Analysis on the Research Progress of Carbon Disclosure: A Bibliometric Mapping Analysis and Systematic Review

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Abstract: In response to climate change risks, some firms have developed carbon disclosure to communicate their climate-related risk management. The literature on various facets of carbon disclosure regarding companies remains limited despite the increased interest in corporate environmental disclosure, particularly the lack of literature review work. Therefore, this article aims to systematically review the available literature by revealing current research evolution and hotspots in carbon disclosure field. By using the visualization software CiteSpace and VOSviewer, this study analyzed 606 research articles of carbon disclosure research that were published between 2000 and 2023 in the Web of Science (WOS) database, and conducted the assessment on journals, reference articles, reference journals, authorship and keywords. The results found the main research themes in carbon disclosure, including 'strategic climate response', 'determinants of carbon disclosure', 'consequences of carbon disclosure' and 'climate change policy'. In addition, the hotspots on carbon disclosure have shifted to the enterprise internal environment, especially enterprise management architecture. It will help readers gain insight into carbon disclosure research, understand the evolving mechanisms in the field, and conduct future research more effectively.
Keywords: Carbon Disclosure, Carbon Emission, Bibliometric Mapping Analysis

1. Introduction

Climate change is a challenge facing all mankind, which has attracted the attention of various countries and relevant international organizations since the 1980s. The massive emission of greenhouse gases (especially carbon dioxide) is the main cause of global warming, which directly threatens the survival of human beings and the sustainable development of the world economy. The Kyoto Protocol, first adopted in 1997, sets legally binding quantitative emission reduction targets fordeveloped and transition countries. Firms face increasing pressure to communicate their climate-related risk management. This pressure is driven by various stakeholder groups (including investors) who are concerned about physical risks and possible future carbon regulations of climate change threatening infrastructures. To address these pressures, some firms have developed carbon disclosure to convey their climate risks and opportunities, carbon abatement plans, actions, and achievements. However, the disclosure of climate change and carbon-related information is still at a low level. Previous studies have found that most companies revealed minimal information related to climate change, with almost all disclosing less than half of the measurement indicators[1][2].

The non-disclosure behavior of firms could be attributed to several factors, such as company executives and directors have limited knowledge and awareness of carbon disclosure, scarce resources, underperformance, concerns about negative publicity, a lack of legal regulations, and a lack of clear guidance,which may lead many firms to choose not to publicly disclose their environmental accounting decisions in full or only disclose part of their accounting treatments.

To report accurate and valuable carbon-emission-information regarding the risks and opportunities, firms have to learn how carbon accounting and disclosure works, how disclosure is developed and progressively enhanced, and which country-level and firm-specific characteristics determine the disclosure approach. However, the literature does not provide a clear definition of carbon accounting and disclosure, and different stakeholder groups perceive carbon activities differently[3]. These divergent disclosure approaches and qualities reduce the ability of stakeholders to evaluate environmental risk performance.

In order for carbon disclosure to be effective, it is necessary to compare the contradictions created by multiple frameworks to assess the existing conflicts and challenges that created in carbon reporting. The literature on various facets of carbon disclosure regarding companies remains limited despite the increased interest in corporate environmental disclosure, particularly the lack of literature review work. Prior literature reviews have attempted to define carbon accounting[4], evaluate the transparency of carbon disclosure in organizations[5] and outline key research areas[6]. Due to the recent growth and fragmentation in the literature, reviewing broad fields of carbon disclosure requires a broader review and agenda for future researches. Nowadays, many scholars are using scientometrics and visualization tools to track research trends and highlight current research hotspots of different disciplines. The present study conducted a systematic review and bibliometric mapping analysis to analyze the literature published in the WOS database to answer the following research questions:

(1)What and who are the major journals publishing the carbon disclosure studies? What are the most cited papers of carbon disclosure research? Who are the most productive and cited authors of carbon disclosure research?

(2)What are the most used keywords of carbon disclosure research? What are the trends of the keywords?

(3)What are the research issues investigated in carbon disclosure research? What are the main gaps in current research that need to be addressed?

