Business, Management and Economics Engineering
ISSN: 2669-2481 / eISSN: 2669-249X 2023
Volume 21 Issue 1: 215–248

A Bibliometric and Visualization Review of Research on Carbon Information Disclosure Using CiteSpace

Weishi Song[1,2], Albattat Ahmad[1*], Zhongye Sun[2], Aza Azlina Binti Md Kassim[1]

[1] Graduate School of Management, Management and Science University, Shah Alam 40100, Selangor, Malaysia
[2] Henan University of Technology, Zhengzhou 450001,China
Corresponding author' email: dr.battat@msu.edu.my
(First author: Weishi Song' email: weishi_song@163.com)

Abstract: Carbon information disclosure, as a forward-looking environmental information disclosure, is an important tool to assist carbon accounting and enhance carbon emission reduction management. It plays an important role in improving environmental issues, reducing carbon emissions and achieving low-carbon development. In recent years, as carbon information disclosure has received widespread attention from scholars, the number of studies on carbon information disclosure has increased significantly. In order to provide a systematic review of carbon information disclosure research, we conducted a CiteSpace-based bibliometric and visualization study of the existing research results. We searched the Web of Science (WOS) database for all papers on carbon information disclosure using relevant keywords. Then, we manually screened the papers and obtained 502 valid articles and 2894 references. We studied the major nations, research institutions, journals, authors, and keywords of carbon disclosure research using CiteSpace software and bibliometric methodologies, and we visualized the analysis results of co-authorship, co-occurrence, co-citation, research hotspots and frontiers. The findings indicate that the United States has the most publications, followed by Australia, the United Kingdom and China. Recent years have seen an increase in publications, and several significant research institutions have been established, such as Western Sydney University, University of Newcastle, Macquarie University, Griffith University, etc. Tang Q, Luo L, Freedman M, Zorio-Grima A are among the leading contributors to carbon disclosure publications. "climate change", "disclosure", "performance" and "emission" are the most intense keywords, and "CSR disclosure", "perception" and "corporate social performance" represented the academic frontier. Ans Kolk, Clarkson Peter M., Luo Le, Deegan, Craig, and Patten, Dennis M. are the most cited scholars. *Journal of Business Ethics* is the journal that receives the most citations, followed by *Journal of Cleaner Production* and *Business Strategy and the Environment*. These findings not only give aspiring researchers a foundational understanding of carbon disclosure but also give academics a framework for qualitative and quantitative study, filling the gap between carbon disclosure research

and bibliometric analysis.

Keywords: carbon information disclosure; CiteSpace; bibliometrics; co-authorship analysis, co-occurrence analysis, co-citation analysis

1. INTRODUCTION

Over the past century, the world's usage of fossil fuels including natural gas, oil, and coal has multiplied 20-fold , resulting in massive CO2 emissions(Zhang, YJ et al,2020) .The IPCC's Sixth Assessment Report shows that global average temperatures are anticipated to approach or surpass 1.5°C during the next 20 years due to anthropogenic greenhouse gas emissions , which have led to an approximately 1. 1°C warming between 1850-1900 (IPCC, 2021). Sea levels are increasing as a result of climate change brought on by global warming. Droughts and frequent natural disasters, posing an increasingly serious challenge to human survival and development (IPCC, 2022). Therefore, reducing carbon emissions, achieving low-carbon development and jointly addressing climate change have gradually become a world consensus (Andrew, J et al, (2013). From the Kyoto Protocol to the Paris Agreement, carbon trading has advanced from theory to practice (He, R et al,2022). The development of the global carbon market began with the implementation of the EU Emissions Trading System (ETS) on January 1, 2005(Clarkson, PM et al,2015). And there are 24 active carbon markets globally as of January 31, 2021, according to the International Carbon Action Partnership (ICAP,2022). Carbon markets currently cover 16% of global greenhouse gas emissions, and approximately 54% of the world's GDP comes from carbon markets, which are home to roughly one-third of the world's population (ICAP,2022).

With the flourishing of carbon trading market, carbon information, as a forward-looking environmental information, has become indispensable for carbon trading and carbon management (Borghei, Z, 2021). Carbon information plays a very important role in disclosure, reference and prediction, whether it is for macroeconomic development, investors' decision making or enterprises' internal operation (Tang, QL et al, 2019). Regulations on climate disclosure also continue to emerge, such as the recent UK proposal for required disclosure for net zero transition plans for listed corporations and financial institutions (Gov. UK 2021). Scholars have now focused on carbon information disclosure framework and quality evaluation (e. g. Tang, QL& Luo, L 2014; Blanco, C et al 2016; Karim, AE et al 2021), factors influencing carbon information disclosure (e. g. Stanny, E& Ely, K 2008; Liao, L et al 2015; Ben-Amar, W et al 2017; Tan, DJ et al 2020) and the economic consequences of carbon disclosure (e. g. Matsumura, EM et al 2014; Lee, SY et al 2015; Clarkson, PM et al 2015) etc. However, carbon information disclosure as a brand-new research topic belongs to cross-field research, involving various dimensions such as corporate organization, environmental ecology, social development, and law and politics, and spanning various disciplines such as environmental economics, environmental

management and environmental accounting (Qian, W et al,2017). It is this multidimensional and interdisciplinary nature that has submerged research results on carbon disclosure and its related carbon issues in multiple fields, relatively lacking in framework and systematicity (Borghei, Z, 2021). Therefore, the use of scientometric software is necessary to analyze this area.

On the other hand, a method called knowledge mapping uses many techniques, including data mining, information analysis, scientometrics, and graphical rendering, to graphically portray knowledge about a study field (Chen, C., 2003). Knowledge mapping software such as CiteSpace, VOSviewer, VantagePoint, BibExcel and Copalred are becoming increasingly popular for discovering research priorities and emerging trends in specific research areas (Cobo, M. J., 2011). The most well-known visualization tool among them is CiteSpace, a Java application created by Prof. Chao-Mei Chen of Drexel University in the United States for analyzing and displaying co-citation networks. Several other bibliometric study types, such as co-authorship network analysis, co-occurrence analysis, co-citation analysis, and textual and geographic visualization, also supported by CiteSpace(Chen, C., 2006). CiteSpace has the benefit over other tools in that it can reveal dynamism by taking more than just pictures of specific areas and using time - series data and linkages to infer changes and trends (Fang, Y., 2017). Using knowledge mapping software is beneficial. First, it helps researchers to build a comprehensive understanding of a discipline or research topic. Second, it helps to analyze the path of research development. Third, the software identifies the knowledge base and research frontiers of a discipline. Finally, it helps to predict new trends.

This study aims to explore carbon information disclosure research using CiteSpace to quantify and reveal the lineage of research and academic evolution in the field. More specifically, the following research questions are what we hope to find out.:

Q1: What are the general trends in carbon information disclosure research?

Q2: What are the contributions of different national regions, institutions and authors to the study of carbon information disclosure?

Q3: What are the main research clusters formed by the existing carbon information disclosure literature?

Q4: Which journals, articles and authors are most cited in the knowledge area of carbon disclosure?

Q5: What is the research lineage, academic evolution and emerging trends in carbon information disclosure research?

