Journal of Cleaner Production 284 (2021) 124711

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Twenty years of water utility benchmarking: A bibliometric analysis of emerging interest in water research and collaboration

Kim Huat Goh [a], Kok Fong See [a, b, *]

[a] Economics Programme, School of Distance Education, Universiti Sains Malaysia, Malaysia
[b] Manning School of Business, University of Massachusetts at Lowell, United States

ARTICLE INFO

Article history:
Received 6 June 2020
Received in revised form
14 September 2020
Accepted 15 October 2020
Available online 24 October 2020

Handling editor: Bin Chen

Keywords:
Benchmarking
Water and sewage industry
Bibliometric analysis
Publication pattern
Research hotspot

ABSTRACT

The research on benchmarking analysis of the water and sewage industry has been expanding over the years. Water utility benchmarking analysis is crucial for mitigating the stress associated with classic issues, including ownership status, deregulation policies, and quality of service. A significant body of literature reviews has focused on the choice of quantitative tools and the issues addressed by studies; thus, the bibliometric analysis method is timely. In this study, bibliometric analysis was employed for the first time to review 142 scientific articles on benchmarking analysis of the water and sewage industry based on the Scopus database during the years 2000–2019. The publication pattern confirms that the total number of related publications increased over the study period. Although the studies are dominated by authors from developed countries and they have a wide range of international collaboration, some authors from developing countries have also been actively publishing in recent years. The findings of research hotspot suggest that more studies should be conducted to address the issues of the water and sewage industry in developing countries. Moreover, a robust method is suggested to be included in the development of modeling frameworks, and it would be interesting to incorporate the undesirable outputs and quality of service. Several determinants of the water industry performance are used in the previous studies but there has been little or no agreement on the relationship between these explanatory variables and water utility's performance. There is no one size fits all and the relationship between determinants and the water utility's performance, to some extent, varies influenced by other non-discretionary factors. To conclude, this review will benefit scholars and practitioners by providing deeper insight into the publication trend in this field and the research gaps on the issues addressed, particularly in policy and regulation.

1. Introduction

Ensuring accessibility to clean water and sanitation is essential for human survival because it represents one of the Sustainable Development Goals (SDGs) established by the United Nations (UN, 2015). For the achievement of sustainability, the water and sewage industry must be efficient in the use of economic resources through technological and capability improvements. In general, the water and sewage industry throughout the world generally operates in monopoly environments and therefore lacks incentive to improve performance (Marques et al., 2016). Several fundamental problems are experienced by the industry worldwide: asymmetric information (Laffont, 2005), effects of externalities (Molinos-Senante et al., 2010), scale and scope of economies (Carvalho and Marques, 2014), and public service obligation (Marques et al., 2011). Without adequate regulation of the industry, the situation is expected to worsen with the changes in customers' water demand over time, environmental degradation (Mikulik and Babina, 2009), and financial constraints upon public water operators (Marques et al., 2011). In this context, there is a need to protect the interests between shareholders and water customers to be responsible in setting water tariffs and ensuring the quality of water provision (Correia and Marques, 2011). To deliver the incentives for enhancing industry performance, the industry has been forced to undergo regulatory reform with the combination of various regulatory tools and the introduction of regulatory bodies (Pinto et al., 2017a).

In general, there is a consensus on how the water and sewage

* Corresponding author.
E-mail address: kfsee@usm.my (K.F. See).

https://doi.org/10.1016/j.jclepro.2020.124711

industry can be efficient in operational management and providing a good quality of service to customers after the industry reform; however, there are no complete guidelines published on how to achieve these goals, and no country has served as a good example in the early stage of industry reforms (Abbott et al., 2012). Stimulating competitive advantages through the public-private participations and the high level of innovations would enhance the economics performance of the industry (Hana, 2013). In doing so, benchmarking analysis is a quantitative technique used to evaluate industry performance (Marques and De Witte, 2010). Benchmarking analysis is essential, as it can determine how well the regulated water and sewage utilities are performing over time (De Witte and Marques, 2012). If the regulator and water operators are aware of their current performance, it will be possible to develop regulatory frameworks effectively and prioritize objectives for future performance.

Given the rapid proliferation of studies evaluating industry performance, a series of literature survey articles has been published based on content analysis and meta-regression analysis. For example, Abbott and Cohen (2009) first reviewed industry performance evaluation studies that concerned the issues of market structure, ownership status, and water industry reform and regulation. While these literature survey articles explored the choice of benchmarking tools and issues covered by existing studies, to the best of our knowledge, none of them explored the existing scientific publications on conceptual, intellectual, and social networking using bibliometric analysis, thus prompting our study. As compared to content and meta-regression analyses, the application of bibliometric analysis observes the scientific trend and visualizes the boundaries of knowledge from the broad elements of publications (Aria and Cuccurullo, 2017). In this study, we perform a comprehensive review in the field of benchmarking analysis of the water and sewage industry from 2000 to 2019 through bibliometric analysis. We analyze the most productive authors, most influential institutions with collaboration networks, key journals, and the most cited articles for the publication pattern. Moreover, the keyword analysis, scope of study, and explanatory variables affecting the industry performance are highlighted to identify the research hotspots. The contributions of this study are two-fold: (1) this study provides comprehensive literature information to the readers from the existing water utility benchmarking studies, and (2) it also presents in-depth information on research hotspots and directions to researchers for developing strategies in their future studies.

This study is organized as follows: Section 2 provides a brief review related to the literature survey of water services industry performance studies. Section 3 outlines the procedures for retrieving and processing data and the research methodology. Section 4 presents the outcomes of bibliometric analysis in the study. The current and future research hotspot, determinants of the performance of water and sewage industry are included in Section 5 while the concluding remarks and roadmap for future research are included in Section 6.

2. Literature Review

Several scholars (Abbott and Cohen, 2009; Walter et al., 2009; Berg and Marques, 2011; Carvalho et al., 2012; Worthington, 2014; Cetrulo et al., 2019) have conducted literature surveys reviewing the benchmarking analysis of the water and sewage industry. Abbott and Cohen (2009) surveyed several quantitative approaches that have been employed to measure the efficiency and productivity growth of the water services industry. They discussed the smaller size of water service utilities that achieved scale and scope of economies. However, the findings on ownership structures of the utilities are ambiguous. Walter et al. (2009) conducted a review on efficiency assessment in water distribution companies from 1998 to 2008. They showed that public and private ownerships were ambiguous, and there is a prevalence of economies of density and economies of scale in the industry. While the institutional design is considered as the main factor for improving the efficiency of the industry, the population density and non-revenue water (NRW) are environmental factors used to explain the industry performance.

A comprehensive review on benchmarking analysis of the water and sewage industry was conducted by Berg and Marques (2011), from which the authors employed a literature survey based on 190 scientific articles published between 1969 and 2008. The authors observed that (1) mixed results have been found for the determination of market structures (scale and scope of economies) and ownership (public versus private) that influence industry efficiency; (2) incentive regulation had a positive influence on industry performance; and (3) new models have been proposed and applied over time, and most of the studies chose the scope based on a single country, region, or cross-country. Carvalho et al. (2012) examined the market structure of the water and sewage industry through meta-regression analysis on literature data from 1986 to 2010. They found a higher probability for the existence of scale and scope of economies in smaller sized water service utilities and multi-service utilities. Also, market structures are more likely to appear in private-owned water service utilities.

Apart from discussing the environmental factors affecting industry performance, Worthington (2014) reviewed the empirical measurements of efficiency and productivity of urban water service utilities and also examined the regulatory factor affecting industry performance based on 27 articles from 1990 to 2014. The only study dedicated solely to reviewing the efficiency level of the industry in developing countries was conducted by Cetrulo et al. (2019). The private-owned water and sewage utilities performed well in developing countries, and the implementation of regulatory incentives does not positively influence industry performance. For the market structure, mixed results have been found for the scale of economies, and only one study covered the scope of economies in developing countries.[1]

Due to the growing number of scientific publications in many fields of research, the bibliometric analysis method has gained attention, as it is widely employed in recent years to assess information in the literature. Bibliometric analysis is a cross-disciplinary science of qualitative information (e.g., research focus and potential future research) and quantitative analysis (e.g., contributing works by authors, institutions, journals, and cited articles) to assess research performance based on published articles (Osareh, 1996; Ellegaard and Wallin, 2015; Xu et al., 2020). Bibliometric analysis has become prominent for analyzing scientific literature in various disciplines, including works from research collaborations in a particular journal (*Journal of Productivity Analysis*) (Choi and Oh, 2020), blockchain technology (bitcoin) (Merediz-Solà and Bariviera, 2019), computer networking (Iqbal et al., 2019), and the industrial revolution (industry 4.0) (Muhuri et al., 2019).

3. Method and data

A literature review is an important element in any field of research. Reviews of previous studies help to critically analyze the boundaries of knowledge and identify the potential research gaps that could be addressed in future studies (Tranfield et al., 2003). According to Moher et al. (2009), the Preferred Reporting Items for

[1] Nauges and Van den Berg (2008) compared the market structure in Brazil, Moldova, Romania, and Vietnam.

Systematic Reviews and Meta-Analyses (PRISMA) can be used to improve the reliability of evidence through four major stages: identifying the keywords to search the literature, screening the literature, determining the eligibility of full-text articles, and choosing the articles to be included for data analysis. In this study, we employed the PRISMA methodology combined with bibliometric analysis to evaluate the research progress of the studies in this field. In general, there are three advantages of using bibliometric analysis in many studies (Feng et al., 2017). First, in comparison to other techniques in literature review studies, such as content analysis and meta-regression analysis, bibliometric analysis is better able to manage a large body of information from the literature. Second, bibliometric analysis helps to deeply analyze the characteristics of related publications on the performance of productive authors, influential institutions, key journals, forward citations, and keywords; therefore, comprehensive information can be delivered to support future studies through the findings of bibliometric analysis. Third, strong visualization networks in bibliometric analysis allow scholars to determine the relationships among, for example, authors, institutions, and keywords and to identify research priorities for future studies.

3.1. Data collection using the PRISMA approach

For the first stage of the PRISMA approach, we collected data to review the benchmarking analysis of the water and sewage industry through the Scopus database. The Scopus database is a comprehensive and reliable tool with various selection criteria (Solvoll et al., 2015; Gao et al., 2016). To search the articles effectively, we searched several terms based on article titles, abstract, and keywords, such as benchmarking analysis of the water industry, benchmarking analysis of the water and sewage industry, performance assessment of the water and sewage industry, data envelopment analysis of the water and sewage industry, and stochastic frontier analysis of the water and sewage industry. In sum, we found a total of 500 articles during the years 2000–2019 based on our search strategy. Subsequently, we removed 38 duplicate articles with redundant information and no authors' name; thus, 462 articles were reserved. In the screening phrase, we determined the selected articles from the peer review journals based on several important criteria: (i) the articles are full-availability; (ii) non-English-language articles will be removed; and (iii) the selected articles must be relevant to our scope of study. Any differing opinions among the authors of this study were addressed through face-to-face discussions. Therefore, a total of 168 articles remained for further analysis in the subsequent stages, as seen in Fig. 1 in the PRISMA flowchart.

In the stage of determining the eligibility of scientific articles, we assessed the full-text articles and examined each article to identify relevant topics and methodologies. We excluded articles that focused solely on descriptive analysis and graphical analysis in the research of this field. As such, we selected only articles that performed benchmarking analysis of the water and sewage industry with various methodologies, including data envelopment analysis (DEA) and stochastic frontier analysis (SFA). In addition, we included full-text articles in this field based on the references in previous review studies. Through the aforementioned steps, we identified 142 full-text articles to be furthered analyzed in this study.

In the final stage of PRISMA, we exported all the information from the 142 articles into Bibtex format on March 31, 2020. The information is then reviewed and compiled into different characteristics, such as author name, title of article, year of publication, forward citation, institution, country, journal, and author-keyword, to be included in the bibliometric analysis. It is important to highlight certain aspects of data processing. First, the author name might have been listed differently for the same author. Similarly, the same author name could also be listed for different authors. Second, the institution of a paper was chosen based on the first author with a complete address of the institution when the authors collaborated internationally from different institutions and countries. Third, different occurrences for the keyword analysis might have appeared even though the words have a similar meaning, such as "data envelopment analysis" and "DEA", and "performance measurement" and "performance assessment". To address this problem, we standardized keywords with similar meanings into a single keyword.

