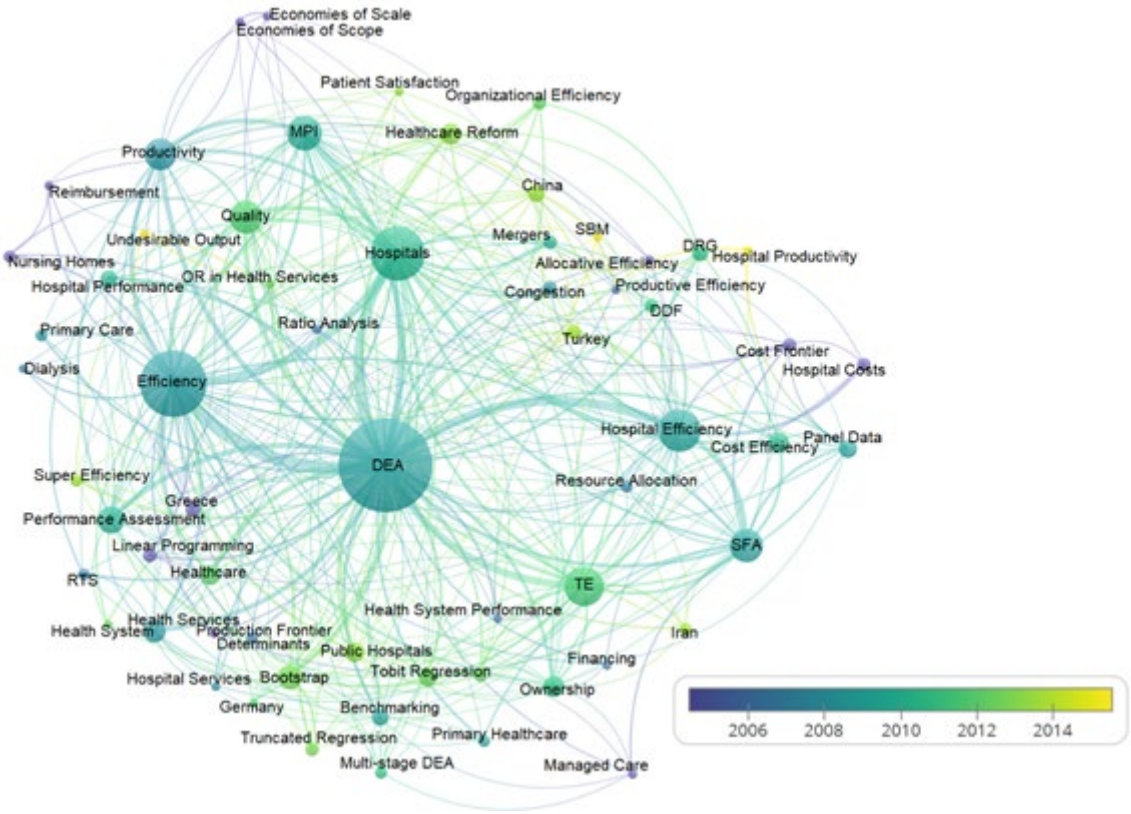


Fig. 9 Combined author and keyword networks for 1983-2019.

One potentially interesting observation in Figure 9 is that Ozcan has strong experience in addressing the performance of the healthcare sector since he is located at the center and connected to the largest number of keywords. It is worth highlighting that Ozcan is a leading contributor in application-oriented healthcare studies and, as identified above when discussing the number of publications from The Virginia Commonwealth University, was until recently the editor of Health Care Management Science.

Temporal overlay is another visualization tool that can be used to review the links between keywords and the more recent publications in healthcare efficiency and productivity. To reflect the more recent topical trends in the overall healthcare efficiency literature, the temporal overlay keyword co-occurrence network from 2005-2015 is presented in Figure 10(a).[8] The darker nodes represent the popular author keywords in the earlier literature, and the lighter shaded nodes are those keywords featured in the more recent literature.



Note: The threshold is set to 3, and the total number of keywords is 61.