2. MATERIAL AND METHODS

2. 1 Data Collection

Data collection for a CiteSpace study involves two processes (Chen, C, 2016). The first step is to choose a trustworthy, thorough bibliographic database that offers a large selection of high-quality reference journal articles (Chen, C, 2016). Web of Science (WoS) is a high-quality digital database that has been extensively used by scholars all over the world and has developed into a standard tool for exploring and analyzing various sorts of publications (Thelwall, M., 2008). It contains more than 15, 000 journals and 50, 000, 000 papers, encompassing 251 categories and 150 fields of study (Merigó, J. M., & Yang, J. B., 2017). In addition, WoS can provide users with a relatively comprehensive unified format of academic literature, which includes title, author, institution, country, abstract, keywords, references, citation information sources, impact factor, etc (Gaviria-Marin et al, H.2019). Additionally, the CiteSpace program processes data in a format that is based on the WoS data download standard, so WoS has good compatibility with CiteSpace, which is also advised by CiteSpace as a data resource (Chen, 2015). Therefore, the WoS database was used as the data source for this study.

Another step is to select articles from the database using appropriate keywords. CiteSpace primarily tracks and analyzes the evolution of a subject, therefore tailored topic retrieval is more successful even if WoS offers a variety of combinations of search algorithms (Chen, 2015).The research theme focused on carbon information disclosure, and after a thorough reading of a large amount of relevant literature, the initial search was conducted in July 2022 using the following keywords:TS = ("disclosure*"or"report" or "statement*") and TS = ("carbon dioxide" or "carbon" or "greenhouse gas" or "GHG"or "climate change" or "climate risk" or "global warming"). Selected "Article" and "Review" as the type of literature and collected 502 articles as of December 31, 2021. The earliest eligible literature was published in 2004, so the time span of this study was limited to 2004-2021. The study carefully checked all article titles and abstracts to make sure that all the data was obtained complied with the specifications. After that, the article's data is kept as a "full record and cited references" for subsequent analysis using a "plain text" format.

2. 2 Research Method

A quantitative tool for assessing and summarizing published papers, bibliometric analysis aids in academics' evaluation of scholarly study on a particular research area (Rey-Martí, A. et al,2016). Bibliometric analysis analyse secondary data from a quantitative and unbiased standpoint (Albort-Morant, G. et al,2016). As a result, it can establish a systematic, accountable, and repeatable review process, which in turn improves the reliability and quality of the review (Bellis, N. D., 2009). With the aid of computer technology, bibliometrics research can be carried out graphically and visually (Cobo, M. J.,2011). Knowledge mapping is a more recent advancement in the field of bibliometric analysis and is a cross-disciplinary field of applied mathematics, information science, and computer science. Knowledge map is a series

of graphics showing the relationship between the development process and structure of knowledge, which can express the information of the internet in a form closer to the human cognitive world and then provide a better way to organize, manage, and use massive information (Y. He et al,2020).

CiteSpace 6. 1. R2, a bibliometric tool created by Prof. Chaomei Chen, was used in this work. It was created with scientometrics and knowledge visualization and is used primarily to find prospective information in scientific publications. Researchers may use this program to better comprehend the fundamentals of their subject, locate classic literature in the area, identify new areas of research, and explain the historical background of their field's development (Chen, 2016). CiteSpace converts concepts from research domains into mapping functions between research frontiers and intellectual foundations, and the three ideas developed within the scope of this mapping function notion are crucial to addressing the following three issues: ① research frontier's nature should be identified, ②the study area should be annotated, ③ new trends and mutations should be noted throughout time (G.L. Jia et al,2019). CiteSpace (6. 1. R2) was utilized to visualize the raw data in order to create a visual knowledge map to assess the data in published articles.It offers a number of features to aid in the identification of rapidly expanding subject areas, the discovery of citation hotspots, the clustering of the network, the discovery of geospatial patterns of collaboration , etc. Different sorts of views, including as collaboration network views, clustering views, time zone views, and emergent word views, can be used to build network images in order to assess various information, such as knowledge structure, time span of topics, and trends.More than 15,000 articles have been published using CiteSpace, which has been utilized by people in over 100 different countries(Xinwei Su et al, 2019).

Using the knowledge mapping program CiteSpace, this study examined carbon information disclosure research. The authors, institutions, and national (regional) collaborations were all analyzed for in this study's scientific research cooperation analysis using a bibliometric methodology. Additionally, literature co-citations, author co-citations, and journal co-citations were examined, as well as co-occurrence, clustering and emergence analysis of keywords.This study follows the standard procedure proposed by Chen(2016) for using CiteSpace. This study refers to the flow chart of CiteSpace application research drawn by Youping Teng et al (2022), as shown in Figure 1. The main steps are as follows:The first step is data collection, which will use key terms to identify relevant studies in the source database to obtain data on published papers. The next step is to set the "years per slice" to 1 and the “time slice” to 2004 to 2021. Thirdly, in the "node type" setting, the visual analysis of each of the following is carried out: nation, institution, author, keyword, reference, cited author, and cited journal.

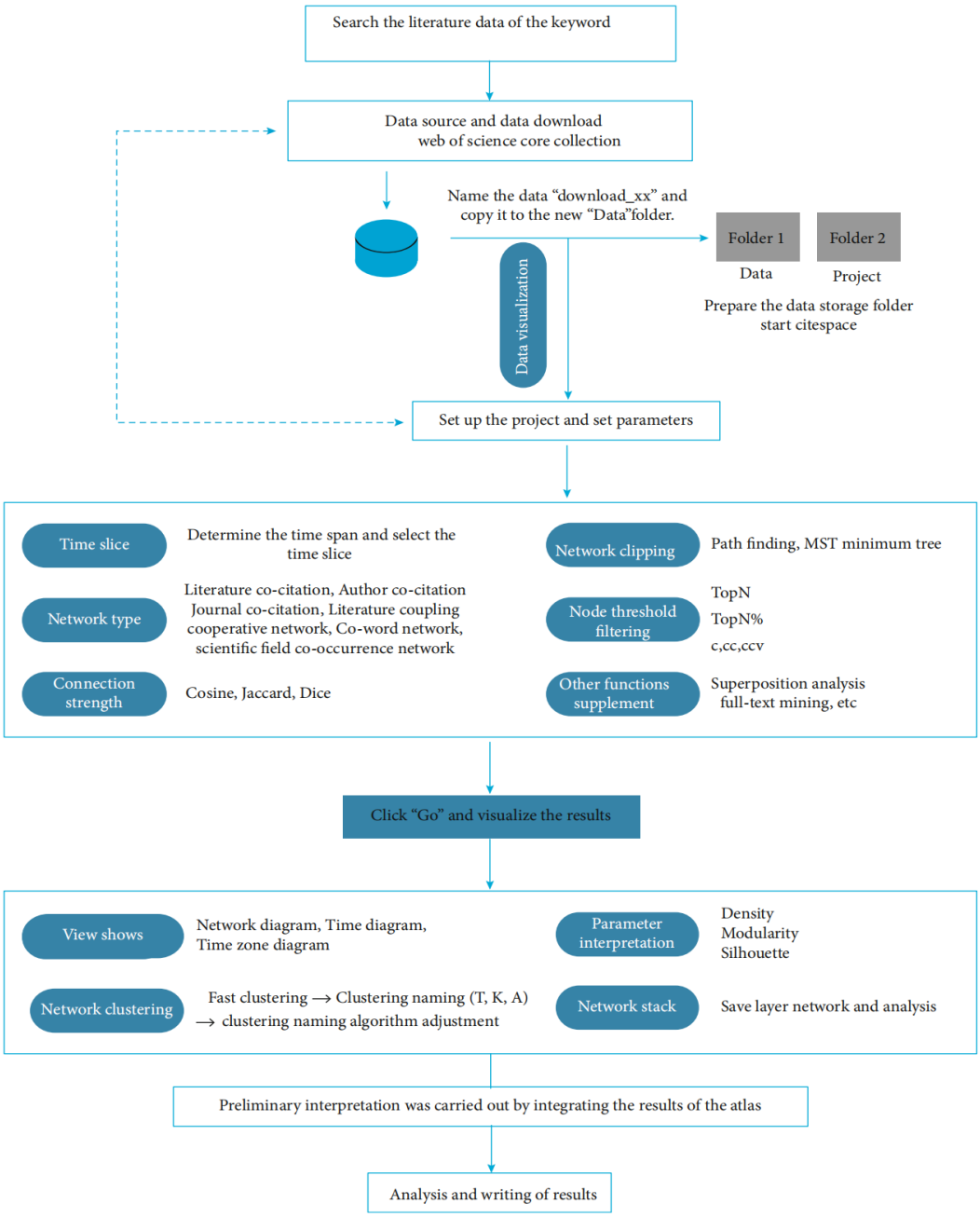

Figure 1:Flow chart of research using CiteSpace applications（Youping Teng et al , 2022）