3.2. Bibliometric approach

The bibliometric approach is complicated because it involves numerous statistical computation and visualization tools in the major procedures: performance analysis, network analysis, and keyword analysis (Pritchard, 1969; Noyons et al., 1999). Performance analysis helps to identify the characteristics of the related publications, including authors, institutions, journals, and most cited articles. The network analysis aims to evaluate the collaborative relationship in different characteristics through a network with node and edge transfer. The nodes in a network represent authors, institutions, and keywords; there is a positive relationship between the size of the node and the frequency of total publication for each characteristics of related publications. The edges show the relationship among the nodes; the thicker the line of an edge, the closer the relationship. Network analysis can aid in estimating the key influence nodes by measuring the degree of the nodes. Differently from performance analysis and network analysis, keyword analysis enables one to determine the current research focus points by summarizing the content of works with frequently used keywords.

The most challenging part of bibliometric analysis of studies is the problem of counting co-authored publications to a single author in terms of total number of publications and forward citations. In general, the most commonly used calculations are the full-counting approach and fractional-counting approach (Waltman and Van Eck, 2015). In the full-counting approach, a co-authored publication by four authors will be rewarded by the unique number of 1. By contrast, the fractional-counting approach allows for each author to be rewarded in equal weight of 1/4 in a publication. The full-counting approach has the issue of counting co-authored publications, leading to the unfair advantage in the co-authorship field. In this study, we followed the approach preferred by Waltman and Van Eck (2015) using the fractional-counting approach in counting the total number of publications and forward citation. In the case of a fractionalized total number of publications for influential institutions, for instance, De Witte and Marques (2012) was written by De Witte (University of Leuven; Maastricht University) and Marques (Technical University of Lisbon). There are three institutions that collaborated in this publication; thus, we rewarded the same weight of 1/3 for each institution in De Witte and Marques's (2012) study. By contrast, if these authors had been from the same institution, we would have recorded the institution only one time to avoid a double-counting error. Similarly, if an author had two different institutions, we considered two different institutions were involved in an article. In addition, weighted in fractionalized total number of publications (TP^F W, %) is the ratio of fractional number of publications (TP^F) to the total number of literatures collected (TP). The factor can be used to measure either author or institution. For instance, TP^F in Technical University of Lisbon is 7.03 while TP is 142 articles. So, the TP^F W for the Technical University of Lisbon is 4.95%.

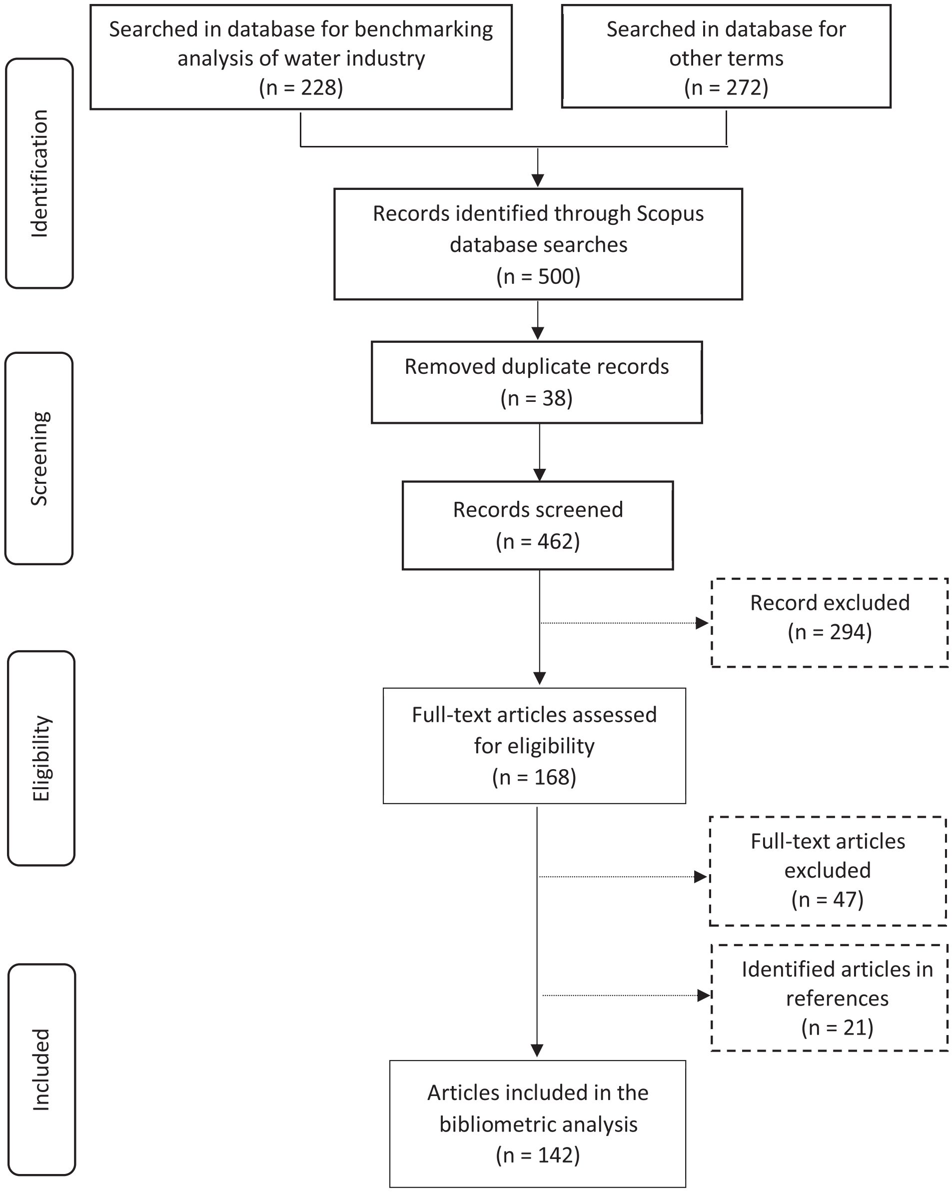

Fig. 1. PRISMA flowchart.

Numerous software tools are available to support bibliometric analysis (e.g., BibExcel, R, CitNetExplorer, VOSviewer, SciMAT, CiteSpace, and VantagePoint). R with the bibliometrix package, which was developed by Aria and Cuccurullo (2017), has frequently been used to conduct bibliometric analysis in recent years. R is an open public software, and it includes many types of statistical computing tools and graphical packages. Aria and Cuccurullo (2017) reorganized a complete workflow of bibliometric analysis in R, and the proposed workflow is highly flexible, enabling it to be integrated with other statistical and graphical packages. Hence, we used R with the bibliometrix package for bibliometric analysis in this study.

3.3. Data

To provide an overview of benchmarking analysis of the water and sewage industry, the publication performance was evaluated based on corresponding authors from 2000 to 2019, as displayed in Fig. 2. While the average growth rate of the publications was recorded at 4.94% over the years, the growth rate was inconsistent in different years. In the early years, the growth rate of publications increased substantially through 2014, prior to the establishment of SDGs in 2015. A significant increase in the number of publications was mainly due to contributions by developed countries and is linked to the increase in regulation of the industry and data availability (Berg and Marques, 2011). Meanwhile, the number of publications for developing countries increased rapidly in recent years, which reveals that developing countries are beginning to increase their attention to the research in this field.

In a similar manner, we calculated the geographical distribution of contributing studies based on the corresponding authors' country. As shown in Fig. 3, a total of 26 countries contributed to the research of benchmarking analysis of the water and sewage industry during the study period. Of all the different countries contributing to this field, a high concentration of authors is from Chile, followed by Italy, the United States, and Portugal. One

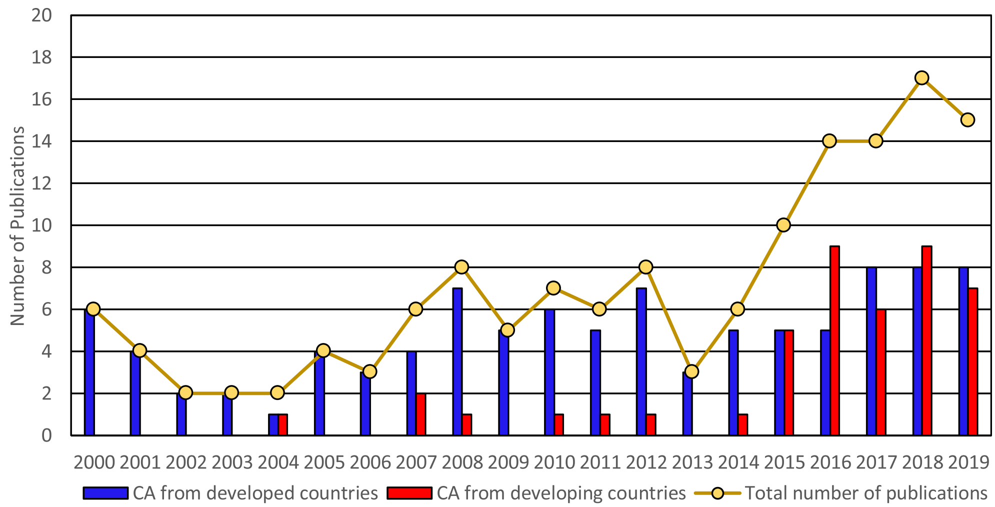

Fig. 2. Publication performance based on CA's country, 2000–2019.
Note: CA: Corresponding author

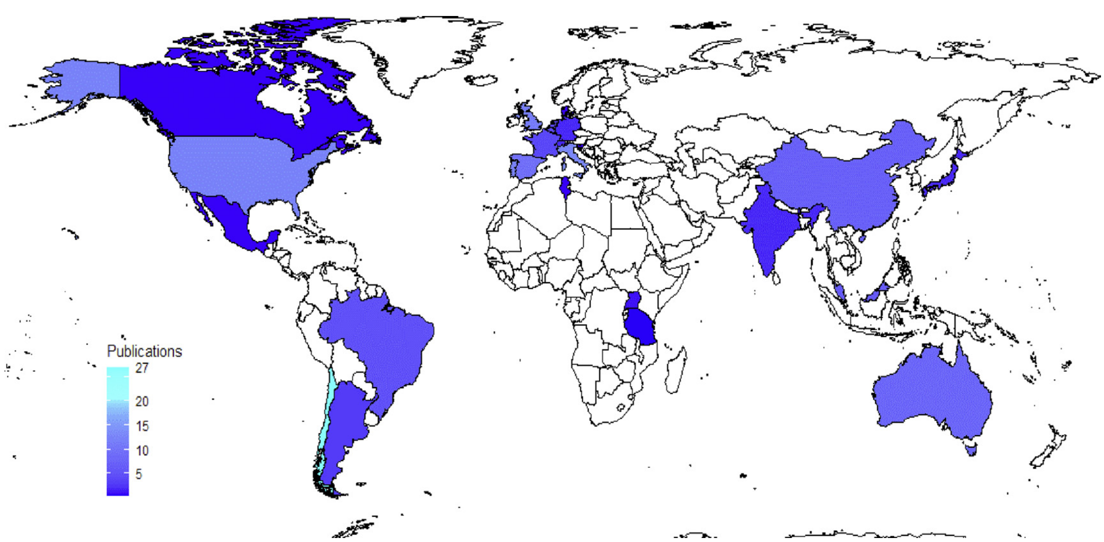

Fig. 3. Geographical distribution of publications based on CAs' country, 2000–2019.
Note: CA: Corresponding author

interesting finding, illustrated in Fig. 3, is that the contributions to the research of this field were dominated by corresponding authors from developed countries. Notably, only 34.62% of the publications were contributed by authors from developing countries. However, although not shown in Fig. 3, Chile, Malaysia, and Brazil provided a considerable number of publications among the developing countries in recent years due to the issues covered under water industry reform (Molinos-Senante and Sala-Garrido, 2015) and NRW (See and Ma, 2018).

4. Publication pattern

The bibliometric analysis proposed a qualitative and quantitative way to manage numerous studies in the academic research. The visualization tools in bibliometric analysis such as network analysis focused on the relationships and dominant players in the studies. Through its flexibility, this technique can provide comprehensive information, since it can manage all the literature. In this section, the publication pattern was analyzed through the elements of publications: authors, institutions, journals, and most cited articles.