2. Methods

2.1 Research methods and tools

Bibliometrics was first introduced in the early 20th century and formed an independent discipline in the 1970s[7]. Bibliometric analysis is a quantitative method to retrospect and investigate published papers, which is widely applied in literature analysis. By using secondary data acquired on digital database, bibliometric analysis can capture details, such as authors, keywords, journals, countries, institutions and references. Thus, researchers can obtain the development of a focal field through this analyzing process. With the help of modern computer technology, graphic and visual analysis becomes an important method in bibliometric research. Moreover, visualized co-citation analysis helps present valuable implied connections of science literature.

CiteSpace and VOSviewer are two main visualization tools in bibliometric research and other research field for mapping science. The knowledge visualization software, CiteSpace, is developed by Dr Chen from Drexel University[8]. The software with Java based on co-citation analysis can use minimum spanning tree algorithm or pathfinder algorithm to process whole co-citations network in specific research fields. CiteSpace can produce different kinds of map views to provide information about knowledge structure and trends of evolution, respectively. VOSviewer is developed by Nees Jan van Eck and Ludo Waltman from the Center for Scientific and Technological Research (CWTS) of Leiden University. It is particularly useful for visualizing and exploring large bibliometric visual maps in an easy-to-interpret manner. Fu and Ding based on the same dataset to compare CiteSpace and VOSviewer, and found that CiteSpace is better at presenting evolution, while VOSviewer is more accurate in cluster algorithm[9]. This study used VOSviewer to perform the co-citation analysis and visualize the knowledge structure of carbon disclosure research. And then, this study used CiteSpace for evolution analysis to explore the development process in this field.

2.2 Data source and selection process

The WOS (Web of Science) is a high-quality digital database that has become an important academic research platform for obtaining world authoritative academic information. In order to ensure the accuracy and representativeness of the retrieved data, this study collected publication information from Science Citation Index Expanded (SCI-EXPANDED) and Social Science Citation Index (SSCI) of WOS database. The search string in the sample collection was set as TS = (Carbon Disclosure). The time span was January 1, 2000 to May 1, 2023, and the retrieval time was May 04, 2023.

As shown in Figure 1, the search process resulted in 733 articles as an initial sample. By excluding non-article types and non-English, 686 articles were retained. By focusing on specific fields, namely, Business, Economics, Environmental Science, Finance, Green Sustainable Science, and Management, the number of sample studies decreased to 627 studies. Following that, a manual review was conducted to examine the content of each article (including paper title and abstract) to eliminate literature review, repeated and irrelevant publications to ensure that the selected articles involved the carbon disclosure. Finally, 606 articles were retained for content and bibliometrics mapping analysis. The 606 papers used in this study were written by 1502 authors from 767 organizations in 156 countries/areas, published in 172 joumals, and cited 25523 references from 9418 journals.

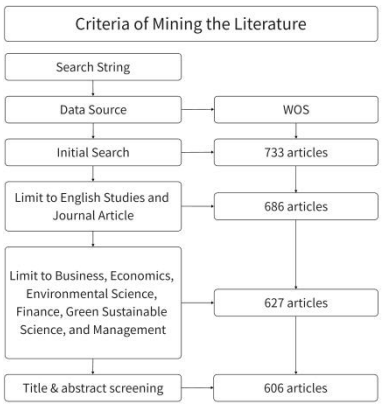

Figure 1 The flow chart of the literature sample collection.

Figure 2 illustrates the number of carbon disclosure publications and cited frequency in each year from 2000 to 2023. Based on the suggestions of several previous studies, the carbon disclosure studies are categorized into three time periods, that is, 2000-2011, 2012–2018 and 2019–2023.

Accordingly, there are 23 publications from 2000 to 2011, 160 from 2012 to 2018 and 423 published papers from 2019 to 2023, as shown in Figure 2. It was found that the number of publications in the latest time period was nearly twofold that of the first two periods, showing the rapid growth of carbon disclosure research in the past four years. It could be related to the cognition that the current costs of adopting corporate action is insignificant compared to the future costs of economic and social disruption caused by climate crisis and environmental degradation.

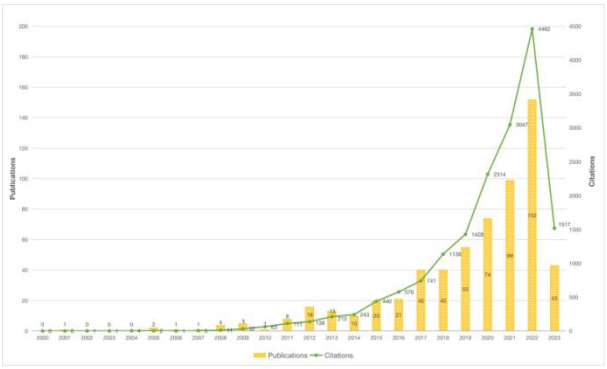

Figure 2 Time trends of the publications and cited frequency on carbon disclosure.