3. RESULTS AND DISCUSSION

This chapter covers the findings of descriptive statistics and collaborative network analysis on publications, authors, journals, institutions, and nations. And we used CiteSpace's keyword co-occurrence analysis, time zone view feature, keyword clustering analysis and keyword emergence analysis to gain a thorough picture of the evolution of carbon disclosure research. The findings of the co-citation analysis of

cited authors, cited references, and cited journals are also provided in this section.

3. 1 Annual Publishing Trend

The quantity of articles is a crucial factor in determining how well-developed a field is, reflecting the level of research results and activity in a discipline (Feiran W et al ,2022). By analyzing the temporal distribution and cumulative output of papers, we can judge the degree of attention paid to the field by society and academia and reveal academic research and development trends (Xue WZ et al ,2020). The temporal distribution of publications in the area of carbon disclosure research is depicted in Figure 2. We eventually found 502 publications by searching and screening, including 481 articles and 21 reviews. Our search indicated that the paper "Carbon Dioxide Emissions and Disclosures by Electric Utilities" by Freedman, Martin and Jaggi, Bikki , published in 2004, is the earliest carbon disclosure publication in the WoS database. It examines the effectiveness of U. S. electric utilities in reducing CO2 emissions, and also examines whether utilities are making adequate disclosures to reflect their pollution performance and finds evidence supporting a positive correlation between pollution disclosures and pollution emissions. Since then, the research results on carbon disclosure have shown a fluctuating upward trend. The study can also be divided into three phases based on the annual trend of the literature volume: The first stage was from 2004 to 2010, when less than 5 articles were released annually, showing that it was still in its infancy. The beginning of this phase may come from the fact that the Kyoto Protocol, adopted in 1997, has been in force since 2005. The number of articles generated in the following phase varied from 2011 to 2016, with an annual volume of 10 to 22 publications, exceeding that of the phase before it by more than four times. The increase in this period may be due to the impact of the first commitment period of the Kyoto Protocol ending in 2012. In the last phase, from 2017 to 2021, publications show a sharp upward trend, with the number of publications growing from 50 to 126, which represents a boom in this period. It's possible that the Paris Agreement's official implementation as of November 4, 2016, is what brought about this period of prosperity. Based on this analysis, it is evident that disclosure of carbon information is receiving more attention and is presently in a boom phase, but more research is required to fully understand the intricacies of the pertinent studies.

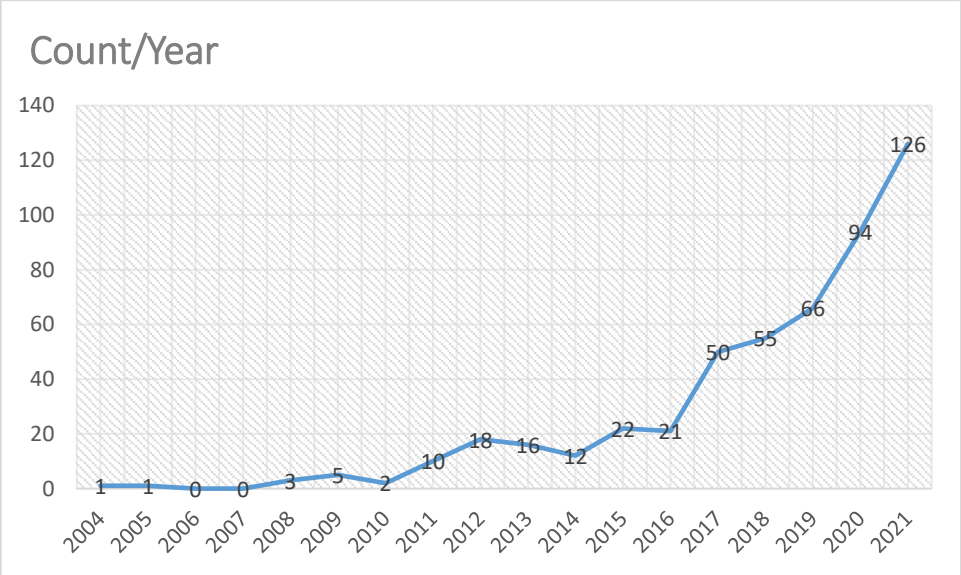

Figure 2 The temporal distribution of publications in CID

3. 2 Analysis of Scientific Research Collaboration

The research group has replaced the individual as the fundamental organizational unit of scientific inquiry, and scientific collaboration has replaced competition as the primary method of scientific investigation (Xinwei Su et al, 2019). The examination of cooperative networks is mostly carried out in scientific metrology research to examine the co-authorship of researchers' scientific and technical accomplishments. Co-authorship is a visible and well-established kind of scientific collaboration at three different levels: individual, institutional, and national, according to Glnzel and Schubert (2005). In actuality, every component of the network of scientific collaboration was recorded by bibliometrics' study of the co-authorship network. As a result, the best scholars in this topic can be found from a variety of perspectives, including authors, institutions, and nations.

3. 2. 1 Co-country (region) network analysis

The number of publications from a given country is a reference to assess its research performance (Chiu, W. T.& Ho, Y. S., 2007). The knowledge map of the country co-authorship network of CID is depicted in Figure 3. We set the "Node Type" to "Country" and the other options to their default values. The number of nodes N is 60, indicating that 60 countries contributed 502 articles in this study to the current research on carbon disclosure, with larger nodes indicating more literature from that country. The top 10 nations by productivity are listed in Table 1, which produce 87. 45% of all articles. According to the data gathered, the US accounts for 17. 93% of all research activity on carbon disclosure, with Australia coming in second accounts for 17. 53%. With 61 and 60 pieces, respectively, the United Kingdom and China came in third and fourth.

Understanding scholarly communication and knowledge diffusion requires

collaborative analysis. The collaboration model was analyzed using CiteSpace, and the inter-node linkage represents the existence of collaborative relationships between nodes. Figure 3 shows that the number of links E is 183, indicating that there are 183 collaborative links with a density of 0. 1034, which shows that the research links between countries are relatively strong. The node's centrality is shown by the ring's thickness; the thicker the ring, the more central the node. Based on Table 1, the highest degree of centralization is found in the United Kingdom (centrality = 0. 39), followed by the United States (centrality = 0. 31), and Australia (centrality = 0. 23).