4.1. Productive authors

To analyze the productive authors, we calculated the frequency of occurrence for all the authors in the related publications. Table 1 shows the most productive authors during the 20 years of the study period; most of them come from developed countries. As seen in Table 1, Molinos-Senante has the highest number of publications, followed by Marques and Sala-Garrido. As we observed in the literature data, Molinos-Senante, Sala-Garrido, and Maziotis have a close collaborative relationship in producing a large number of articles. Moreover, Marques has a variety of collaborators for publishing articles in the research of this field.

The forward citations for the most productive authors are also shown in Table 1. We calculated the forward citations for each author by multiplying the proportional contribution of an author with forward citations in an article. Marques (255.92) was ranked

Table 1
The most productive authors during the years 2000–2019.

Author	TP^F	TP^F W (%)	FC^F
Molinos-Senante M	11.67 (1)	8.22	111.75 (4)
Marques RC	7.17 (2)	5.05	255.92 (1)
Sala-Garrido R	6.83 (3)	4.81	82.33 (7)
Maziotis A	5.08 (4)	3.58	52.16 (13)
Ananda J	3.00 (5)	2.11	20.00 (16)
Thanassoulis E	2.75 (6)	1.94	207.75 (3)
De Witte K	2.33 (7 =)	1.64	107.50 (5)
Guerrini A	2.33 (7 =)	1.64	80.17 (8 =)
Romano G	2.33 (7 =)	1.64	80.17 (8 =)
Berg S	2.33 (7 =)	1.64	73.50 (11)
Saal DS	2.33 (7 =)	1.64	218.58 (2)
Ashton JK	2.00 (12 =)	1.41	75.00 (10)
Lin C	2.00 (12 =)	1.41	83.00 (6)
Mugisha S	2.00 (12 =)	1.41	23.00 (15)
Carvalho P	1.83 (15 =)	1.29	63.50 (12)
See KF	1.83 (15 =)	1.29	41.83 (14)

Note: TP^F is the fractionalized total number of publications; TP^F W (%) is the weighted in fractionalized total number of publications; FC^F is the fractionalized number of forward citations. Number of parentheses represent the rankings for fractionalized total number of publications and fractionalized number of forward citations shown in the authors.

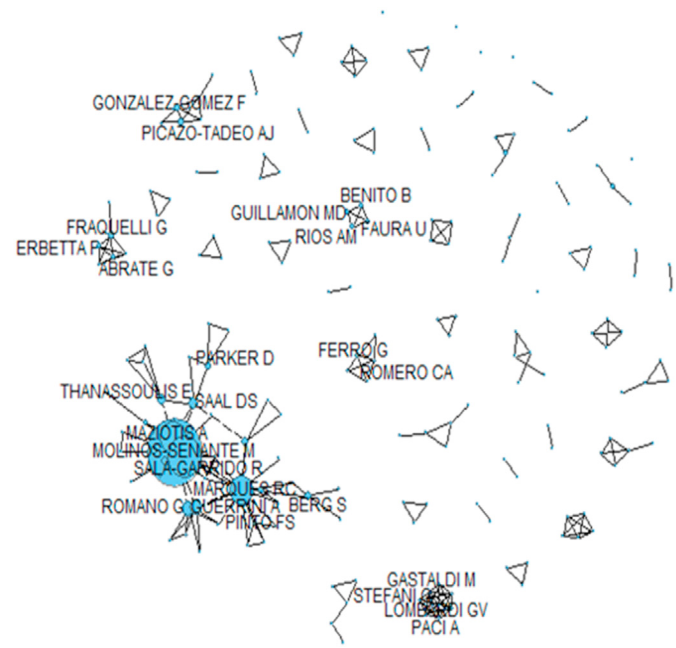

Fig. 4. Authors collaboration network.

at the top for the forward citation authors, followed by Saal (218.58) and Thanassoulis (207.75). Only five authors have more than 100 forward citations, and it was observed that the forward citation of these authors corresponds to the total number of publications. According to Choi and Oh (2020), the total publications and forward citations can be a proxy for the quantity and quality of research, respectively. The present results indicate that Marques is considered an author who focused the most on the quality of publications. To obtain deeper insight into the characteristics of authors in the research of this field, we also examined the authors' collaboration network, as reported in Table 2 and illustrated in Fig. 4.

During the years 2000–2019, we found a distinctive cluster formed from the connections between the first cluster to fourth cluster, and the majority of the most productive authors appeared in this cluster and contributed 34.5% of the fractional number of publications. The leading author of this cluster was Molinos-Senante, followed by Sala-Garrido, Maziotis, and Marques. There are several small clusters in this network, as presented in Table 2. We observed that authors with methodological-based publications were linked to authors who are focused on special issues-oriented publications. This finding suggests that such connections can create more innovative and quality research outcomes in this field. Furthermore, many clusters are dispersed because the authors might have a limited number of publications corresponding to the limited number of co-authors. The authors from small clusters are more likely to have domestically collaborated. One interesting finding is that few studies on benchmarking analysis of the water and sewage industry were found in the early years; through the study, we have seen that the numbers of scholars and publications

Table 2
The cluster relationship in the authors collaboration network during the period 2000–2019.

Cluster	Authors			
1	Molinos-Senante M	Sala-Garrido R	Maziotis A	Mocholi-Arce M
	Vellegas A	Porcher S	Donoso G	Perez F
	Gomez T	Caballero R	Cabrera JR	Estruch-Juan E
	Lafuente M	Lannier AL	Farias R	Guzman C
2	Marques RC	Berg S	De Witte K	Carvalho P
	Pinto FS	Lin C	Yane S	Corton ML
	Costa AS	Figueira JR	Pedro I	Mbuvi D
	Perelman S	Simoes P	Correia T	
3	Romano G	Guerrini A	Leardini C	Da Cruz NF
	Martini M	Campedelli B		
4	Saal DS	Thanassoulis E	Parker D	Portela MCAS
	Horncastle A	Maugg T	Kirkpatrick C	Zhang YF
	Weyman-Jones T			
5	Picazo-Tadeo AJ	Gonzalez-Gomez F	Garcia-Valinas MA	Saez-Fernandez FJ
	Suarez-Varela M	Muniz MA		
6	Fraquelli G	Abrate G	Erbetta F	Bruno C
	Giolitti A	Fabbri P		
7	Benito B	Faura U	Guillamon MD	Rios AM
8	Ferro G	Romero CA	Mercadier AC	Lentini EJ
	Covelli MP			
9	Lombardi GV	Stefani G	Paci A	Becagli C
	Miliacca M	Gastaldi M	Giannetti BF	Almeida CMVB
10	See KF	Li J	Chi J	Ma XC
	Ma Z			

in the research of this field are increasing over time. Some of the emerging scholars (e.g., Molinos-Senante, Sala-Garrido, and Maziotis) have been actively publishing in recent years and have become influential authors of the research in this field. Although this analysis is somewhat conjectural, it calls for a better understanding of the collaboration relationships across co-authors at both domestic and international levels.

4.2. Contributions by institutions

Among all 142 publications, 66.20% involved a collaborative relationship in the research of this field. Table 3 presents the 12 most influential institutions that contributed to the research in the field from 2000 to 2019. The results indicate that CEDEUS-Conicyt (Chile) and Pontificia Universidad Católica de Chile (Chile) were ranked at the top with 8.58 (6.04%) publications, followed by the University of Valencia (Spain) with 7.48 (5.27%) and the Technical University of Lisbon (Portugal) with 7.03 (4.95%). Remarkably, the CEDEUS-Conicyt and Pontificia Universidad Católica de Chile are the only institutions from developing countries among the list of the 12 most influential institutions. Of the forward citations of all the institutions, only four institutions from developed countries have more than 100 forward citations, and Aston University has the highest number of forward citations, followed by the Technical University of Lisbon, the University of Florida, and the University of Valencia. This finding indicates that these institutions were focused more on producing quality publications.

The research focusing on benchmarking analysis of the water and sewage industry has built up a strong collaborative relationship among the institutions at both national and international levels. Several factors, including geographical distance, academic culture of the institutions, and language, could affect the strength of collaborations among the institutions (Melin and Persson, 1996). Table 4 and Fig. 5 show the collaborative relationships among the research institutions during the study period. Several institutions have strong international collaboration relationships following the co-authored publications. For example, the CEDEUS-Conicyt, Pontificia Universidad Católica de Chile, the University of Valencia, and Fondazione Eni Enrico Mattei have the strongest collaboration relationships. Additionally, these institutions have broadly based international collaborative relationships with many other institutions. Moreover, the Technical University of Lisbon also worked closely with several institutions in the world, including the Katholieke Universiteit Leuven, Maastricht University, and the University of Liege. A similar case can be observed for the University of Florida, which has actively collaborated internationally with Momoyama Gakuin University, Lingnan University, and Institutional Development and External Services. For inter-country collaboration, the University of Verona and the University of Pisa have relatively strong relationships for producing research outcomes.

On the other extreme, several institutions from developing countries (e.g., University of Delhi, and Islamic Azad University) are more likely to have relatively weak collaboration relationships at both domestic and international levels across institutions. This network analysis illustrates the directions towards successful research outcomes with respect to the strong collaborative relationships across institutions. The first approach involves a strong relationship between domestic institutions, and the alternative approach is to create international collaborations.

4.3. Distribution of publications by journals

Table 5 presents the 13 most influential peer-reviewed journals, which account for approximately 63.38% of the total journals publishing the scientific research in this field during the 20 years of the study period. A total of 142 articles were published in 58 journals. *Utilities Policy* (18.31%), *Water Policy* (6.34%), *Journal of Productivity Analysis* (5.63%), and *Journal of Cleaner Production* (5.63%) were ranked as the top four most influential journals, with 26, 9, 8, and 8 publications, respectively. The percentage of publications in the top four influential journals is not high, accounting for only 35.92% among all the publications, which reveals a wide range of key journals available and more opportunities with the broad interest related to the research in this field. Furthermore, this study also provides the impact factor (IF) of each journal based on 2019, as shown in Table 5. The IF is used as a proxy for quality measurement of journals with the proportional of average citations of the journal in the current year to the articles published in the journal during the last two years (Dorto-Gonzalez and Dorta-González, 2013). The *Journal of Cleaner Production*, *Journal of Environmental Management*, *Environmental Science and Policy,* and *European Journal of Operational Research* have IF values that greater than 4. This indicates that these journals will be given priority by researchers for publishing their works in this field. We also found that *Utilities Policy* has the highest count of forward citations, followed by the *Journal of Productivity Analysis* and the *European Journal of Operational Research.* All of these core journals have a considerable influence on the benchmarking analysis of water and sewage industry studies. The influence of these journals can be determined based on the number of publications, IF, and number of forward citations.

Table 3
The most influential institutions during the years 2000–2019.

Institution	Country	TP^F	TP^F W (%)	FC^F
CEDEUS – Conicyt	Chile	8.58 (1 =)	6.04	77.43 (7 =)
Pontificia Universidad Católica de Chile	Chile	8.58 (1 =)	6.04	77.43 (7 =)
University of Valencia	Spain	7.48 (3)	5.27	132.72 (4)
Technical University of Lisbon	Portugal	7.03 (4)	4.95	284.53 (2)
Aston University	United Kingdom	5.57 (5)	3.92	579.47 (1)
University of Florida	United States	5.33 (6)	3.75	191.00 (3)
Fondazione Eni Enrico Mattei	Italy	3.42 (7)	2.41	41.42 (10)
University of Lisbon	Portugal	3.00 (8)	2.11	47.50 (9)
Central Queensland University	Australia	2.83 (9 =)	2.00	17.00 (11)
University of Verona	Italy	2.83 (9 =)	2.00	96.42 (5 =)
University of Pisa	Italy	2.83 (9 =)	2.00	96.42 (5 =)
University of Murcia	Spain	2.25 (12)	1.58	7.75 (12)

Note: TP^F is the fractionalized total number of publications; TP^F W (%) is the weighted in fractionalized total number of publications; FC^F is the fractionalized number of forward citations. Number of parentheses represent the rankings for fractionalized total number of publications and fractionalized number of forward citations shown in the institutions.

Table 4
The cluster relationship in the institutions collaboration network during the period 2000–2019.