3. Result

3.1 Main Journals, Most Cited Papers and Most Productive and Cited Authors

Figure 3 shows five journals with the largest number of articles in carbon disclosure research between 2000 and 2023. They were Business Strategy and The Environment (publications=65), Sustainability (publications=57), Journal of Cleaner Production (publications=55), Environmental Science and Pollution Research (publications=21), and Corporate Social Responsibility and Environmental Management (publications=18). It also shows that the most cited journals are Business Strategy and The Environment (citations=1909) and Journal of Cleaner Production (citations =1489).

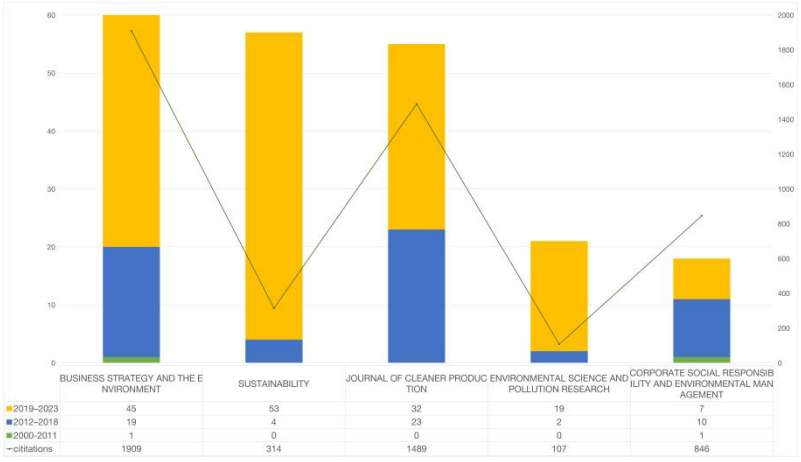

Figure 3 Top 5 journals by total number of publications from 2000 to 2023.

In addition, co-citation analysis and cited sources were selected. The minimum number of citations from sources was adjusted to 201, and the number of sources to be selected was automatically displayed as 25. Figure 4 shows that the top three most cited journals are Journal of Cleaner Production (1622 co-citations), Business Strategy and the Environment (1567 co-citations) and Journal of Business Ethics (1523 co-citations).

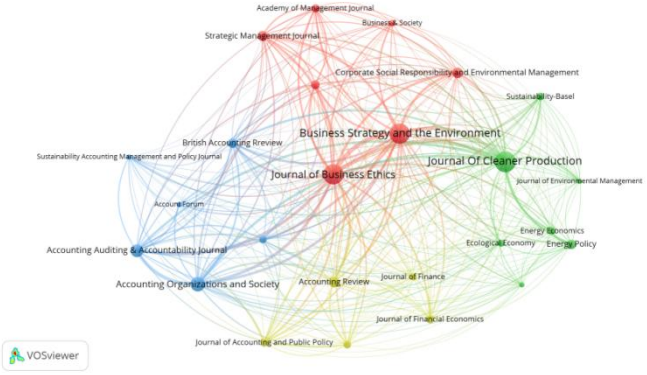

Figure 4 Co-Citation of Cited Journals on carbon disclosure.

Table 1 shows the top three most-cited papers, which were published by British Accounting Review, Accounting Review and Strategic Management Journal, respectively. This indicates that the journals have taken the studies of carbon disclosure as important research foci. The first study by Liao Lin et al. examined the impact of corporate board's characteristics on the voluntary disclosure of greenhouse gas (GHG) emissions[10]. The results found that a diversified and independent board and the existence of a board-level environmental committee can increase the propensity to disclose GHG information as well as the extensiveness of that disclosure. The second study by Matsumura et al. investigated effects on firm value of carbon emissions and of the act of voluntary carbon disclosure[11]. They indicated that the markets will impose a further penalty on firms that do not disclose emissions information. The third by Reid et al. explored the conditions under which firms participate in carbon disclosure[12], showing that both activist groups and government actors can spur changes in organizational practices.

Table 1 Top 3 most-cited papers.