The study demonstrates that the U. S. leads in both the volume and concentration, demonstrating the country's major research accomplishments and contributions to the area. Even though it is in fourth place in terms of publications, China has a significantly lower centrality than other nations, at just 0. 09. This suggests that China has a role in the field of carbon accounting research, but China's global influence is not as strong as other nations.

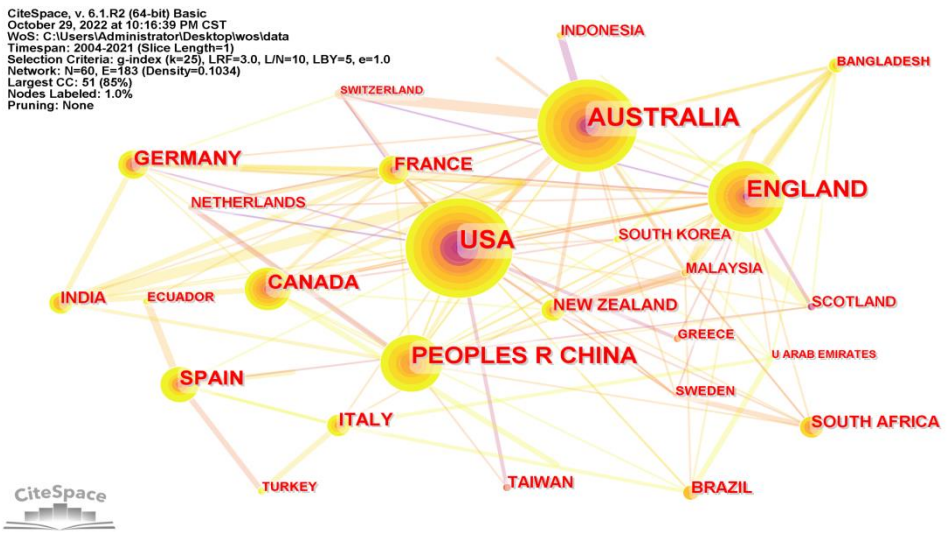

Figure 3 The knowledge map of co-country (region) network of CID

Ranking	Countries	Start year	Counts	Percentage	Centrality
1	USA	2004	90	17. 93%	0. 31
2	AUSTRALIA	2011	88	17. 53%	0. 23
3	ENGLAND	2009	61	12. 15%	0. 39
4	PEOPLES R CHINA	2014	60	11. 95%	0. 09
5	CANADA	2011	32	6. 37%	0. 13
6	SPAIN	2014	26	5. 18%	0. 08
7	GERMANY	2011	24	4. 78%	0. 02

8	FRANCE	2008	23	4. 58%	0. 14
9	ITALY	2015	19	3. 78%	0. 06
10	INDIA	2017	16	3. 19%	0. 01

Table 1 Top 10 productive countries of CID papers

3. 2. 2 Co-institute network analysis

The knowledge map of institution co-authorship network of CID is displayed in Figure 4. As mentioned before, each node represents a separate institution and the number N indicates that 298 research institutions contributed all articles. Table 2 shows the top 10 major institutions. Western Sydney University ranked first with 15 publications, and second was Newcastle University with 11 publications. With 10 and 9 publications, respectively, Macquarie University and Griffith University came in third and fourth place. The number of papers published by the top 10 institutions was 82, accounting for 16. 33% of the total data.

Figure 4 shows the collaborative relationships of research institutions, with 266(E=266) collaborative links in the collaborative network, and the key institutions at the core of the collaboration are Griffith University, University of Valencia, Towson University, Swinburne University of Technology and Hunan University of Commerce, among others. However, the density is only 0. 008, indicating a weak strength of collaboration.

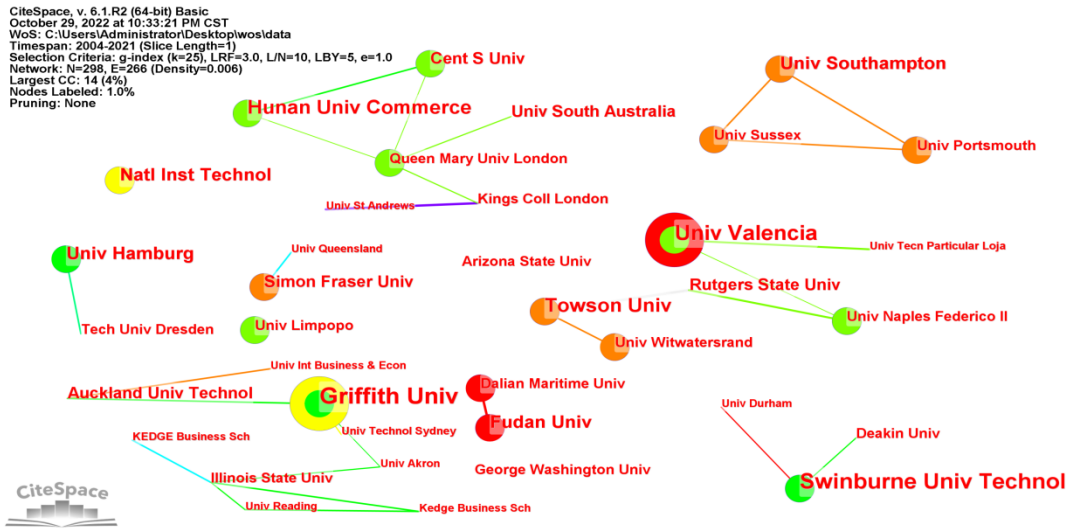

Figure 4 The knowledge map of Co-institute network of CID

Ranking	Institutions	Start Year	Counts
1	Western Sydney University	2018	15
2	Newcastle University	2014	11
3	Macquarie University	2018	10
4	Griffith University	2013	9
5	Swinburne University of Technology	2016	8

6	University of Valencia	2018	7
7	Towson University	2004	6
8	Hunan University of Commerce	2017	6
9	Georgia Institute of Technology	2012	5
10	Natl Institute of Technology	2018	5

Table 2 Top 10 productive institutions of CID papers

3. 2. 3 Co-author network analysis

Co-author analysis is a prerequisite to grasp the research areas and research trends in a particular discipline (Bellis, N. D., 2009). As shown in Figure 5, the node N is 323, indicating that 323 authors contributed 502 articles in this field. Table 3 provides a list of the top 10 most active authors, with Tang, Q ranking first with 15 publications and Luo, L second with 11 publications. Both Freedman, M and Zorio-Grima A tied for third place with 6 publications.

Figure 5 shows the author's collaborations, where there are 224(E=224) collaborative links in the collaborative network, generating many closed-loop loops. The larger the circles, which correspond to the number of publications by the writers. The closer together the circles are, the more collaboration between authors is indicated. Circles of the same color represent the same group of authors. It is clear that the strongest collaboration exists in the entire collaborative network with several core authors such as Luo, L, Tang, Q, Freedman, M and Zorio-Grima . However, the density is only 0. 0043, indicating the weak strength of collaboration among authors.