Cluster	Institutions	
1	CEDEUS-CONICYT (Chile)	Pontificia Universidad Catolica de Chile (Chile)
	University of Valencia (Spain)	Fondazione Eni Enrico Mattei (Italy)
	Aston University (UK)	University of Pisa (Italy)
	University of Verona (Italy)	Loughborough University (UK)
	Universidad Tecnica Federico Santa Maria (Chile)	Sorbonne Business School (France)
	London School of Economics (UK)	New York College (Greece)
	University of Stirling (UK)	University of Granada (Spain)
	University of Murcia (Spain)	University of Malaga (Spain)
	National Research Center for Integrated Natural Disaster Management (Chile)	
2	Technical University of Lisbon (Portugal)	Katholieke Universiteit Leuven (Belgium)
	Maastricht University (Netherlands)	University of Liege (Belgium)
3	University of Florida (US)	Momoyama Gakuin University (Japan)
	Lingnan University (China)	Institutional Development and External Services, NWSC (Uganda)
4	Central University of Queensland (Australia)	La Trobe University (Australia)
	University of New England (Australia)	Darmstadt University of Technology (Germany)
	Charles Sturt University (Australia)	
5	University of Lugano (Switzerland)	Swiss Federal Institute of Technology (Switzerland)
	University of Ljubljana (Slovenia)	University of Ferrara (Italy)

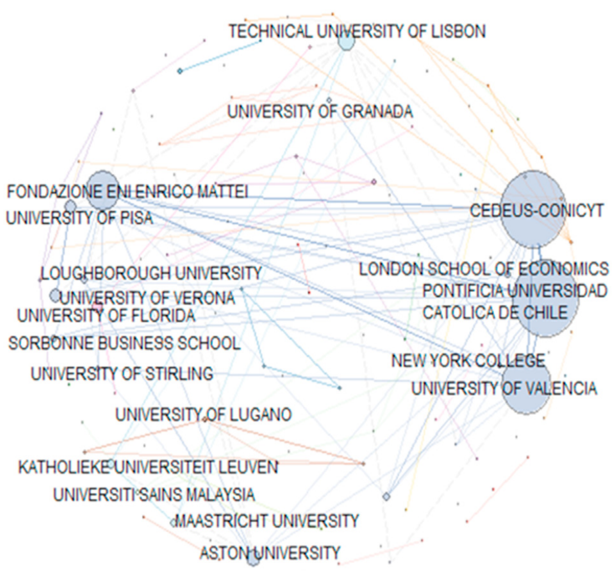

Fig. 5. Institutions collaboration network.

4.4. Most cited publications

The number of forward citations for an article in the scientific journals denotes its impact on authors' performance and key journals (Wang et al., 2017). Table 6 shows the 10 most cited articles in the field of benchmarking analysis of the water and sewage industry during the 20 years of the study period. These articles were all published by authors from developed countries and were co-authored collaborations (except for Thanassoulis) prior to 2010. The most frequently cited article was "Productivity and price performance in the privatized water and sewerage companies of England and Wales" by Saal and Parker (2001), published in the *Journal of Regulatory Economics* with 174 forward citations. The second most cited article was "How different is the efficiency of public and private water companies in Asia?", authored by Estache and Rossi (2002) and published in *World Bank Economic Review*, with 148 forward citations. From the published journals based on the frequency of forward citations, we observed that a variety of published journals are related to the research in this field. Of particular interest is that these influential scientific articles have consistently addressed the regulations and privatization of the water and sewage industry. A number of authors cited these studies

Table 5
The most influential journals from 2000 to 2019.

Journal	TP	TP W (%)	IF_{2019}	FC
Utilities Policy	26 (1)	18.31	1.835	742 (1)
Water Policy	9 (2)	6.34	1.093	203 (4)
Journal of Productivity Analysis	8 (3 =)	5.63	1.375	418 (2)
Journal of Cleaner Production	8 (3 =)	5.63	7.246	71 (9)
Water Resources Management	7 (5 =)	4.93	2.924	127 (6)
Environmental Science and Pollution Research	7 (5 =)	4.93	3.056	78 (8)
Applied Economics	6 (7)	4.23	1.103	183 (5)
Urban Water Journal	4 (8)	2.82	1.888	29 (13)
European Journal of Operational Research	3 (9 =)	2.11	4.213	234 (3)
Journal of Environmental Management	3 (9 =)	2.11	5.647	119 (7)
Journal of Water Resources Planning and Management	3 (9 =)	2.11	2.406	61 (10)
Environmental Science and Policy	3 (9 =)	2.11	4.767	51 (11)
Water	3 (9 =)	2.11	2.544	49 (12)

Note: TP is the total number of publications; TP W (%) is the weighted in total number of publications; IF is the 2019 journal impact factor listed in Incites Journal Citation Reports, Clarivate Analytics; FC is the number of forward citations. Number of parentheses represent the rankings for total publications and forward citations shown in the journals.

Table 6
The most cited publications from 2000 to 2019.

Title	Author(s)	Year	Journal	FC
Productivity and price performance in the privatized water and sewerage companies of England and Wales	Saal & Parker	2001	Journal of Regulatory Economics	174
How different is the efficiency of public and private water companies in Asia?	Estache & Rossi	2002	World Bank Economic Review	148
Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985–2000	Saal, Parker & Weyman-Jones	2007	Journal of Productivity Analysis	142
The impact of privatization and regulation on the water and sewerage industry in England and Wales: a translog cost function model	Saal & Parker	2000	Managerial and Decision Economics	131
The structure of municipal water supply costs: application to a panel of French local communities	Garcia & Thomas	2001	Journal of Productivity Analysis	127
An empirical analysis of state and private-sector provision of water services in Africa	Kirkpatrick, Parker & Zhang	2006	World Bank Economics Review	126
Efficiency and regulatory issues in the Brazilian water and sewage sector: an empirical study	Tupper & Resende	2004	Utilities Policy	110
The use of data envelopment analysis in the regulation of UK water utilities: water distribution	Thanassoulis	2000	European Journal of Operational Research	108
Designing performance incentives, an international benchmark study in the water sector	De Witte & Marques	2010	Central European Journal of Operational Research	97
DEA and its use in the regulation of water companies	Thanassoulis	2000	European Journal of Operational Research	84

Note: FC is the number of forward citations.

to estimate the impact of regulations and privatization on the performance of the water and sewage industry, which has become a common issue in this field.

5. Research hotspots

To analyze the issue topics, the bibliometric technique using keyword analysis and visualization tools was employed in this study. In general, the characteristics of publications such as article title, abstract, and keywords are used to capture the research hotspots and emerging trends for future studies. Specifically, author keywords are more suitable to describe research focus and characteristics in an article based on the authors' points of view (Wang et al., 2012). Hence, we analyze the author keywords in this study through keyword cloud and network analysis. Furthermore, we visualize the scope of the study from the literature collected and review the explanatory variables that potentially influence the performance of the water and sewage industry.

5.1. Keyword analysis

It has been suggested that keyword analysis is an effective tool to determine the research hotspots and directions for future studies. The author keywords were employed because they reflect the issues covered and preferences of the authors in the articles (Wang et al., 2017). The most frequently used author keywords are presented in Table 7 and illustrated in Fig. 6. Apart from the keywords "water industry" and "performance assessment", the three most frequently used author keywords are "DEA," "efficiency," and "regulation." To provide a deeper understanding of the keywords, we present several notable keywords in Table 7, and we review the keywords associated with quantitative approaches and issues addressed in the literature.

Table 7
The 15 most frequent used of author's keywords during the year 2000–2019.

Author keywords	Frequency	Rank (%)
Water industry	57	1 (40.14)
DEA	48	2 (33.80)
Efficiency	42	3 (29.58)
Performance assessment	20	4 (14.08)
Regulation	16	5 (11.27)
Benchmarking	15	6 (10.56)
Water services	14	7 (9.86)
SFA	13	8 (9.15)
Productivity growth	12	9 (8.45)
Determinants	11	10 (7.75)
Quality of service	11	10 (7.75)
Water and sewage industry	11	10 (7.75)
Economies of scale	10	13 (7.04)
Economies of scope	7	14 (4.93)
TFP	7	14 (4.93)

Note: DEA: data envelopment analysis; SFA: stochastic frontier analysis; TFP: total factor productivity.

5.1.1. Data envelopment analysis

DEA is a non-parametric mathematical programming technique used to describe the production technology used to evaluate the efficiency in homogeneous decision-making units (DMUs) (Charnes et al., 1978). Such an approach was first proposed by Charnes et al. (1978) in measuring the performance of DMUs at the constant returns to scale (CRS) and later extended by Banker et al. (1984) for variable returns to scale (VRS). The DEA approach can be selected as either input-oriented or output-oriented based on the characteristic of the DMUs.

As shown in Table 7, approximately 33.80% of the "DEA" keyword instances appeared in application-based water and sewage publications. This implies that the DEA approach has showed a great interest for water and sewage industry performance evaluation. For instance, the work by Byrnes et al. (2010) applied the conventional DEA approach to estimate the relative technical efficiency of the water companies in cross-regions of Australia. Berg and Lin (2008) measured the efficiency of Peruvian water companies using DEA and SFA approaches to provide a consistency ranking across the companies. The mathematical framework of DEA has been widely developed into the advanced framework over the study period. For instance, Kamarudin et al. (2015) demonstrated the inclusion of NRW as an undesirable output into the DEA-directional distance function for efficiency analysis. Similarly, Deng et al. (2016) employed slack-based measure DEA (SBM-DEA), which is considered the sewage as unexpected output for Chinese industry performance evaluation. By analyzing the English and Welsh water and sewage industry, Pointon and Matthews (2016) incorporated the intertemporal effects of capital in dynamic DEA model for determining the optimum level of resource allocation. Gidion et al. (2019) applied a network DEA model for the first time to estimate the urban water companies. None of the studies used a network DEA model incorporated with the undesirable outputs for efficiency estimations in the water and sewage industry.

In general, DEA approach is the most frequently used

Fig. 6. Keywords cloud, 2000–2019.

benchmarking tool to evaluate the water and sewage industry performance over the SFA approach, for two reasons. First, DEA approach allows for integrating multiple input and output combinations to the scalar measure of relative efficiency in the production frontier. Second, unlike the SFA approach, DEA approach does not require to specify the functional form of either production function or cost function. However, a major drawback is that there is no statistical inference for the DEA approach, and thus it is sensitive to the outlier data, leading to biased estimations. To improve the accuracy of efficiency estimations, Carvalho and Marques (2014) proposed the partial frontier non-parametric approach to estimate the scale and scope economies in the Portuguese water industry during the period 2002–2008. Another method is the application of bootstrap algorithms, suggested by Simar and Wilson (2007), to generate the statistical inference. See (2015); Molinos-Senante et al. (2018a); and Villegas et al. (2019) applied a double bootstrap DEA model for resampling the efficiency scores of the industry.

5.1.2. Regulation

The relationship between regulation and performance of the water and sewage industry has been a topic of public debate over the past decades. Often, the core objective of many industry performance evaluation studies is to determine the impact of the regulation. In general, the regulatory framework is designed with numerous aims, such as sustainability (e.g., assess the clean drinking water and service quality), affordability (e.g., water pricing and incentives), and environmental health (Abbott and Cohen, 2009). The privatization is part of the regulatory reform from which the privatization has the potential to enhance the industry performance. Many countries have undertaken privatization to stimulate competition across the companies, and privatization is a broad term including the types of regulatory mechanisms, such as rate of return regulation, price-cap regulation, incentive regulation, and sunshine regulation. In the case of Chilean water and sewage companies, the works by Molinos-Senante and Sala-Garrido (2016b) and Molinos-Senante et al. (2018b) found that the efficiency and productivity of fully privatized companies are performed better than the concessionary companies after privatization. For the English and Welsh water industry, Saal and Parker (2001, 2004) and Saal et al. (2007) highlighted that the efficiency and productivity of the industry improved after the regulations, but not with privatization.