Title	Journal	Authors	Year	Citations
Gender Diversity, Board Independence, Environmental Committee And Greenhouse Gas Disclosure	British Accounting Review	Liao Lin, Luo Le and Tang Qingliang	2015	565
Firm-Value Effects of Carbon Emissions and Carbon Disclosures	Accounting Review	Matsumura, Ella Mae, Prakash, Rachna and Vera-Munoz Sandra C.	2014	480
Responding To Public And Private Politics: Corporate Disclosure Of Climate Change Strategies	Strategic Management Journal	Reid Erin M. and Toffel Michael W.	2009	478

Table 2 shows the authors who have published six or more carbon disclosure studies. The top three authors with the highest number of citations were Tang Qingliang (citations=1075, publications=19), Le Luo (citations=1177, publications=16) and Kuo Lopin (citations=238, publications=6).

Table 2 Top 5 authors ranked by number of publications.

Author	Countries/Areas	Publications	Citations	Citations Per Paper
Tang Qingliang	Australia	19	1075	56.58
Le Luo	Australia	16	1177	73.56
Kuo Lopin	Taiwan	6	238	39.67
Frank Schiemann	Germany	6	158	26.33
Constancio Zamora-Ramírez	Spain	6	45	7.50

Figure 5 shows the co-citation analysis results by setting the minimum number of citations as 80. It was found that the publications by Le Luo (353 citations), Clarkson Priscilla M (322 citations) and Kolk Ans (265 citations) have been co-cited the most in carbon disclosure research.

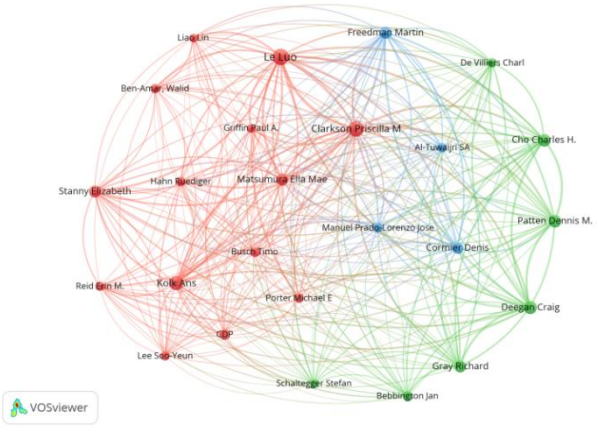

Figure 5 Co-Citation of Cited Authors.

3.2 Most Used Keywords

A total of 1646 author keywords are included in the 606 carbon disclosure articles. Figure 6 shows the cluster analysis network map generated by VOSviewer. The most frequently used keywords are 'climate change' (f=234) , 'performance' (f=135) , 'management' (f=101), 'corporate social-responsibility' (f=97), 'environmental performance' (f=96), 'legitimacy' (f=91), 'determinants' (f=89), 'impact' (f=86), 'sustainability'(f=80), and 'governance'(f=80). There are four main clusters of carbon disclosure research, that is, 'strategic climate response', 'determinants of carbon disclosure', 'consequences of carbon disclosure', and 'climate change policy', as displayed in red, green, blue, and yellow.

The studies in Cluster 1 (red) focuses on the strategic climate response of companies. For example, Kolk and Pinkse presented a typology for climate strategies that include vertical (supply chain) level, horizontal (with other companies) level, and internal (company) level strategies[13]. However, Kolk and Pinkse failed to explain what firm-specific characteristics and other influential factors could impact the adoption of low levels of strategic response. Some literature assessed the major factors influencing strategic climate response and discussed strategic dilemmas. Stanny reviewed business and political elements that impact the strategic response, finding that some organizations only disclose the minimum amount to avoid scrutiny[14].

Cluster 2 (green) focuses on the determinant of companies to disclose voluntarily. Carbon disclosure is a strategic corporate climate response which is not mandatory and largely unregulated. A number of researchers in this field specified the motivations to carbon disclosure, such as 'profit, 'guiding against risk', 'investor pressure', 'other stakeholders', 'type of ownership'[15][16], 'credibility and leverage in climate policy development', 'form of regulation and government directives'[17], 'environmental management systems (EMS)'[18] and 'the percentage of female directors on the board'[19]. In addition, the barriers to proactive climate actions are associated with uncertainty about the marketplace and policies.