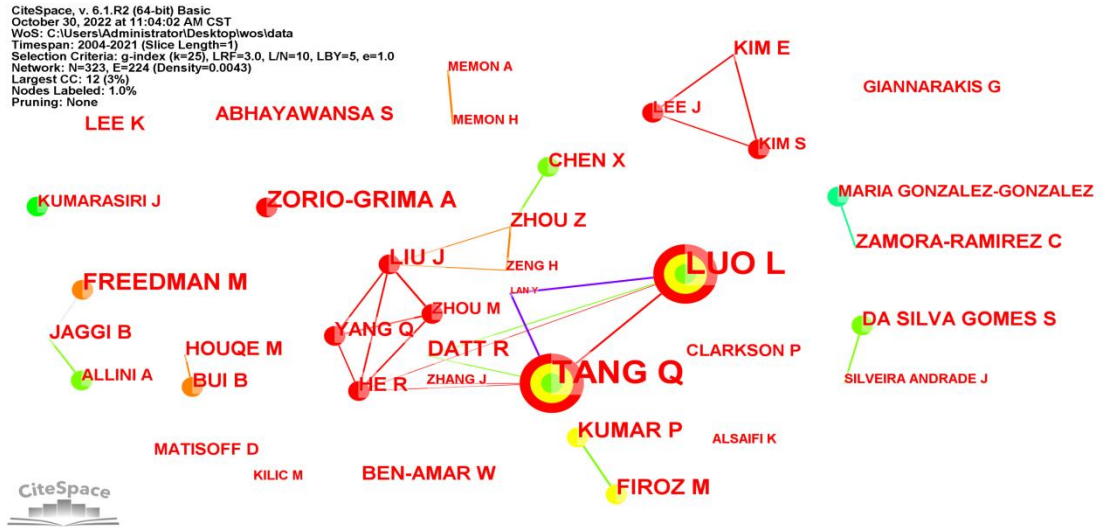

Figure 5 Knowledge map of co-author network of CID

Ranking	Authors	Start Year	Counts
1	TANG Q	2012	15
2	LUO L	2012	14
3	FREEDMAN M	2004	6

4	ZORIO-GRIMA A	2018	6
5	KUMAR P	2018	5
6	LIU J	2020	5
7	DATT R	2018	5
8	FIROZ M	2018	5
9	KIM E	2011	4
10	BEN-AMAR W	2015	4

Table 3 Top 10 prolific authors of CID papers

3. 3 Co-citation Analysis

Henry Small (1973) proposed a study of literature's co-citations. The fundamental idea behind co-citation is to count all the times a piece of writing, including magazines, documents, and authors, are cited together to determine how similar two pieces of writing are to one another. McCain, K. W. (1991) asserts that two literature are co-cited when they are referenced together in subsequent publications. Because the co-citation patterns that have been seen over time can provide us hints about how professional development works, it is useful to map the structure of scientific knowledge (Fang, Y. et al, 2017). The most cited literature, authors, and journals are also listed in this section along with the literary co-citation network, author co-citation network, and journal co-citation network.

3. 3. 1 Literature co-citation analysis

In Bibliometrics, the frontier of the research field represents the current development of a discipline, and the references in the frontier articles constitute the knowledge base of the field (Liang, C. et al, 2018). CiteSpace summarizes the co-citation relationship between documents according to nodes and lines and generates a co-citation network. The network is composed of nodes representing documents (Chen, C., 2017). If two documents are cited together in another paper, the two nodes are connected by lines. In the CiteSpace analysis tool, we choose the "reference" parameter to get the co-cited literature knowledge map of carbon information disclosure. As shown in FIG. 6, it is composed of 737 nodes and 2900 lines, with a density of 0. 0107. Table 4 shows the top 10 citations by count, with more than 38 citations per article. The columns included in the table include citation times, centrality, first author, publication year and journal information. The most frequently cited reference is Qian, W & Schaltegger, S, published on the *British Accounting Review* in 2017, with a total of 66 times.

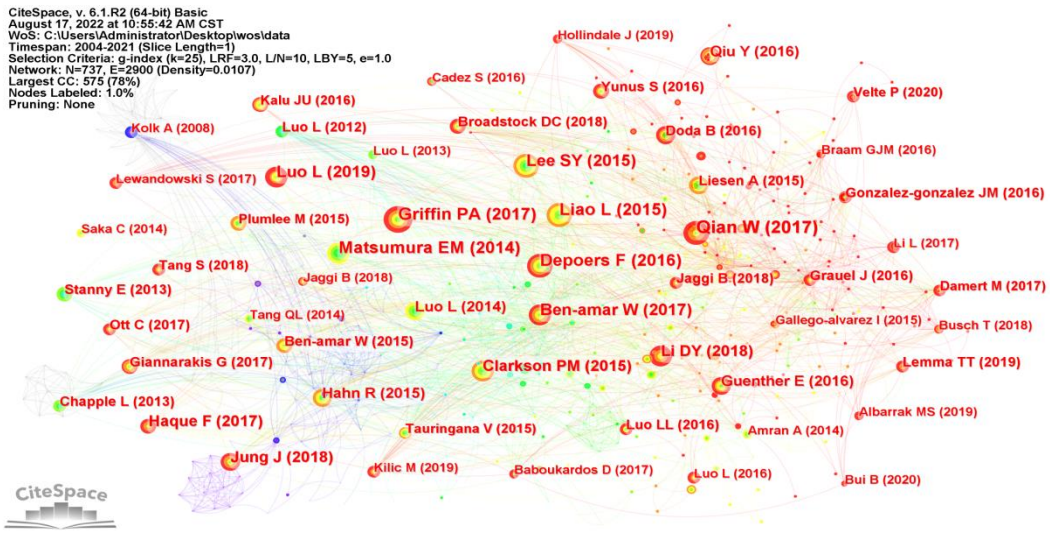

Figure 6 The knowledge map of the literature co-citation network of CID

Rank	Documents	Year	Counts	Source Journals	Authors	Main contents
1	Qian W, 2017, BRIT ACCOUNT REV, V49, P365, DOI 10. 1016/j. bar. 2017. 05. 005	2017	66	《BRITISH ACCOUNTING REVIEW》	Qian, W ; Schaltegger, S	The subsequent change in carbon performance is positively correlated with the change in carbon disclosure. The relationship in high energy intensive enterprises is relatively weak.
2	Griffin PA, 2017, CONTEMP ACCOUNT RES, V34, P1265, DOI 10. 1111/1911-3846. 12298	2017	55	《CONTEMPORARY ACCOUNTING RESEARCH》	Griffin, PA; Lont, DH; Sun, EY	An estimation model that takes into account firm characteristics and industries calculates the GHG emissions of non-polluters, and the GHG emissions are what lead to the implied equity discount in the market.
3	Matsumura EM, 2014, ACCOUNT REV, V89, P695, DOI 10. 2308/accr-50629	2014	54	《ACCOUNTING REVIEW》	Matsumura, EM; Prakash, R; Vera-Munoz, SC	The value of the company is negatively impacted by carbon emissions and voluntary disclosure of carbon emissions. The market penalizes all companies for carbon emissions but imposes further penalties on companies that do not disclose emission information.