Specifically, Aubert and Reynaud (2005) observed that the efficiency level of Wisconsin water companies improved under rate of return and price-cap regulations in which the companies provide information on costs, investment, and water pricing to the regulator. Furthermore, price-cap regulation has been adopted for regulating the English and Welsh water industry during privatization. The work by Molinos-Senante et al. (2017) evidenced that the performance of English and Welsh water companies improved partly because the price-cap regulation positively influenced those companies to be more efficient during privatization. The results were consistent with the research by Maziotis et al. (2016), which showed improvement of productivity in the water industry when the regulator tightens the price review. The regulatory reform of the Italian water industry following the introduction of a new tariff system as an incentive for investments slightly positively influenced the productivity of the industry (Guerrini et al., 2018). By analyzing the Dutch water industry performance, De Witte and Saal (2010) suggested that the introduction of sunshine regulation was effective to improve the industry's productivity, particularly for publicly owned companies, which is attributed to the technical change.

5.1.3. Benchmarking

Benchmarking water and sewage operators is essential for the regulator in developing a regulatory framework. Through benchmarking analysis, a regulator may apply the results to set a water tariff under incentive regulation and to compare the efficient behaviors in the water services market (Marques et al., 2011). There is a variety of choices in benchmarking tools such as DEA, SFA, and the price-based index number for evaluating the industry performance (Worthington, 2014). We found that almost all the studies had benchmarked the performance of the water and sewage industry in a single country. Nevertheless, a few studies have compared the industry across regions or countries such as Byrnes et al. (2010) for New South Wales and Victoria, Ferro et al. (2011) for Latin America, Molinos-Senante and Sala-Garrido (2016a) for some European and Asian countries, and See (2015) for Southeast Asian countries. Following Berg and Marques (2011) and Cetrulo et al. (2019), there are limited studies considering the quality of service to generate the ranking of the water and sewage companies in developing countries. Based on our literature data, none of the studies included the greenhouse emissions that aimed on capital cost minimization across regions.

5.1.4. Stochastic frontier analysis

SFA is a parametric approach to measure the efficiency level of the DMUs. Differently from the non-parametric technique, SFA approach is an econometric model proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) that is required to define *a priori* assumptions of functional form for production function or cost function. Following Berg and Lin (2008), SFA approach arguably has its advantage over the DEA approach as it considers the statistical error for the heterogeneity between input and output variables. By focusing the study period between 2000 and 2019, a total of 38 articles employed SFA approach in their analysis and 9.15% of the "SFA" keywords were appeared in the articles as reported in Table 7. SFA approach is the second most popular benchmarking tool applied in water and sewage industry performance evaluation studies. Of the 38 studies, the most commonly used function is cost function (24 articles), followed by input distance function (10 articles) and production function (4 articles). Almost all of the SFA studies primarily adopted translog distribution for cost function and input distance function. The majority of applications of this approach are covered in developed countries for assessing the cost efficiency of the water and sewage industry. In our literature collected, the water and sewage industries of several developing countries have been evaluated through this approach, such as Chile (Ferro and Mercadier, 2016; Molinos-Senante et al., 2018b, 2019; Molinos-Senante and Maziotis, 2019), Venezuela (Higuerey et al., 2017), Brazil (Ferro et al., 2014), Sri Lanka (Dharmaratna and Paranis, 2012), and Africa (Buafa, 2015). Recently, many studies have integrated multiple input and output variables as well as explanatory variables into the stochastic input distance function for assessing industry performance. For instance, Molinos-Senante et al. (2018b) applied input distance function and generalized parametric productivity index for estimating the productivity growth in the Chilean water industry. The undesirable outputs can be incorporated in the hyperbolic distance function in which the desirable outputs increase and undesirable outputs decrease in the multiplicative form. Nonetheless, no studies were conducted using the hyperbolic distance function, as proposed by Cuesta et al. (2009), in the translog form of production technology in the SFA approach. In doing this, the potential of undesirable outputs that are considered in the hyperbolic distance function for the water industry are NRW and greenhouse emissions.

5.1.5. Quality of service

As the water and sewage industry is regulated by the government and the technology of the industry has progressed, the quality of water services is an important issue to the public. The quality of service is a complex indicator for rating the performance of the water and sewage companies (Golder et al., 2012). From the consumer perspectives, the customers care about the accessibility and sustainability of clean drinking water, public health, and the average maintenance time. Although regulated companies are utilizing resources with lower costs, improving the quality of service in water and sewage has been the main responsibility of companies as part of the performance indicators (Calabrese, 2012). Provisioning a good quality of services to customers is typically associated with high opportunity cost (Ananda and Pawsey, 2019). Nowadays, maintaining equality between the cost and quality of service is a key challenge for the water and sewage industry.

Several studies have omitted the quality of service in the performance evaluation of the water and sewage industry. This could lead to biased estimations, as companies that provide low quality of service might be labeled as efficient, partly due to the lower operational cost (Picazo-Tadeo et al., 2008). Several variables in lack of service quality are widely considered by previous studies, such as water service coverage, water complaint, water pipe breaks, passing rate of chlorine test, unplanned interruptions, and continuity of water provisioning, for evaluating industry performance. Lin and Berg (2008) found that Peruvian water companies have a lack of incentives to enhance quality of service. Kumar and Managi (2010) considered the hours of water supply and water quality as the outputs representing the quality of service. They highlighted that maintaining the quality of service involved an opportunity cost of about 9% of the water delivered. Molinos-Senante et al. (2016a) demonstrated a slight decrease in quality-adjusted technical efficiency compared to quantity-adjusted measurement when introducing the lack of service quality (number of complaints, unplanned interruptions, and properties below reference level) in the English and Welsh water industry. A similar case was addressed by Molinos-Senante et al. (2016b) for Chilean water and sewage companies, where the authors applied the non-radial DEA model considering the lack of service quality for assessing the inefficiency score of the Chilean water and sewage companies. In the case of the Australian urban water industry, Ananda and Pawsey (2019) found that the quality of service improved as the productivity growth of the industry increased at an annual rate of 1.3% during the period 2009–2016.

5.2. Author–keyword network analysis

This section investigates the two-combinations network, which consists of several productive authors and keywords, to show how the authors considered these keywords in their topic of research in this field. We processed similar meanings of keywords, such as the words "quality" and "determinants", to minimize the double-counting error. As illustrated in Fig. 7, two different modes of the network were constructed, where one of the colors is the author

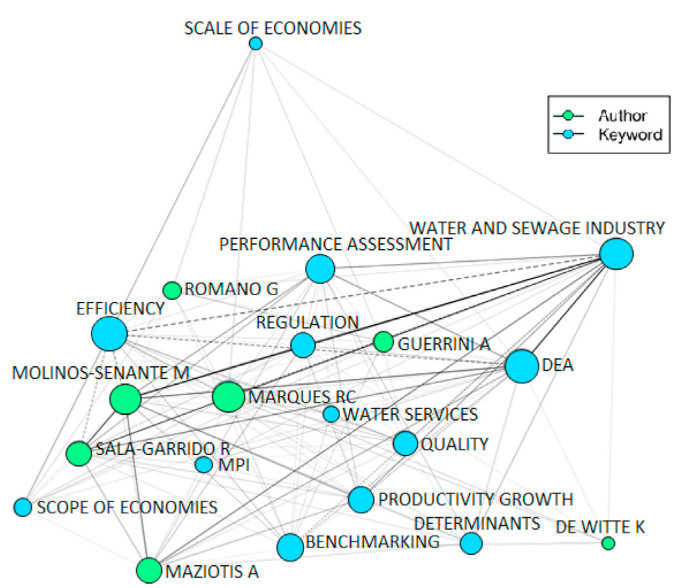

Fig. 7. Author-keyword network for most productive authors and keywords applications. 2000–2019.

and the blue color node represents keywords. There are two observations from this network. First, the productive authors closely collaborated with each other through a few frequent keywords. For instance, Molinos-Senante, Sala-Garrido, and Maziotis often worked closely in the related publications concentrated on several keywords, such as efficiency, Malmquist productivity index (MPI), and benchmarking. Second, we found that Marques was located at the center of the network in Fig. 7, connecting with most of the productive authors and diverse application keywords. This finding indicates that Marques has numerous collaborators for producing research outcomes, and he focused on many issues related to the water and sewage industry. One interesting finding from Fig. 7 is that most of the productive authors are more likely to evaluate industry performance using DEA approach.

5.3. Scope of the study

This subsection examines the countries covered in the publications during the years 2000–2019. The selection of countries covered in the benchmarking analysis of the water and sewage industry highly corresponded to data availability and the increasing attention in comparison performance assessments across companies (Berg and Marques, 2011). While the studies in this field have significantly increased in recent years, most of the studies covered the water and sewage industry in the United Kingdom, followed by studies in Chile and Italy, as shown in Fig. 8. We excluded certain studies that covered a large number of countries, including the works from Estache and Rossi (2002), See (2015), and Molinos-Senante and Sala-Garrido (2016a), due to the difficulties in fractionalization. The privatized water and sewage industry in England and Wales, for instance, has provided a good example of industry reforms and attracted attention worldwide. The Office of Water Services (Ofwat) as an economics regulator has been authorized to assess the performance of the water and sewage industry. The Ofwat regulates and monitors all the operating activities of the privatized water and sewage industry in England and Wales. We observed that the number of studies on the Chilean water and sewage industry showed an upsurge in recent years. This finding indicates that there are experienced researchers with expertise in this area focused on Chilean water and sewage industry performance assessment. The Chilean water and sewage industry privatized in 1990s with the establishment of a regulator. Most of the customers were served by private water and sewage companies. One impression from Fig. 8 is that previous studies were conducted in many developed countries. The application of advanced quantitative techniques to performance assessment helps to enhance the industry performance, since most of the industry in developed countries is responsible solely for providing water to (and collecting sewage from) customers. There is a limited number of studies related to this field from developing countries. There is a debate on whether benchmarking analysis improves the industry performance in developing countries due to regulatory failure (Cetrulo et al., 2019); however, it could be helpful if researchers integrate equities, undesirable outputs, and quality of services into the benchmarking studies.

5.4. Determinants of the water and sewage industry performance

The inclusion series of explanatory variables as determinants is essential for the industry performance evaluation research (De Witte and Marques, 2010b). The explanatory variables seek to capture the factors affecting the performance of the industry from which the conditions are either within or beyond the control of the water operators. In most cases, lack of consideration of these variables could lead to unobserved heterogeneity matter across the companies and obtain a biased efficiency estimation, if these variables have a strong effect on the industrial production process (Daraio and Simar, 2005). Many studies (e.g., Carvalho and Marques, 2011; Marques et al., 2014; Pinto et al., 2017b; Villegas et al., 2019) have examined the factors influencing the performance of the water and sewage industry as the main research objective. A review study on these variables is important to provide better insight for future researchers, as displayed in Fig. 9.

From our literature collected, 53 of the 142 articles studied the explanatory variables affecting the performance of the water and sewage industry. The main findings of the explanatory variables from these studies are briefly discussed below. Over the past decades, there has been debate about the impact of ownership status (public vs private) associated with the performance of the water and sewage industry, leading to endless conclusions. Following our literature survey, this variable is most frequently used as an explanatory variable in many empirical water efficiency studies. *A priori* expectation for the variable is that the privately owned companies have superior performance to publicly owned companies. However, the findings of the variable are ambiguous (Berg and Marques, 2011). In Portugal, Correia and Marques (2011) and

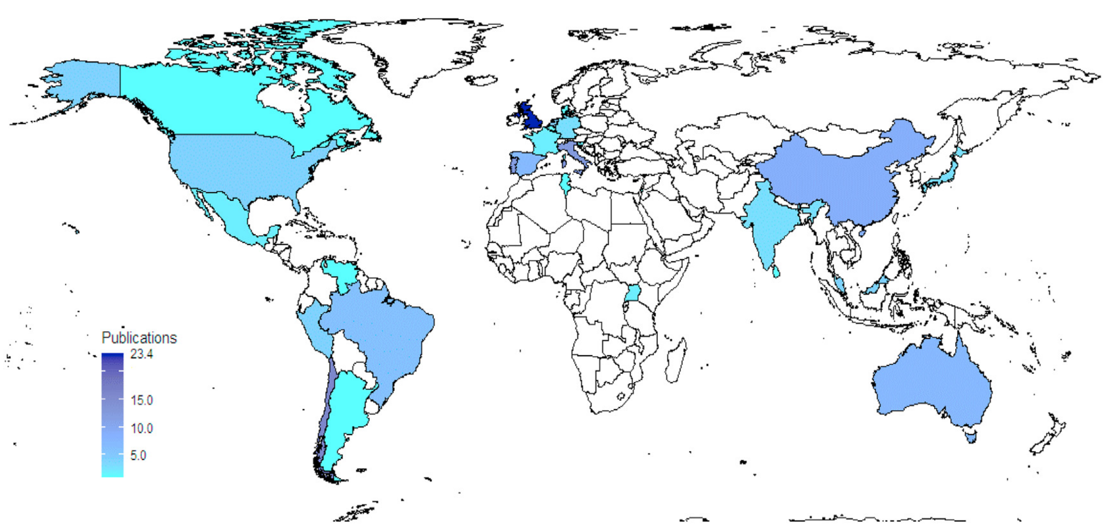

Fig. 8. Scope of the study from 2000 to 2019.