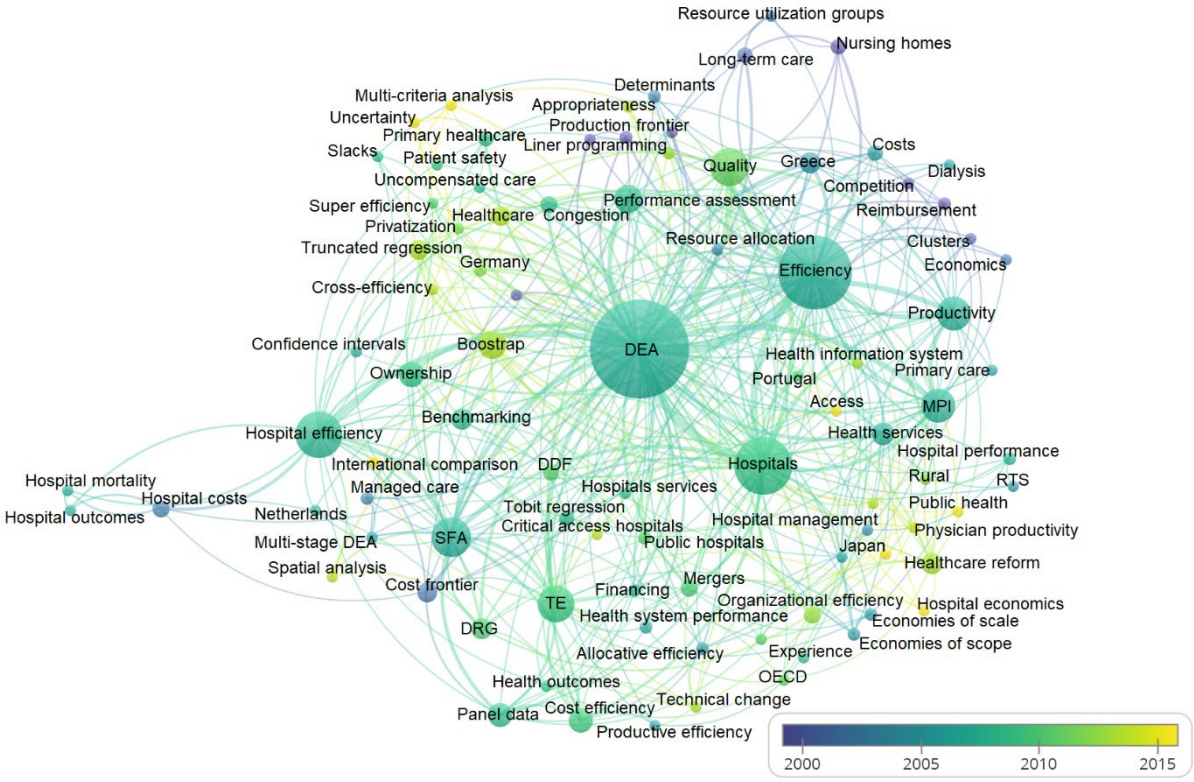
Fig. 10(a) Temporal overlay keyword co-occurrence network from 2005-2015

As shown in Figure 10(a), we observe that there has been a change in research focus in healthcare benchmarking studies over these 11 years. The keywords “DEA”, “efficiency”, “hospital efficiency”, and “productivity” are the core keywords representing the earlier literature. In recent years, there has been a growing emphasis on topics such as “slack-based measure”, “healthcare reform”, “undesirable output”, “bootstrap”, “patient satisfaction” and “truncated regression”. The mapping also revealed that the keyword “healthcare reform” is closely linked with “patient satisfaction” and “organizational efficiency”, while recent keywords such as “bootstrap”, “truncated regression”, “Tobit regression”,

[8] The temporal overlay for the keyword co-occurrence network is selected based on the threshold setting.