4	Liao L, 2015, BRIT ACCOUNT REV, V47, P409, DOI 10. 1016/j. bar. 2014. 01. 002	2015	54	《BRITISH ACCOUNTING REVIEW》	Liao, L; Luo, L; Tang, QL	The inclination and scope of GHG information sharing are significantly positively correlated with gender diversity. The board with more independent directors or environmental committees is more inclined to ecological transparency.
5	Depoers F, 2016, J BUS ETHICS, V134, P445, DOI 10. 1007/s10551-014-2432-0	2016	53	《JOURNAL OF BUSINESS ETHICS》	Depoers, F; Jeanjean, T; Jerome, T	GHG emissions are far lower in the corporate report (CR) than they are in the CDP. and when there is difference in information disclosure between the two channels, the enterprise will increase the traceability of corporate responsibility data.
6	Luo L, 2019, ACCOUNT FINANC, V59, P1235, DOI 10. 1111/acfi. 12267	2019	46	《ACCOUNTING AND FINANCE》	Luo, L	Voluntary carbon disclosure has a negative relationship with carbon emission performance, and institutional context is a regulatory factor.
7	Lee SY, 2015, CORP SOC RESP ENV MA, V22, P1, DOI 10. 1002/csr. 1321	2015	45	《CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT》	Lee, SY; Park, YS; Klassen, RD	When businesses disclose their carbon emissions, the market might respond unfavorably. but enterprises can mitigate the negative market impact by regularly releasing carbon information through the media.
8	Ben-amar W, 2017, J BUS ETHICS, V142, P369, DOI 10. 1007/s10551-015-2759-1	2017	44	《JOURNAL OF BUSINESS ETHICS》	Ben-Amar, W; Chang, M; McIlkenny, P	The likelihood of voluntarily disclosing climate change increases as the percentage of women on the board rises.
9	Clarkson PM, 2015, EUR ACCOUNT REV, V24, P551, DOI 10. 1080/09638180. 2014. 927782	2015	40	《EUROPEAN ACCOUNTING REVIEW》	Clarkson, PM; Li, Y; Pinnuck, M; Richardson, GD	The carbon emission quota of an enterprise has nothing to do with enterprise valuation but is negatively related to insufficient allocation.

10	Jung J, 2018, J BUS ETHICS, V150, P1151, DOI 10.1007/s10551-016-3207-6	2018	38	《JOURNAL OF BUSINESS ETHICS》	Jung, J; Herbohn, K; Clarkson, P	For enterprises that fail to respond to CDP, there is a positive correlation between debt cost and carbon risk.

Table 4 Top 10 co-cited documents of CID

By analyzing the high-frequency cited literature, we found that the key theories on the disclosure of carbon information are the legitimacy theory, institutional theory, stakeholder theory, and signaling theory. To determine the driving force behind disclosure, researchers examine the link between carbon performance and disclosure quality using the signaling theory and legitimacy theory. For instance, Clarkson et al. (2015) contend that companies with higher carbon performance deliberately disseminate positive signals and high-quality information to minimize concerns with adverse selection. High-quality carbon information disclosure is a tactic to increase organizational legitimacy, as shown by Ben-Amar et al (2017). The whole framework of variables impacting carbon information disclosure quality, including demand from stakeholders like the government, is built using system theory and stakeholder theory.

3. 3. 2 Author co-citation analysis

We may learn more about significant academics and their disciplines by using the author's co-citation analysis. To get the author co-citation network knowledge map, we choose the "author" option in the CiteSpace analysis tool. As seen in FIG. 7, there are 595 high cited authors and 3842 network lines. The larger the node on the chart, the higher the reference frequency. We evaluated the writers based on their frequency and centrality of citations. According to Table 5, Ans Kolk、Clarkson, Peter M. 、Luo, Le、Deegan, Craig、Patten, Dennis M. were cited more frequently. This suggests that the findings of their research have had a significant influence on this field. These most often referenced writers are involved in research on carbon information disclosure from several scientific vantage points: An Kolk is a full-time professor at the University of Amsterdam's Amsterdam Business School in the Netherlands. Her professional fields are corporate social responsibility, sustainable development and sustainable development, especially those related to international business. Clarkson, Peter M. is a professor at the University of Queensland's Business School. His main research contents include issues related to voluntary disclosure, corporate performance and valuation, and the economic impact of environmental performance. Luo, Le from Macquarie University is mainly engaged in enterprise sustainable development, carbon disclosure and carbon management. Deegan, Craig REGg is a professor of University of Tasmania. His research interests are social and environmental responsibility and accounting, financial accounting and financial

accounting theory. Dennis M. is from Illinois State University. His main research fields are accounting, environmental disclosure, public policy, legitimacy and legitimacy theory. However, the centrality score showed slightly different results: CDP, Ans Kolk、Stanny, Elizabeth、Patten, Dennis M. 、Bebbington, Jan were the top five authors with the highest centrality, showing that they were bridging various co-author networks. We may better understand the significant researchers in carbon information disclosure and related fields by using the tracking analysis of important researchers mentioned above.

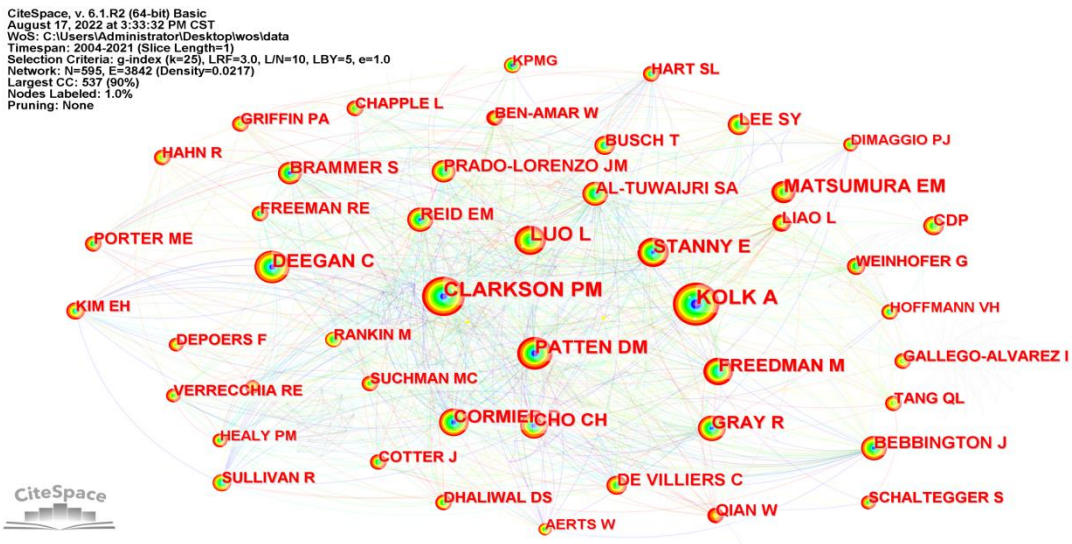

Figure 7 The knowledge map of the author co-citation network of CID

Rank	Authors	Start Year	Counts	Centrality
1	KOLK A	2011	195	0. 09
2	CLARKSON PM	2008	191	0. 05
3	LUO L	2015	150	0. 02
4	DEEGAN C	2011	126	0. 04
5	PATTEN DM	2004	123	0. 08
6	MATSUMURA EM	2016	118	0. 01
7	STANNY E	2012	117	0. 09
8	GRAY R	2011	107	0. 04
9	FREEDMAN M	2004	107	0. 03
10	CORMIER D	2008	100	0. 04

Table 5 Top 10 cited authors of CID

3. 3. 3 Journal co-citation analysis

The journal co-citation analysis can assist us in determining the journal's contribution and identifying journals to which we should submit our works (X. Li, &H. Li.,2018). To get the journal co-citation network map, we choose the "Journal" option in the CiteSpace . Journals are represented by nodes in Figure 8, and linkages between nodes indicate the co-citation relationship between two journals. A total of 585 highly cited journals and 3574 network lines were extracted from CiteSpace journal citation analysis. The size of nodes reflects their significance, while the distance between nodes reflects how frequently journals are cited. The top 10 journals for carbon disclosure research papers are shown in Table 6. With 287 papers, *Journal of Business Ethics* is the journal that has received the most citations, followed by *Business Strategy and the Environment*(275 papers), *Journal Of Cleaner Production*(274 papers), *Acounting Organisations and Societies*(257 papers), *Accounting Auditing & Accountability Journal*(231 papers), *European Accounting Review*(228 papers), *Corporate Social Responsibility and Environmental Management*(218 papers), *Accounting Review* (203 papers), *Strategic Management Journal*(194 papers) and *British Accounting Review*(190 papers). The ten journals listed above can serve as reliable sources for research on carbon information disclosure. From the centrality value, the centrality value of *Corporate Governance - International Review*（0. 13）、*Aacademy of Management Journal*（0. 1）and *Global Environmental Politics*（0. 1）are higher than 0. 1, indicating that these three journals play a greater role. From the perspective of the research fields, carbon information disclosure study is closely connected to management science, accounting science, environmental science and other research fields. Additionally, there are three journals with an impact factor of at least 10: *Journal of Cleaner Production* (11. 016), *Strategic Management Journal* (12. 247), and *Business Strategy and the Environment* (11. 604). Such a high impact factor suggests that the topic of carbon information has a significant number of key journals.