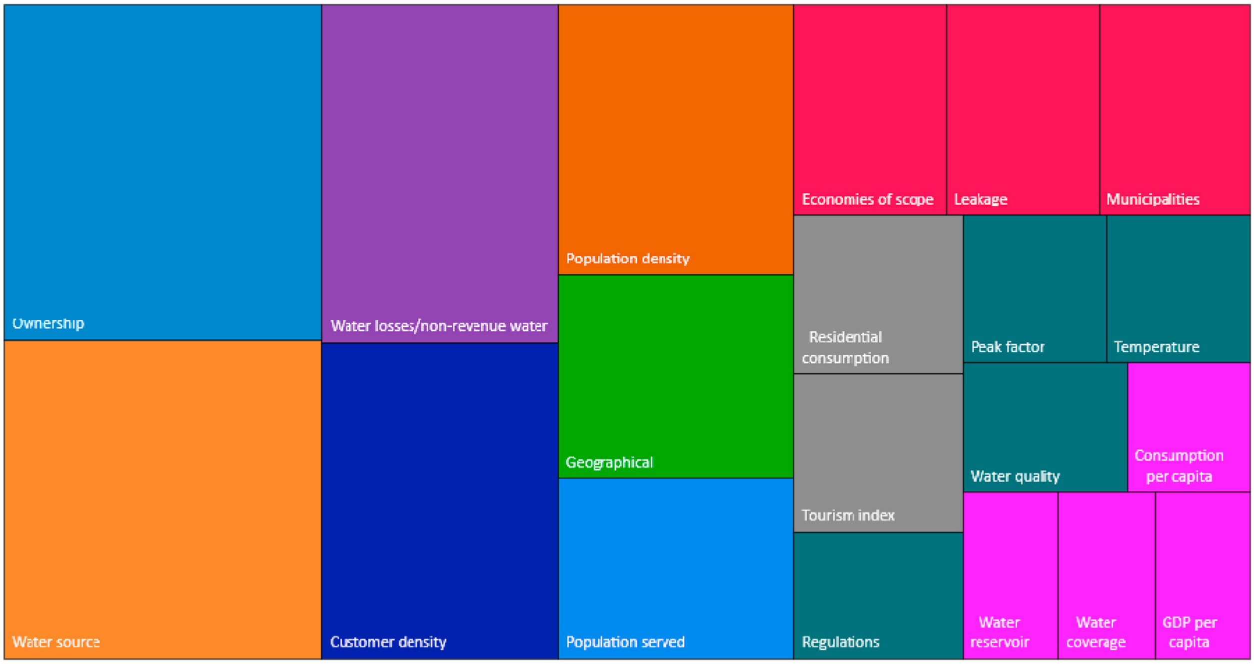

Fig. 9. Treemap of 20 explanatory variables influence on water and sewage industry performance.

Pinto et al. (2017b) found that the privately owned companies were more efficient and productive than the publicly owned companies. This implies that the privately owned companies performed better in the managerial competencies (labor and provisioning of water pipelines) and performance contracts. By contrast, 10 studies (e.g., Kirkpatrick et al., 2006; Carvalho and Marques, 2011; Molinos-Senante et al., 2018a) found that the ownership was inconclusive to the performance of the industry. Only two studies (Romano and Guerrini, 2011 for Italian water industry; Benito et al., 2019 for Spanish water companies) found that the publicly owned companies performed at a higher technical and scale efficiencies. This implies that public ownership better handles inputs purchased and consumed.

In general, the water and sewage industry normally obtains raw water from groundwater and surface water. In certain situations, several water utilities prefer purchased or imported water as their source. Groundwater only requires drilling and pumping costs, and surface water tends to have higher treatment costs (Filippini et al., 2008). The coagulation and flocculation are still commonly used in modern water treatment processes partly because of the simplicity; however, the aluminium and ferric hydroxides employed for flocculation involved higher treatment cost (Maroušek et al., 2019). The average costs of water sources depend on the process of water extraction and treatment (Garcia and Thomas, 2001). Indeed, the research of Byrnes et al. (2010) for urban water companies in New South Wales and Victoria and Higuerey et al. (2017) for the water industry in Venezuela concluded that groundwater has a significantly positive influence on the efficiency of the water industry, due to cheaper treatment cost. However, studying the water and sewage industry internationally (De Witte and Marques, 2010a), in Southeast Asia (See, 2015), in Chile (Molinos-Senante et al., 2015, 2018a), and in Japan (Marques et al., 2014) evidenced that groundwater is not significant for efficiency. In contrast, Carvalho and Marques (2011) provided evidence that the positive sign in purchased water and surface water could be evolved to negative influenced on Portuguese water operator's performance.

The water losses are the third most common explanatory variable used to capture the water service quality in many studies, as shown in Fig. 9. The water losses can be defined as the difference in volume of water produced and water sold as the ratio of water produced. There are several studies (e.g., De Witte and Marques, 2010a; Pointon and Matthews, 2016; Villegas et al., 2019) also considered water leakage (referred to one of the components in NRW) as the determinant for the industry performance. In Chile, studies (e.g., Molinos-Senante et al., 2015, 2018a, 2018b) found that water loss statistically significantly negatively influences the efficiency of the water and sewage industry. The findings are consistent with previous studies for other countries: Mexico (Anwandter and Ozuna, 2002), and Venezuela (Higuerey et al., 2017). In addition, Ferro and Mercadier (2016) and Molinos-Senante and Maziotis (2018) stated that the costs for technology investment associated with leakage detection and prediction are important for water loss reduction. Nonetheless, Correia and Marques (2011) for the Portuguese water industry, Ferro et al. (2011) for the Latin American water and sewage industry, Marques et al. (2014) for the Japanese water industry, See (2015) for Southeast Asian public water companies, and Molinos-Senante et al. (2017) for English and Welsh water companies evidenced that water losses is statistically insignificant in terms of efficiency. A possible explanation is that the percentage of water losses might be relatively low in several countries, and hence a low value of water losses is irrelevant to the inefficiency.

Many water utility benchmarking studies have introduced population density as the common indicator to explain the impact on the performance of the water and sewage industry. This variable is measured as person per square kilometre. The increase in population density reflects overall cost reduction in serving customers and the existence of economies density; therefore, the efficiency of the industry is greater. In England and Wales, Molinos-Senante and Maziotis (2018) and Villegas et al. (2019) concluded that technical efficiency is improved in companies serving densely populated areas. Similar findings were obtained in the water and sewage industry in Southeast Asia (See, 2015) and Spain (García-Sánchez, 2006; Benito et al., 2019). By contrast, Picazo-Tadeo et al. (2009)

for Spanish water companies showed inconclusive evidence for population density in their empirical study. Alternatively, customer density is another option used to examine the economies density if the data for the population density are not available. Customer density may have a similar effect as population density, which influences the industry performance, since customer density is often used to represent population density in many studies. However, Marques et al. (2014) highlighted that extremely high customer density will cause the level of efficiency to decrease due to the complexity of the network.

Other explanatory variables influence the performance of the water and sewage industry, such as peak factor, water reservoir, and gross domestic product (GDP) per capita, which have been employed in empirical studies. Molinos-Senante et al. (2015) found that the peak factor has a significantly positive influence on the efficiency of the water industry in Chile. The water companies operating in the touristic areas are considered better cash flows for capital investment. Analyzing English and Welsh water services companies, the water reservoir does not have higher inputs consumed, and it has lower overall costs; thus, the level of efficiency increased (Molinos-Senante et al., 2017; Molinos-Senante and Maziotis, 2018). Mbuvi et al. (2012) and Buafa (2015), studying African countries, evidenced a positive impact of GDP per capita on the efficiency of the industry. Comparing the cross-national efficiency of the water sector in the Netherlands, England and Wales, Australia, Portugal, and Belgium, De Witte and Marques (2010a) concluded that the explanatory variables (i.e., gross regional product per capita, incentive schemes , and existence of a regulator) have a positive effect on efficiency level.

6. Concluding remarks and roadmap for future research

Given the importance of water and sewage services to the public, scientific studies increased in the field of water and sewage industry performance evaluation research during the years 2000–2019. The studies appeared to cover the classic issues associated with ownership status, regulation, quality of service, and economies of scale and scope. Along with the long-standing debate on the classic issues, it is still early to conclude that the performance evaluation research of the water and sewage industry has moved toward a mature stage. Since a high number of works have been published in this field, this paper offers the first bibliometric analysis to review 142 articles on benchmarking analysis of the water and sewage industry from 2000 to 2019, mapping the publication pattern over the study period and identifying the research hotspots for future directions.

The publication pattern showed an increasing trend in the number of publications, with an annual growth rate of 4.94% during the study period. The literature on benchmarking analysis of the water and sewage industry relies on a distinctive cluster of authors. The majority of the most productive authors collaborated, contributing 48.98 of fractional total publications in the distinctive cluster. Regarding the institutional collaboration network, the CEDEUS-Conicyt and Pontificia Universidad Católica de Chile (8.58 of fractional publications) are the leading institutions that highly collaborated internationally with institutions from developed countries in the distinctive cluster. *Utilities Policy* (18.31%), *Water Policy* (6.34%), the *Journal of Productivity Analysis* (5.63%), and the *Journal of Cleaner Production* (5.63%) are the influential journals in the field. The concentration of authors and institutions reflected the research experiences and data availability for research purposes. There is a limited number of water and sewage industry performance assessments in developing countries. As the industry in developing countries is still in the early phrase of regulatory reform, indicator information such as NRW, quality of service, universalization, and capital should be considered in performance assessment. Through the international collaboration and the development of databases, more performance evaluation studies of the water and sewage industry are expected to progress in developing countries.

For the research hotspots, our keyword analysis revealed that the DEA approach is popularly employed by many authors in performance evaluation studies. The application of this technique corresponds to the development of a policy framework in the water industry reform. However, the DEA approach has several limitations such as lack of statistical inference. It would be interesting to apply more simulation methods (e.g., Monte Carlo, bootstrapping, partial frontier) in future research to deal with the extreme data. Alternatively, the SFA approach is the second most commonly used benchmarking tool in the field. Although the SFA approach is used to capture the statistical error term, none of the studies integrated the undesirable outputs such as NRW and greenhouse emissions in the regressions. For future studies, extension of the econometric framework in the SFA approach could be an interesting strategy to incorporate the undesirable outputs and service quality for industry performance assessment.

There is a general debate on the explanatory variables such as ownership status, water sources, and regulation for the performance of the water and sewage industry worldwide. The inconclusive findings of these variables were observed in many studies, raising concerns of inappropriate applications of benchmarking tools to estimate the explanatory variables influencing industry performance. One could deduce that the ineffectiveness of the regulatory bodies in regulating the publicly owned and privately owned companies is a possible reason for regulatory failures. Moreover, the increasing demand for clean drinking water has made it difficult to fulfill customer satisfaction due to the ineffectiveness of water operators and regulatory bodies in handling water scarcity. In the future, evaluation of the governance arrangement and the effectiveness of policy frameworks would be interesting issues to discuss. The current review and bibliometric analysis are expected to benefit scholars who are interested in the benchmarking analysis of water and sewage industry studies. We believe that the findings in this review can provide ideas to those researchers whom interested in the current research progress in this field and the literature gaps on the issues addressed. Moreover, the review provides significant policy insight for practitioners that serves as a reference on the experts in this field and the key journals.