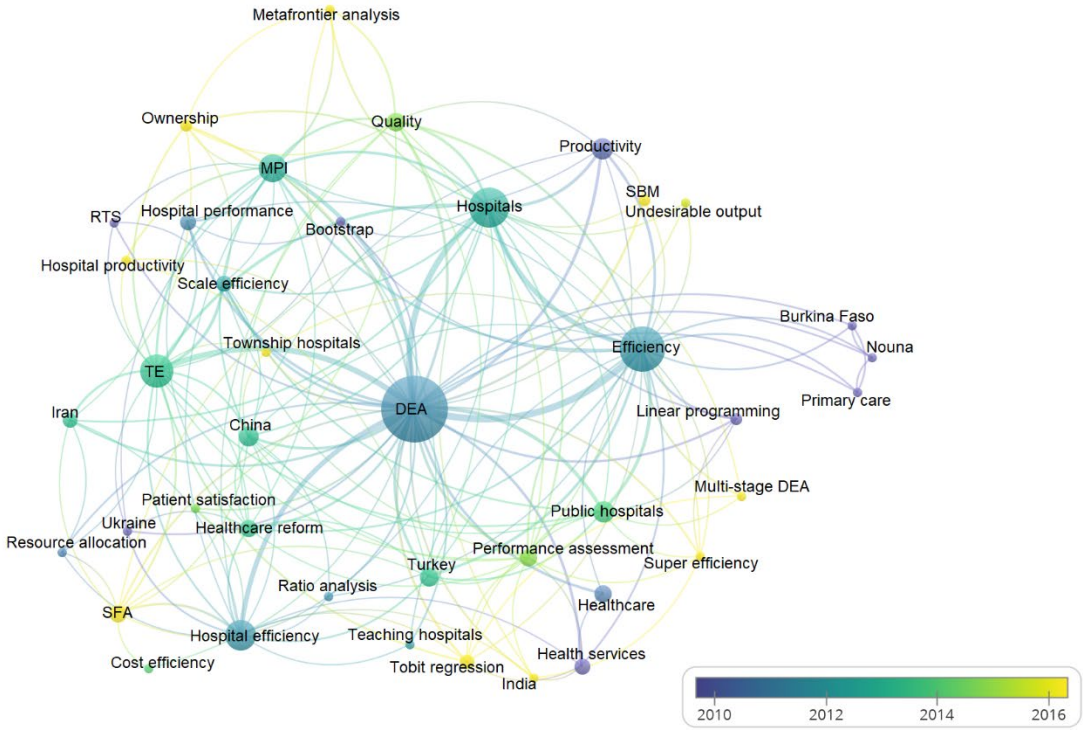
and “ownership” are linked together and associated with the identification of determinants of healthcare efficiency.

Temporal overlays of the keyword co-occurrence network in the healthcare efficiency literature involving developed and developing countries is illustrated in Figure 10(b)-(c), respectively. We observe that the relative emphases on topics in developed countries have grown faster over the last 18 years. The research frontiers in the healthcare efficiency literature are concentrated on “DEA”, “hospital”, “efficiency”, and “SFA”, while recent interest revolves around “bootstrap”, “cross efficiency”, “healthcare reform”, “quality”, “uncertainty” and “access”. These findings are consistent with findings from other recent reviews. Research frontiers similar to those applied in developed countries are also appear in developing countries. However, more recent topical trends from 2009 to 2017 in developing countries are focused on “SFA”, “ownership”, “meta frontier”, “Tobit regression”, “SBM”, and “super efficiency”.



Note: The threshold is set to 2, and the total number of keywords is 91.

Fig. 10(b) Temporal overlay keyword co-occurrence network in developed countries, 1999-2016



Note: The threshold is set to 2, and the total number of keywords is 41.

FI 10(c) Temporal overlay keyword co-occurrence network in developing countries, 2009-2017

3.8 Country analysis

The geographical distribution of healthcare benchmarking analyses over the study period is presented in Figure 11. It is important to note that those articles involving a large number of countries, such as Puig-Junoy (1998), Retzlaff-Roberts et al. (2004), Varabyova and Schreyogg (2013), and Ozcan and Khushalani (2017), are excluded from this particular analysis because assigning the fractional weight to individual countries becomes challenging when a large number of countries are involved in a single study.

As previously discussed, there is a growing number of total publications in healthcare efficiency and productivity analysis, and most of the literature is focused on the healthcare sector in the United States (151.17 fractionalized publications), followed by China (24), Iran (22), Greece (21) and the UK (21). In total, healthcare benchmarking analyses have been conducted in 66 countries from 1983 to 2019.