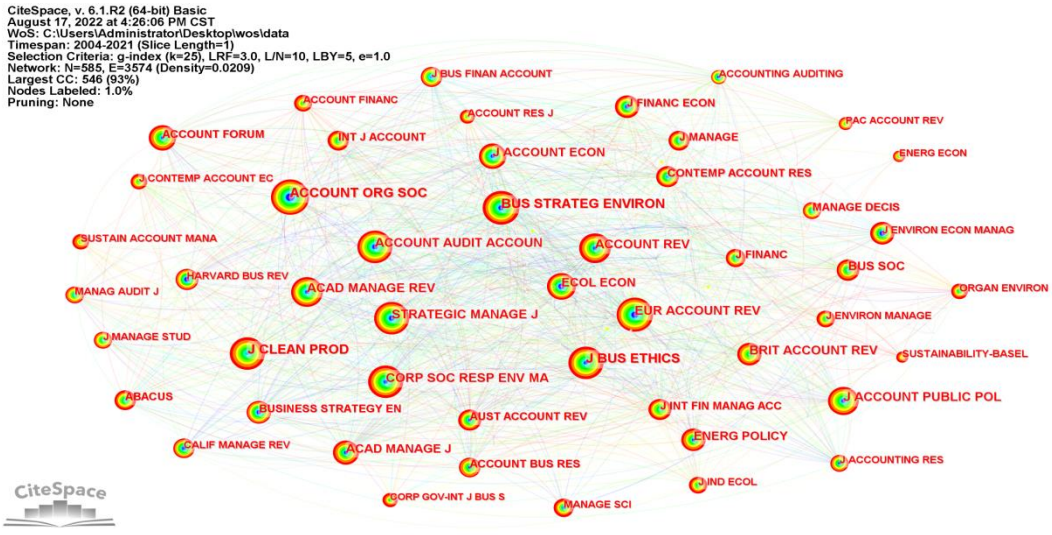

Figure 8 The knowledge map of the journal co-citation network of CID

Rank	Cited Journals	Start Year	Counts	Centrality	IF
1	JOURNAL OF BUSINESS ETHICS	2011	287	0. 02	8. 086
2	BUSINESS STRATEGY & ENVIRONMENT	2010	275	0. 03	11. 604
3	JOURNAL OF CLEANER PRODUCTION	2012	274	0. 03	11. 016
4	ACCOUNTING ORGANIZATIONS AND SOCIETY	2004	257	0. 03	5. 688
5	ACCOUNTING AUDITING & ACCOUNTABILITY JOURNAL	2004	231	0. 04	5. 701
6	EUROPEAN ACCOUNTING REVIEW	2008	228	0. 01	3. 433
7	CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT	2008	218	0. 02	8. 796
8	ACCOUNTING REVIEW	2009	203	0. 02	7. 818
9	STRATEGIC MANAGEMENT JOURNAL	2009	194	0. 02	12. 247
10	BRITISH ACCOUNTING REVIEW	2012	190	0. 01	6. 684

Table 6 Top 10 high frequency cited journals

3. 4 Keywords Network Analysis

3. 4. 1 Co-occurrence of keywords

Analyzing the co-occurrence of keywords is a useful technique for identifying the structure of scientific knowledge, identifying new trends, and tracking research subjects (Chen, Cribbin, Macredie, & Morar, 2002). Keywords give a clear, high-level overview of a document, which can aid scholars in understanding the evolution of a certain study subject. The CiteSpace-based keyword co-occurrence analysis consists mostly of the following two steps: Extraction of keywords is followed by classification, separation, and frequency calculation (Chen, Dubin, & Kim, 2014). A keyword co-occurrence matrix can also be obtained.

Figure 9 depicts the keyword map of carbon information disclosure research from 2004 to 2021. There are 378 keyword nodes and 2379 connecting lines. Key nodes are those that appear frequently and have a high degree of centrality in the co-occurrence analysis, indicating that they have a significant impact on the network. The top 10 keywords in terms of frequency and centrality are listed in Table 7. The node “climate change” has the highest frequency, and this keyword appears 165 times. And its centrality is also high, with a center value of 0. 1. The second and third places in frequency are “disclosure” and “performance”, with centrality of 0. 11 and 0. 06 respectively, followed by “corporate social responsibility”, “anagement”,

"legitimacy", "determinant", "environmental performance", "emission"and"impact". The keyword "emission" ranked ninth in frequency has the highest centrality, with a central value of 0. 17.

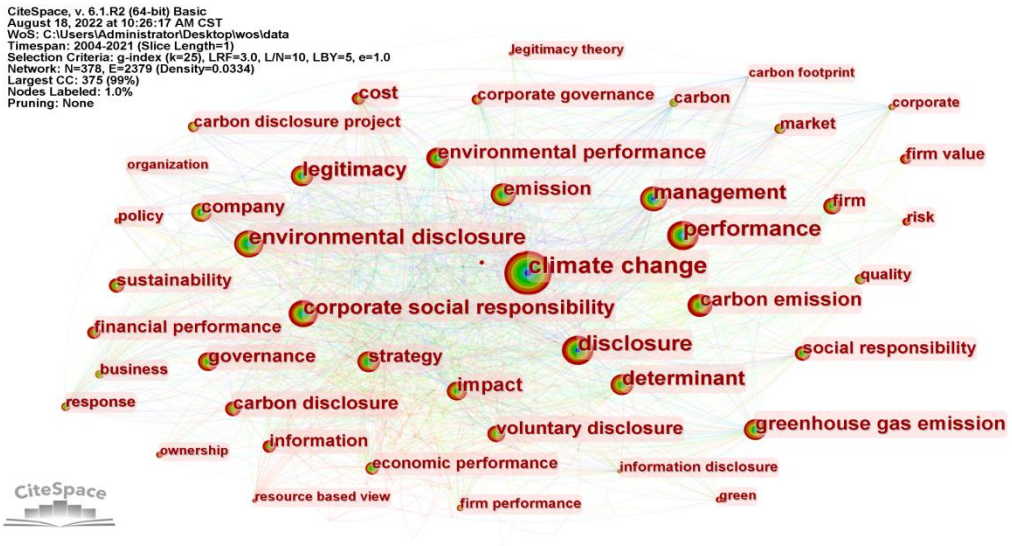

Figure 9 The knowledge map of the keywords co-occurrence network of CID

Rank	Keywords	Start Year	Counts	Centrality
1	climate change	2008	165	0. 1
2	disclosure	2009	96	0. 11
3	performance	2008	94	0. 06
4	corporate social responsibility	2009	85	0. 06
5	management	2009	74	0. 08
6	legitimacy	2009	73	0. 09
7	determinant	2011	72	0. 07
8	environmental performance	2009	69	0. 05
9	emission	2009	66	0. 17
10	impact	2011	62	0. 05