Cluster 3 (blue) focuses on the consequence of carbon disclosure on financial markets and firm performance. Several authors found that the response of financial markets to carbon disclosure varies. In Europe, the relationship between share performance and carbon disclosure is positive for firms[20]. On the contrary to the European market, the Korean financial market shows a negative response to carbon disclosure by corporations[21]. Prior research has shown that efficient environmental reporting is favored by both customers and shareholders. However, there is no academic consensus on whether carbon disclosure is beneficial for company valuation, which is the major problem facing the field. Zamora-Ramirez

et al. emphasized that the participation of firms in Carbon Disclosure Project (CDP) is an important attribute variable for business valuation[22]. Other studies argued that carbon disclosure has no direct impact on firm value, while other factors maybe influence this association[23].

Cluster 4 (yellow) focuses on the climate change policy. Regulation and policies are effective strategies for enhancing environmentally beneficial actions. Fagotto et al. recommended that the USA needs government legislation to require product labeling and industry reporting of carbon emissions[24]. Karplus et al. showed that boosting firms' compliance incentives needs reforms in national institutions[25].

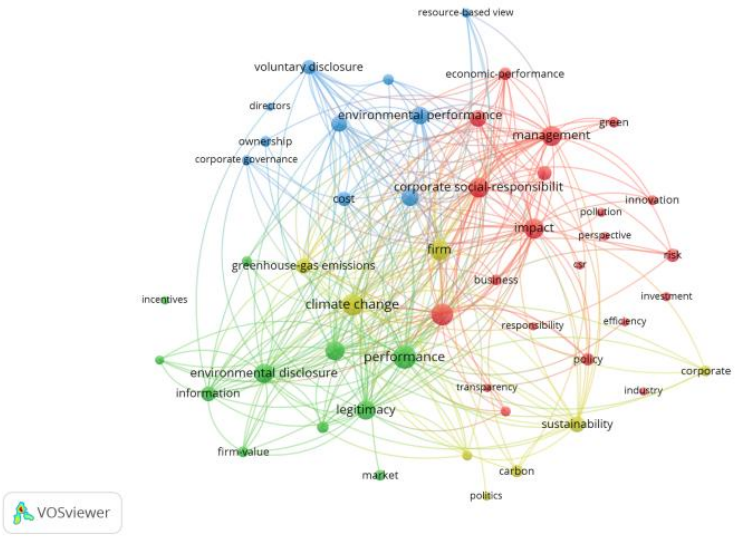

Figure 6 Co-Occurrence of Keywords.

3.3 Evolution of Research Topic

To demonstrate the trajectories of carbon disclosure research, Figure 7 shows the timezone knowledge map generated by CitesSpace. The average yearly quantity of published articles between 2000 and 2007 is less than one, which is not conducive to analysis. Therefore, this study selected the literature from 2008 to 2023 as the analysis sample. In 2007, the Bali Road Map required developed countries to reduce GHG emissions by 25-40% by 2020. Researchers in carbon disclosure field focused more on the topic of climate change between 2008 and 2011. In 2012, developing countries began to undertake carbon reduction obligations. With increased voluntary initiatives on a global scale, including the CDP, more attention was paid to the impact of carbon disclosure. From 2012 to 2018, the main research contents were the determinant, strategic, and consequence of companies to disclose voluntarily. During the last stage (2019–2023), many keywords related to firm-specific characteristics have appeared, such as 'board characteristics', 'ownership', 'gender diversity', and 'directors'. This implies that the main focus of carbon disclosure research is to adopt the strategic climate response in TMT (Top Management Team) -centered contexts.