The selection of publications for bibliometric analysis was based on a deterministic approach. We were unable to capture all the publications in the research of this field by all of the authors. For instance, some authors might have published book chapters, proceeding papers, and newspaper articles related to this field. To some extent, we are aware that bibliometric information can be distorted, as it cannot reflect exact performance, but at minimum, the information helps researchers to develop strategies to produce better quality research in the future. For future studies of these analyses, it could be helpful for researchers to incorporate other databases, including Web of Science and Google Scholar to capture vast amount of existing studies. The findings in this study can be further improved, in particular we could see more clusters emerge in the collaboration networks for co-authored publications. Since the data processing is a challenging task and time-consuming, data mining tools use to extract the cumulative knowledge from the articles could enhance efficiency in future works.

CRediT authorship contribution statement

Kim Huat Goh: Conceptualization, Investigation, Data curation, Writing - Original draft, Writing - Review & editing, Visualization.

Kok Fong See: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - Review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This project is support by the Ministry of Higher Education of Malaysia under the Long-term Research Grant Scheme (203/PHU-MANITI/67215003). The corresponding author thanks the Fulbright Visiting Scholar Award for the opportunity to perform research in the United States while part of this research was conducted. The authors would like to thank the Editors-in-Chief, Executive Editor and four anonymous referees for their helpful comments on this paper. All the remaining errors are the responsibility of the authors.

References

Abbott, M., Cohen, B., 2009. Productivity and efficiency in the water industry. Util. Pol. 17 (3–4), 233–244. https://doi.org/10.1016/j.jup.2009.05.001.

Abbott, M., Cohen, B., Wang, W.C., 2012. The performance of the urban water and wastewater sectors in Australia. Util. Pol. 20 (1), 52–63. https://doi.org/10.1016/j.jup.2011.11.003.

Aigner, D., Lovell, C.K., Schmidt, P., 1977. Formulation and estimation of stochastic frontier production function models. J. Econom. 6 (1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5.

Ananda, J., Pawsey, N., 2019. Benchmarking service quality in the urban water industry. J. Prod. Anal. 51 (1), 55–72. https://doi.org/10.1007/s11123-019-00545-w.

Anwandter, L., Ozuna, T.J., 2002. Can public sector reforms improve the efficiency of public water utilities? Environ. Dev. Econ. 7, 687–700. https://doi.org/10.1017/S1355770X02000414.

Aria, M., Cuccurullo, C., 2017. Bibliometrix: an R-tool for comprehensive science mapping analysis. J. Informetr. 11 (1), 959–975. https://doi.org/10.1016/j.joi.2017.08.007.

Aubert, C., Reynaud, A., 2005. The impact of regulation on cost efficiency: an empirical analysis of Wisconsin water utilities. J. Prod. Anal. 23 (3), 383–409. https://doi.org/10.1007/s11123-005-2216-8.

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manag. Sci. 30 (9), 48–58. https://doi.org/10.1287/mnsc.30.9.1078.

Benito, B., Faura, Ú., Guillamón, M.D., Ríos, A.M., 2019. The efficiency of public services in small municipalities: the case of drinking water supply. Cities 93, 95–103. https://doi.org/10.1016/j.cities.2019.04.016.

Berg, S., Lin, C., 2008. Consistency in performance rankings: the Peru water sector. Appl. Econ. 40 (6), 793–805. https://doi.org/10.1080/00036840600749409.

Berg, S., Marques, R.C., 2011. Quantitative studies of water and sanitation utilities: a benchmarking literature survey. Water Pol. 13 (5), 591–606. https://doi.org/10.2166/wp.2011.041.

Buafua, P.M., 2015. Efficiency of urban water supply in Sub-Saharan Africa: do organization and regulation matter? Util. Pol. 37, 13–22. https://doi.org/10.1016/j.jup.2015.06.010.

Byrnes, J., Crase, L., Dollery, B., Villano, R., 2010. The relative economic efficiency of urban water utilities in regional New South Wales and Victoria. Resour. Energy Econ. 32 (3), 439–455. https://doi.org/10.1016/j.reseneeco.2009.08.001.

Calabrese, A., 2012. Service productivity and service quality: a necessary trade-off? Int. J. Prod. Econ. 135 (2), 800–812. https://doi.org/10.1016/j.ijpe.2011.10.014.

Carvalho, P., Marques, R.C., 2011. The influence of the operational environment on the efficiency of water utilities. J. Environ. Manag. 92 (10), 2698–2707. https://doi.org/10.1016/j.jenvman.2011.06.008.

Carvalho, P., Marques, R.C., 2014. Computing economies of vertical integration, economies of scope and economies of scale using partial frontier nonparametric methods. Eur. J. Oper. Res. 234 (1), 292–307. https://doi.org/10.1016/j.ejor.2013.09.022.

Carvalho, P., Marques, R.C., Berg, S., 2012. A meta-regression analysis of benchmarking studies on water utilities market structure. Util. Pol. 21, 40–49. https://doi.org/10.1016/j.jup.2011.12.005.

Cetrulo, T.B., Marques, R.C., Malheiros, T.F., 2019. An analytical review of the efficiency of water and sanitation utilities in developing countries. Water Res. 161, 372–380. https://doi.org/10.1016/j.watres.2019.05.044.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. Eur. J. Oper. Res. 2 (6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8.

Choi, H.D., Oh, D.H., 2020. The importance of research teams with diverse backgrounds: research collaboration in the Journal of Productivity Analysis. J. Prod. Anal. 53 (1), 5–19. https://doi.org/10.1007/s11123-019-00567-4.

Correia, T., Marques, R.C., 2011. Performance of Portuguese water utilities: how do ownership, size, diversification and vertical integration relate to efficiency? Water Pol. 13 (3), 343–361. https://doi.org/10.2166/wp.2010.032.

Cuesta, R.A., Lovell, C.K., Zofío, J.L., 2009. Environmental efficiency measurement with translog distance functions: a parametric approach. Ecol. Econ. 68 (8–9), 2232–2242. https://doi.org/10.1016/j.ecolecon.2009.02.001.

Daraio, C., Simar, L., 2005. Introducing environmental variables in nonparametric frontier models: a probabilistic approach. J. Prod. Anal. 24 (1), 93–121. https://doi.org/10.1007/s11123-005-3042-8.

De Witte, K., Marques, R.C., 2010a. Designing performance incentives, an international benchmark study in the water sector. Cent. Eur. J. Oper. Res. 18 (2), 189–220. https://doi.org/10.1007/s10100-009-0108-0.

De Witte, K., Marques, R.C., 2010b. Influential observations in frontier models, a robust non-oriented approach to the water sector. Ann. Oper. Res. 181, 377–392. https://doi.org/10.1007/s10479-010-0754-6.

De Witte, K., Marques, R.C., 2012. Gaming in a benchmarking environment. A non-parametric analysis of benchmarking in the water sector. Water Pol. 14 (1), 45–66. https://doi.org/10.2166/wp.2011.087.

De Witte, K., Saal, D.S., 2010. Is a little sunshine all we need? On the impact of sunshine regulation on profits, productivity, and prices in the Dutch drinking water sector. J. Regul. Econ. 37, 219–242. https://doi.org/10.1007/s11149-009-9112-5.

Deng, G., Li, L., Song, Y., 2016. Provincial water use efficiency measurement and factor analysis in China: based on SBM-DEA model. Ecol. Indicat. 69, 12–18. https://doi.org/10.1016/j.ecolind.2016.03.052.

Dharmaratna, D., Parasnis, J., 2012. An analysis of the cost structure of water supply in Sri Lanka. J. Asia Pac. Econ. 17 (2), 298–314. https://doi.org/10.1080/13547860.2012.668092.

Dorta-Gonzalez, P., Dorta-González, M.I., 2013. Comparing journals from different fields of science and social science through a JCR subject categories normalized impact factor. Scientometrics 95 (2), 645–672. https://doi.org/10.1007/s11192-012-0929-9.

Ellegaard, O., Wallin, J.A., 2015. The bibliometric analysis of scholarly production: how great is the impact? Scientometrics 105 (3), 1809–1831. https://doi.org/10.1007/s11192-015-1645-z.

Estache, A., Rossi, M.A., 2002. How different is the efficiency of public and private water companies in Asia? World Bank Econ. Rev. 16 (1), 139–148. https://doi.org/10.1093/wber/16.1.139.

Feng, Y., Zhu, Q., Lai, K.H., 2017. Corporate social responsibility for supply chain management: a literature review and bibliometric analysis. J. Clean. Prod. 158, 296–307. https://doi.org/10.1016/j.jclepro.2017.05.018.

Ferro, G., Lentini, E.J., Mercadier, A.C., Romero, C.A., 2014. Efficiency in Brazil's water and sanitation sector and its relationship with regional provision, property and the independence of operators. Util. Pol. 28, 42–51. https://doi.org/10.1016/j.jup.2013.12.001.

Ferro, G., Mercadier, A.C., 2016. Technical efficiency in Chile's water and sanitation providers. Util. Pol. 43, 97–106. https://doi.org/10.1016/j.jup.2016.04.016.

Ferro, G., Romero, C.A., Covelli, M.P., 2011. Regulation and performance: a production frontier estimate for the Latin American water and sanitation sector. Util. Pol. 19, 211–217. https://doi.org/10.1016/j.jup.2011.08.003.

Filippini, M., Hrovatin, N., Zorić, J., 2008. Cost efficiency of Slovenian water distribution utilities: an application of stochastic frontier methods. J. Prod. Anal. 29 (2), 169–182. https://doi.org/10.1007/s11123-007-0069-z.

Gao, C., Sun, M., Geng, Y., Wu, R., Chen, W., 2016. A bibliometric analysis based review on wind power price. Appl. Energy 182, 602–612. https://doi.org/10.1016/j.apenergy.2016.08.144.

García-Sánchez, I.M., 2006. Efficiency measurement in Spanish local government: the case of municipal water services. Rev. Pol. Res. 23 (2), 355–372. https://doi.org/10.1111/j.1541-1338.2006.00205.x.

Garcia, S., Thomas, A., 2001. The structure of municipal water supply costs: application to a panel of French local communities. J. Prod. Anal. 16, 5–29. https://doi.org/10.1023/A:1011142901799.

Gidion, D.K., Hong, J., Adams, M.Z., Khoveyni, M., 2019. Network DEA models for assessing urban water utility efficiency. Util. Pol. 57, 48–58. https://doi.org/10.1016/j.jup.2019.02.001.

Golder, P.N., Mitra, D., Moorman, C., 2012. What is quality? An integrative framework of processes and states. J. Market. 76 (4), 1–23. https://doi.org/10.1509/2Fjm.09.0416.

Guerrini, A., Molinos-Senante, M., Romano, G., 2018. Italian regulatory reform and water utility performance: an impact analysis. Util. Pol. 52, 95–102. https://doi.org/10.1016/j.jup.2018.03.005.

Hana, U., 2013. Competitive advantage achievement through innovation and knowledge. J. Competitiveness 5 (1), 82–96. https://doi.org/10.7441/joc.2013.01.06.

Higuerey, A., Trujillo, L., González, M.M., 2017. Has efficiency improved after the decentralization in the water industry in Venezuela? Util. Pol. 49, 127–136. https://doi.org/10.1016/j.jup.2017.05.003.

Iqbal, W., Qadir, J., Tyson, G., Mian, A.N., Hassan, S., Crowcroft, J., 2019. A bibliometric analysis of publications in computer networking research. Scientometrics 119 (2), 1121–1155. https://doi.org/10.1007/s11192-019-03086-z.