However, there are 'white spaces' in the world mapping, as shown in Figure 11. The majority of countries in this 'white space' are developing countries. The reasons for the lack of research output in this area are likely explained by the standard challenges these countries face: for example, lack of research infrastructure and funding and, closely related and perhaps most important, a lack of accurate data. With further advances in information technologies that simplify and facilitate data collection and reduce the barriers to knowledge and skills, we believe that these `white spaces' will be substantially diminished in the next decade.

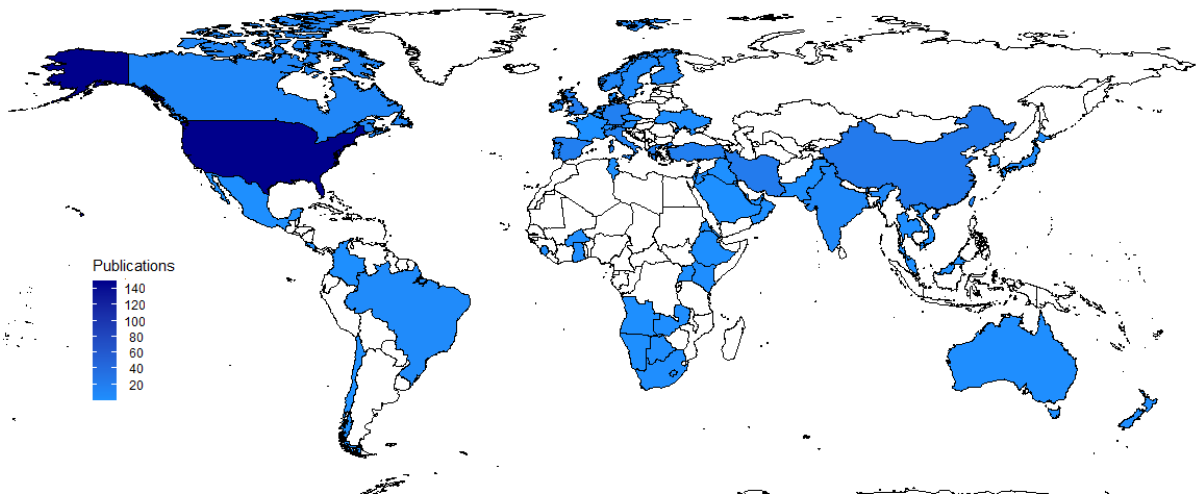


Fig. 11 Geographical distribution of healthcare benchmarking studies for 1983-2019.

4. Concluding Remarks

To the best of our knowledge, this is the first study offering a comprehensive and systematic review of the literature on healthcare efficiency and productivity research using machine learning tools for bibliometric analysis. Specifically, the PRISMA procedure was adopted to identify the literature collection from Scopus indexed journals, and a total of 477 articles published in Scopus-indexed journals from 1983 to 2019 were collected and reviewed using machine learning tools. Compared to other papers surveying healthcare benchmarking analysis, our study is focused on research impact from the author, affiliation, and country perspectives. A summary of key findings from our bibliometric study is presented in Table 6.

From an author perspective, a total of 921 authors are involved in healthcare benchmarking studies. Several distinct clusters are found in the author collaboration networks; for instance, Ozcan, Valdmanis, Kirigia, and Linna were identified as the leading authors over the study period. We also observe that collaboration network size continued to expand, and many new and small clusters are observed appearing over the study period. In addition, researchers from the USA have produced one-third of the total literature collection and have also attracted more than 6000 citations. Several developed countries including the USA, the UK, and Germany are the most active for international collaborations in this research field.

The total number of published articles has been increasing since the first healthcare benchmarking study was published in Health Service Research in 1983. In total, 477 articles have been accepted and published in 148 Scopus-indexed journal titles. Health Care Management Science, Journal of Medical Systems, Health Economics, Applied Economics, Health Policy are frequently considered as publication outlets for those researchers involved in this area of study, and more than one-third of the total literature is published in these five journals.