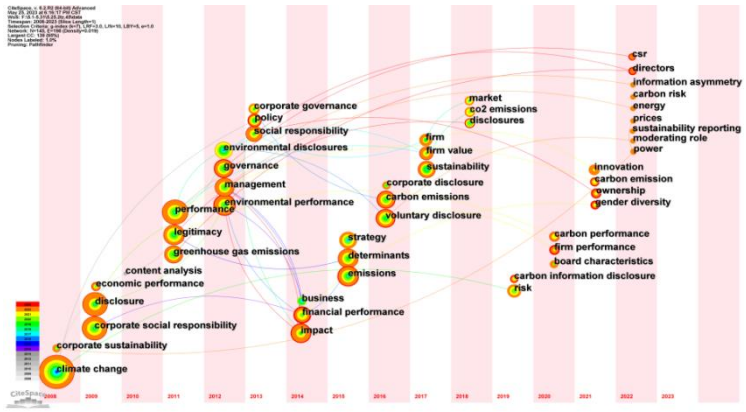

Figure 7 Timezone Knowledge Map (2008–2023) on carbon disclosure

Through the detection of 'mutated words', Table 3 shows the historical distribution of word frequency analysed by CitesSpace. It found that the strongest mutated word of carbon disclosure research is ‘Business’ (5.63), followed by ‘Environmental Disclosures’ (5.52) and ‘Climate Change’ (5.12). The large mutated value indicates that scholars may conduct in-depth exploration of multidimension at this stage. The first two mutated words appeared in the medium term (2012-2018) and made some progress in carbon disclosure research. Keeping tracking the mutation maturity of these words, including Business in 2014 and Environmental Disclosures in 2015, the maturity period distribution of word frequency is relatively uniform. This indicates a sustainable and balance development of these research topics. Moreover, the earliest mutated words, Climate Change in 2008, had the longest maturity period of word frequency.

In order to further analyze this change and trend, this study used the ‘Citation History’ function of CiteSpace to show the mutation year distribution and trend of hot keywords. Figure 8 shows that the mutation value of Business increased sharply in 2016, Environmental Disclosures started to mutate in 2015, and Climate Change showed rapid growth in 2019. It shows that research studies on these topics are developing further.

Table 3 Top 10 mutated words ranked by strength.

Keywords	Year	Strength	Begin	End	2008-2023
Business	2014	5.63	2014	2020	
Environmental Disclosures	2012	5.52	2015	2019	
Climate Change	2008	5.12	2008	2017	
Responses	2012	4.96	2012	2019	
Strategy	2015	4.66	2015	2017	
Sustainability	2017	4.61	2017	2019	
Innovation	2021	3.67	2021	2023	
CSR	2022	3.40	2022	2023	
Carbon Disclosure Project	2011	3.25	2011	2016	
Efficiency	2022	3.21	2022	2023	

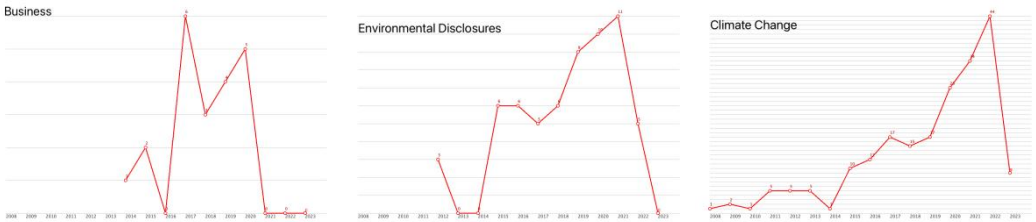

Figure 8 Mutation Year Distribution and Trend of Popular Keywords.

4. Conclusion

Despite alarming GHG emission levels, the quality of carbon and climate change disclosure remains a low level. This study analyzed 606 research articles of carbon disclosure research that were published between 2000 and 2023 in the WOS database. Combining VOSviewer and CiteSpace to conduct a bibliometric analysis, the following findings and implications were derived:

(1) The greatest amount of carbon disclosure research was published in Business Strategy and the Environment, followed by Sustainability and Journal of Cleaner Production. In addition, the top three most cited journals (co-citation analysis) are Journal of Cleaner Production, Business Strategy and the Environment, and Journal of Business Ethics.

(2) From the results of using cluster analysis on author keywords, four clusters of carbon disclosure studies were found; that is, 'strategic climate response', 'determinants of carbon disclosure', 'consequences of carbon disclosure' and 'climate change policy'. Existing relevant literature has deepened research on corporate environment-related issues.

(3) The evolution of carbon disclosure research consists of two trends: first, from the macro-economic background to the enterprise internal environment, second, from enterprise asset elements to enterprise management architecture. Besides, there have been several emerging research studies on gender, innovation and efficiency.

Comparing with literature reviews method, this study clearly and hololog ically shows the structure and evolution of carbon disclosure research. The panorama will help scholars interested in carbon disclosure research understand the development process in this field, and provide ideas for future research. It should be admitted that there are some limitations in this study. First, Scopus databases and multiple databases could be considered for a more extensive review study in the future. Second, future study could focus on specific aspects of corporate environment-related topics.

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