Kamarudin, N., Ismail, W.R., Ramli, N.A., 2015. Malaysian water utilities performance with the presence of undesirable output: a directional distance function

approach. Jurnal Teknologi 78 (4–3), 17–22. https://doi.org/10.11113/jt.v78.8232.
Kirkpatrick, C., Parker, D., Zhang, Y.F., 2006. An empirical analysis of state and private-sector provision of water services in Africa. World Bank Econ. Rev. 20 (1), 143–163. https://doi.org/10.1093/wber/lhj001.
Kumar, S., Managi, S., 2010. Service quality and performance measurement: evidence from the Indian water sector. Int. J. Water Resour. Dev. 26 (2), 173–191. https://doi.org/10.1080/07900621003655726.
Laffont, J.J., 2005. Regulation and Development. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139163392.
Lin, C., Berg, S.V., 2008. Incorporating service quality into yardstick regulation: an application to the Peru water sector. Rev. Ind. Organ. 32 (1), 53–75. https://doi.org/10.1007/s11151-008-9160-5.
Marques, R.C., Carvalho, P., Pires, J., Fontainhas, A., 2016. Willingness to pay for the water supply service in Cape Verde – how far can it go? Water Sci. Technol. Water Supply 16 (6), 1721–1734. https://doi.org/10.2166/ws.2016.090.
Marques, R.C., De Witte, K., 2010. Towards a benchmarking paradigm in the European water and sewerage services. Publ. Money Manag. 30 (1), 42–48. https://doi.org/10.1080/09540960903492364.
Marques, R.C., Simões, P., Pires, J.S., 2011. Performance benchmarking in utility regulation: the worldwide experience. Pol. J. Environ. Stud. 20 (1), 125–132.
Marques, R.C., Berg, S., Yane, S., 2014. Nonparametric benchmarking of Japanese water utilities: institutional and environmental factors affecting efficiency. J. Water Resour. Plann. Manag. 140, 562–571. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000366.
Maziotis, A., Saal, D.S., Thanassoulis, E., Molinos-Senante, M., 2016. Price-cap regulation in the English and Welsh water industry: a proposal for measuring productivity performance. Util. Pol. 41, 22–30. https://doi.org/10.1016/j.jup.2016.04.002.
Mbuvi, D., De Witte, K., Perelman, S., 2012. Urban water sector performance in Africa: a step-wise bias-corrected efficiency and effectiveness analysis. Util. Pol. 22, 31–40. https://doi.org/10.1016/j.jup.2012.02.004.
Melin, G., Persson, O., 1996. Studying research collaboration using co-authorships. Scientometrics 36, 363–377. https://doi.org/10.1007/BF02129600.
Merediz-Solà, I., Bariviera, A.F., 2019. A bibliometric analysis of bitcoin scientific production. Res. Int. Bus. Finance 50, 294–305. https://doi.org/10.1016/j.ribaf.2019.06.008.
Meeusen, W., van den Broeck, J., 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. Int. Econ. Rev. 18 (2), 435–444. https://doi.org/10.2307/2525757.
Mikulik, J., Babina, M., 2009. The role of universities in environmental management. Pol. J. Environ. Stud. 18 (4), 527–531.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLos Med. 6 (7) https://doi.org/10.1371/journal.pmed.1000097.
Molinos-Senante, M., Donoso, G., Sala-Garrido, R., Villegas, A., 2018a. Benchmarking the efficiency of the Chilean water and sewerage companies: a double-bootstrap approach. Environ. Sci. Pollut. Res. 25 (9), 8432–8440. https://doi.org/10.1007/s11356-017-1149-x.
Molinos-Senante, M., Hernández-Sancho, F., Sala-Garrido, R., 2010. Economic feasibility study for wastewater treatment: a cost-benefit analysis. Sci. Total Environ. 408 (20), 4396–4402. https://doi.org/10.1016/j.scitotenv.2010.07.014.
Molinos-Senante, M., Maziotis, A., 2018. Assessing the influence of exogeneous and quality of service variables on water companies' performance using a true-fixed stochastic frontier approach. Urban Water J. 15 (7), 682–691. https://doi.org/10.1080/1573062X.2018.1539502.
Molinos-Senante, M., Maziotis, A., 2019. Productivity growth and its drivers in the Chilean water and sewerage industry: a comparison of alternative benchmarking techniques. Urban Water J. 16 (5), 353–364. https://doi.org/10.1080/1573062X.2019.1669196.
Molinos-Senante, M., Maziotis, A., Mocholí-Arce, M., Sala-Garrido, R., 2016a. Accounting for service quality to customers in the efficiency of water companies: evidence from England and Wales. Water Pol. 18, 513–532. https://doi.org/10.2166/wp.2015.062.
Molinos-Senante, M., Mocholí-Arce, M., Sala-Garrido, R., 2016b. Efficiency assessment of water and sewerage companies: a disaggregated approach accounting for service quality. Water Resour. Manag. 30, 4311–4328. https://doi.org/10.1007/s11269-016-1422-7.
Molinos-Senante, M., Porcher, S., Maziotis, A., 2017. Impact of regulation on English and Welsh water-only companies: an input-distance function approach. Environ. Sci. Pollut. Res. 24 (20), 16994–17005. https://doi.org/10.1007/s11356-017-9345-2.
Molinos-Senante, M., Porcher, S., Maziotis, A., 2018b. Productivity change and its drivers for the Chilean water companies: a comparison of full private and concessionary companies. J. Clean. Prod. 183, 908–916. https://doi.org/10.1016/j.jclepro.2018.02.227.
Molinos-Senante, M., Sala-Garrido, R., 2015. The impact of privatization approaches on the productivity growth of the water industry: a case study of Chile. Environ. Sci. Pol. 50, 166–179. https://doi.org/10.1016/j.envsci.2015.02.015.
Molinos-Senante, M., Sala-Garrido, R., 2016a. Cross-national comparison of efficiency for water utilities: a metafrontier approach. Clean Technol. Environ. Policy 18, 1611–1619. https://doi.org/10.1007/s10098-016-1133-z.
Molinos-Senante, M., Sala-Garrido, R., 2016b. Performance of fully private and concessionary water and sewerage companies: a metafrontier approach. Environ. Sci. Pollut. Res. 23 (12), 11620–11629. https://doi.org/10.1007/s11356-016-6359-0.
Molinos-Senante, M., Sala-Garrido, R., Lafuente, M., 2015. The role of environmental variables on the efficiency of water and sewerage companies: a case study of Chile. Environ. Sci. Pollut. Res. 22 (13), 10242–10253. https://doi.org/10.1007/s11356-015-4225-0.
Molinos-Senante, M., Villegas, A., Maziotis, A., 2019. Are water tariffs sufficient incentives to reduce water leakages? An empirical approach for Chile. Util. Pol. 61, 100971. https://doi.org/10.1016/j.jup.2019.100971.
Maroušek, J., Stehel, V., Vochozka, M., Kolář, L., Maroušková, A., Strunecký, O., Peterka, J., Kopecký, M., Shreedhar, S., 2019. Ferrous sludge from water clarification: changes in waste management practices advisable. J. Clean. Prod. 218, 459–464. https://doi.org/10.1016/j.jclepro.2019.02.037.
Muhuri, P.K., Shukla, A.K., Abraham, A., 2019. Industry 4.0: a bibliometric analysis and detailed overview. Eng. Appl. Artif. Intell. 78, 218–235. https://doi.org/10.1016/j.engappai.2018.11.007.
Nauges, C., Van den Berg, C.J., 2008. Economies of density, scale and scope in the water supply and sewerage sector: a study of four developing and transition economies. J. Regul. Econ. 34 (2), 144–163. https://doi.org/10.1007/s11149-008-9063-2.
Noyons, E.C.M., Moed, H.F., Luwel, M., 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: a bibliometric study. J. Am. Soc. Inf. Sci. 50 (2), 115–131. https://doi.org/10.1002/(SICI)1097-4571(1999)50:2%3C115::AID-ASI3%3E3.0.CO;2-J.
Osareh, F., 1996. Bibliometrics, citation analysis and co-citation analysis: a review of literature. Int. J. Libr. Inf. Stud. 46 (3), 149–158.
Picazo-Tadeo, A.J., Sáez-Fernández, F.J., González-Gómez, F., 2008. Does service quality matter in measuring the performance of water utilities? Util. Pol. 16 (1), 30–38. https://doi.org/10.1016/j.jup.2007.10.001.
Picazo-Tadeo, A.J., Sáez-Fernández, F.J., González-Gómez, F., 2009. The role of environmental factors in water utilities' technical efficiency. Empirical evidence from Spanish companies. Appl. Econ. 41 (5), 615–628. https://doi.org/10.1080/00036840601007310.
Pinto, F.S., Simões, P., Marques, R.C., 2017a. Raising the bar: the role of governance in performance assessments. Util. Pol. 49, 1–10. https://doi.org/10.1016/j.jup.2017.09.001.
Pinto, F.S., Simões, P., Marques, R.C., 2017b. Water services performance: do operational environment and quality factors count? Urban Water J. 14 (8), 773–781. https://doi.org/10.1080/1573062X.2016.1254254.
Pointon, C., Matthews, K., 2016. Dynamic efficiency in the English and Welsh water and sewerage industry. Omega Int. J. Manag. Sci. 58, 86–96. https://doi.org/10.1016/j.omega.2015.04.001.
Pritchard, A., 1969. Statistical bibliography or bibliometrics. J. Doc. 25 (4), 348.
Romano, G., Guerrini, A., 2011. Measuring and comparing the efficiency of water utility companies: a data envelopment analysis approach. Util. Pol. 19 (3), 202–209. https://doi.org/10.1016/j.jup.2011.05.005.
Saal, D.S., Parker, D., 2001. Productivity and price performance in the privatized water and sewerage companies of England and Wales. J. Regul. Econ. 20 (1), 61–90. https://doi.org/10.1023/A:1011162214995.
Saal, D.S., Parker, D., 2004. The comparative impact of privatization and regulation on productivity growth in the English and Welsh water and sewerage industry, 1985-99. Int. J. Regul. Govern. 4 (2), 139–170. https://doi.org/10.3233/IJR-120039.
Saal, D.S., Parker, D., Weyman-Jones, T., 2007. Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985-2000. J. Prod. Anal. 28, 127–139. https://doi.org/10.1007/s11123-007-0040-z.
See, K.F., 2015. Exploring and analysing sources of technical efficiency in water supply services: some evidence from Southeast Asian public water utilities. Water Resour. Econ. 9, 23–44. https://doi.org/10.1016/j.wre.2014.11.002.
See, K.F., Ma, Z., 2018. Does non-revenue water affect Malaysia's water services industry productivity. Util. Pol. 54, 125–131. https://doi.org/10.1016/j.jup.2018.04.006.
Simar, L., Wilson, P.W., 2007. Estimation and inference in two-stage, semi-parametric models of production processes. J. Econom. 136 (1), 31–64. https://doi.org/10.1016/j.jeconom.2005.07.009.
Solvoll, S., Alsos, G.A., Bulanova, O., 2015. Tourism entrepreneurship: review and future directions. Scand. J. Hospit. Tourism 15 (1), 120–137. https://doi.org/10.1080/15022250.2015.1065592.
Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manag. 14, 207–222. https://doi.org/10.1111/1467-8551.00375.
UN, 2015. Transforming our world: the 2030 agenda for sustainable development. General Assembley 70 session. https://www.un.org/sustainabledevelopment/sustainabledevelopment-goals/.
Villegas, A., Molinos-Senante, M., Maziotis, A., 2019. Impact of environmental variables on the efficiency of water companies in England and Wales: a double-bootstrap approach. Environ. Sci. Pollut. Res. 26 (30), 31014–31025. https://doi.org/10.1007/s11356-019-06238-z.
Waltman, L., Van Eck, N.J., 2015. Field-normalized citation impact indicators and the choice of an appropriate counting method. J. Informetr. 9, 872–894. https://doi.org/10.1016/j.joi.2015.08.001.
Walter, M., Cullmann, A., Hirschhausen, C.V., Wand, R., Zchille, M., 2009. Quo vadis efficiency analysis of water distribution? a comparative literature review. Util. Pol. 17 (3–4), 225–232. https://doi.org/10.1016/j.jup.2009.05.002.
Wang, H., He, Q., Liu, X., Zhuang, Y., Hong, S., 2012. Global urbanization research

from 1991 to 2009: a systematic literature review. Landsc. Urban Plann. 104, 299–309. https://doi.org/10.1016/j.landurbplan.2011.11.006.
Wang, L., Wei, Y., Brown, M.A., 2017. Global transition to low-carbon electricity: a bibliometric analysis. Appl. Energy 205, 57–68. https://doi.org/10.1016/j.apenergy.2017.07.107.
Worthington, A.C., 2014. A review of frontier approaches to efficiency and productivity measurement in urban water utilities. Urban Water J. 11 (1), 55–73. https://doi.org/10.1080/1573062X.2013.765488.
Xu, S., Zhang, X., Feng, L., Yang, W., 2020. Disruption risks in supply chain management: a literature review based on bibliometric analysis. Int. J. Prod. Res. 58 (11), 3508–3526. https://doi.org/10.1080/00207543.2020.1717011.