From the article impact perspective, there is a significant gap between local and global citations, which implies that healthcare studies are well cited by researchers in other disciplines. From the citation network analysis, several clusters—including the development of new DEA models, the determinants of healthcare efficiency, and primary care are detected based on the most cited articles among those with at least 70 global citations. Such analysis is essential to explore the spread of the influence of healthcare benchmarking studies.

In terms of keyword analysis, we observe that there is a significant difference in author keywords between developed and developing countries. This is partly due to the national income levels and the development of the healthcare industry. In addition, the relative emphases on topics in developed countries have grown faster over the last 18 years compared to those in developing countries. We also observe that only one third of the total number of countries in the world have focused on healthcare benchmarking exercises. Therefore, more efforts and guidance should be provided by developed countries through international collaborations.

This study was conducted based on Scopus indexed journals using bibliometric analysis. Clearly, the article collection may not reflect the actual number of healthcare efficiency studies because some journal titles are not Scopus-indexed journals. Furthermore, analyses such as regression can be used to generalize publication characteristics. To overcome these limitations of the study, a comprehensive and reliable global citations database must be identified. This bibliometric analysis approach will be useful as more efficiency and productivity studies appear using variants and methodological changes of DEA and SFA as well as investigating other health care agencies. Several issues are growing in prominence such as health care and COVID-19, public health, changes in regulations such as staffing requirements, and virtual medicine and could be observed through such analysis. Similarly, additional analyses could be interesting, such as application of a random forest model to classify the number of citations, which we leave for future research.

Table 6. Summary of key findings from the bibliometric analysis

Key finding	Method	Location
A total of 921 authors contributed to publications on healthcare benchmarking analysis: (a) Several distinctive clusters were detected and many new and small clusters arose in the network over the study period. (b) Leading authors have a broad collaborative relationship with many authors in this research field. (c) Collaboration network size continued expanding from 123 to 484 nodes between 1983 and 2019.	Author collaboration network	Figures 4(a)-(d) Table 1
A total of 13 affiliations have more than 100 total citations: (a) Total of 154 clusters in this field consisting of independent and interconnected affiliations. (b) Virginia Commonwealth University was ranked at the top, contributing the most publications, followed by University of York and Widener University.	Collaborative network	Figure 5 Table 2
Research collaborations can develop innovative solutions and improve the quality of research work: (a) Authors from the USA have produced the largest number of publications (33.79% out of entire literature collection) related to healthcare benchmarking studies and also attracted the total citations of 6728. (b) USA, UK, Germany, Turkey, and Greece are the top 5 most active countries in international collaborations.	Chord diagram	Figures 6(a)-(c) Table 3
A total of 477 articles were published in 148 journals over the period of 1983-2019: (a) Provide some useful guidance to researchers in submitting their work to the most appropriate publication outlets. (b) More than 30% of total articles are published from the most top 5 productive journals.		Table 4

Table 6 (cont…). Summary of key findings from the bibliometric analysis

Key finding	Method	Location
Total citations for an article represent the significance of its impact and the spread of its influence in the healthcare benchmarking studies: (a) There is a significant gap between local citations and global citations and indicates that the literature on healthcare benchmarking attract attention from researchers in other disciplines (b) Six main themes, i.e. development of new DEA model, pure efficiency analysis, determinants of health care efficiency, public and private hospitals, healthcare efficiency studies using DEA model, primary care, are found by the citation network within this literature information.	Co-citation network	Figure 7 Table 5(a)-(b)
Research direction and hotspots of healthcare benchmarking studies using keyword analysis: (a) A significant difference in author keywords between developed and developing countries. (b) The relative emphases on topics in developed countries have grown faster over the last 18 years as compared to developing countries.	Word cloud Author-keyword network analysis Temporal overlay keyword co-occurrence network	Figure 8 Figure 9 Figure 10(a)-(b)
Healthcare benchmarking analyses have been conducted in 66 countries over the study period: (a) Lack of research infrastructure, funding, and accurate data contributed to “white space” in world wide mapping. (b) The most popular healthcare benchamarking studies are conducted in United States, China, Iran, Greece and United Kingdom.	Global Heatmap	Figure 11

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