Table 7 Top 10 keywords in terms of frequency and centrality

3. 4. 2 Keywords time zone map analysis

According to the frequency and year of keyword occurrence, we can understand the research hotspot and its occurrence time and duration (Yuzhen Li et al,2022). The time of occurrence of hot spots reflects the change of research focus (Liang, C. et al, 2018). In order to further explore the evolution path of the research direction, CiteSpace is visualized as the "time zone map" in the control panel, which shows the keywords that appear with the passage of time. Figure 10 shows that the research boom related to the publication of carbon information started in early 2008 and was

the subject of study in the years that followed. The years 2008 and 2009 had a lot of keyword activity. The primary subject of these research is “climate change”, “performance”, “corporate social responsibility”, “environmental disclosure”, “management” etc. From 2011 to 2013, “governance”, “decision”, “greenhouse gas emission”, “impact”, “Carbon Disclosure Project”, “policy” and other aspects have become research hotspots. Since 2015, the number of keywords has started to decrease, and the main research topics are “strategy”, “carbon emission”, “sustainability”, “risk”, “firm value”, etc., which indicates that the study of carbon information disclosure has progressively reached a steady stage following a period of tremendous development.

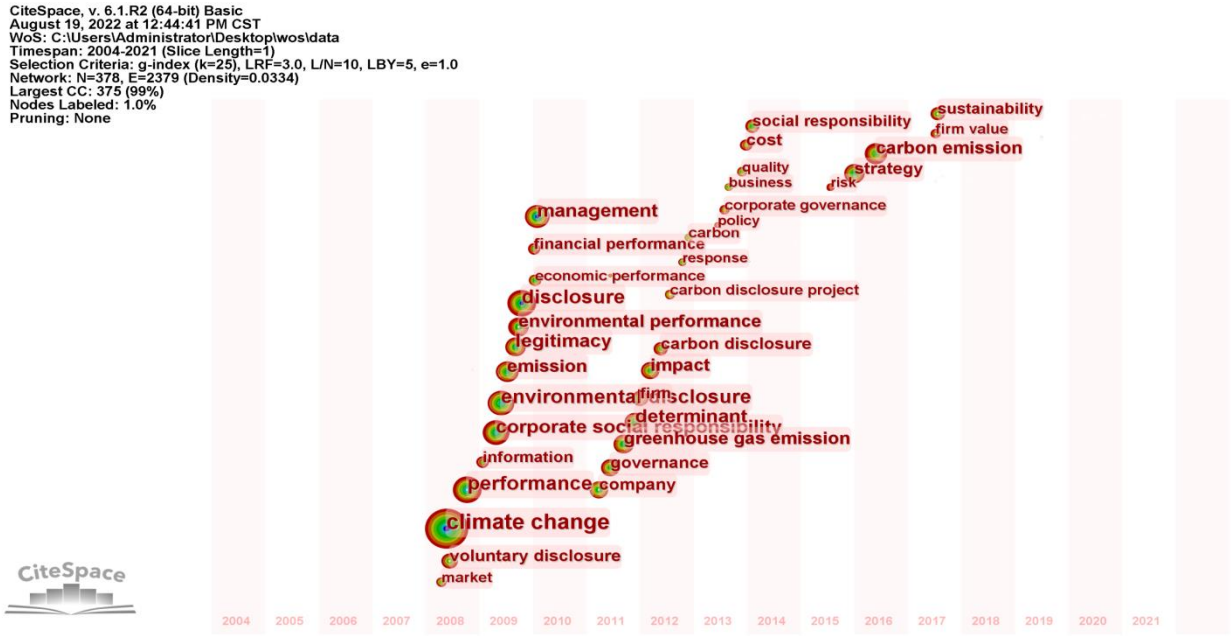

Figure 10 The knowledge map of the keywords time zone of CID

3. 4. 3 Keywords clustering Analysis

Clustering is the division of a collection of tangible or intangible items into several groupings. A cluster's elements are very similar to one another, whereas other clusters' elements are highly diverse from one another (Chen, 2003). Clustering tags in CiteSpace are taken from the referenced literature and can be found in the title, index, or abstract of the cited literature (Chen, 2015). Keyword clustering analysis is based on the keyword co-occurrence analysis through the method of clustering statistics, which simplifies the network relationship of keyword co-occurrence into clustering. The log likelihood ratio algorithm (LLR) can automatically identify each cluster and help users quickly and comprehensively understand the hot spots and

evolution of research content (Chenet al., 2015). Compared with the keyword co-occurrence graph, clustering focuses more on reflecting the structural characteristics, highlighting the important relationship between key points and clustering. Fig.11 is a thematic clustering map of keywords obtained by clustering documents using the log likelihood ratio algorithm (LLR).Fig.12 is the knowledge map of the keywords clustering time line. The reliability of the clustering structure is significant because the cluster Q value (module value) is 0. 4093, which is more than 0. 3. The siloette's value (average contour value) is 0. 7483, which is greater than 0. 7, indicating that the cluster has sufficient similarity and reliability. Cluster naming is extracted from keywords, clusters with enough nodes are screened, and duplicate items are deleted. A total of 7 topics are obtained. There are 7 clusters in Table 8, representing 7 research hotspots in carbon information disclosure research. The label words identified by the LLR algorithm in each cluster in Table 5 are displayed in the order of high to low. The highest scored tag word with a greater LLR among these terms in each cluster serves as the cluster's representative. The homogeneity inside the cluster is measured using the degree of clustering silhouette. Higher homogeneity values are closer to 1, but their dependability is diminished if the cluster has fewer members. Data were arbitrarily chosen in representative clusters as instructive instances in order to better understand the clustering results.

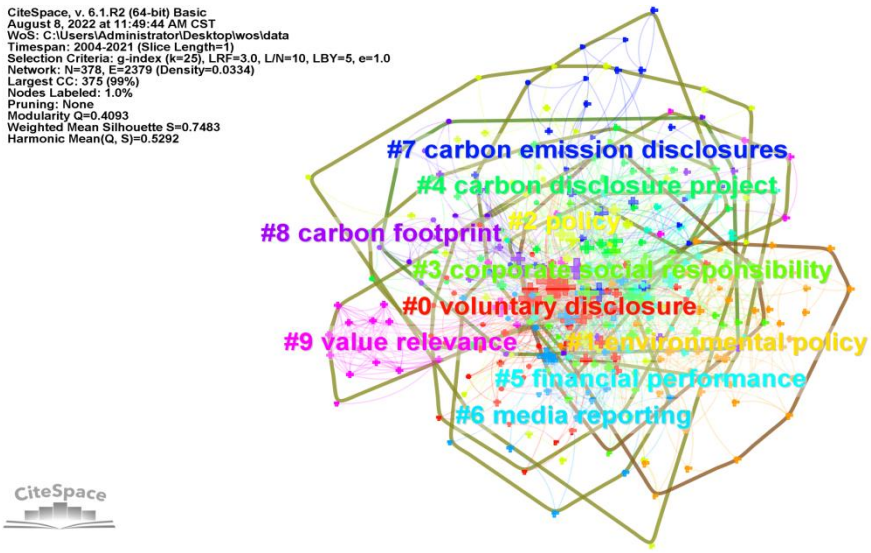

Figure 11 The knowledge map of the keywords clustering of CID

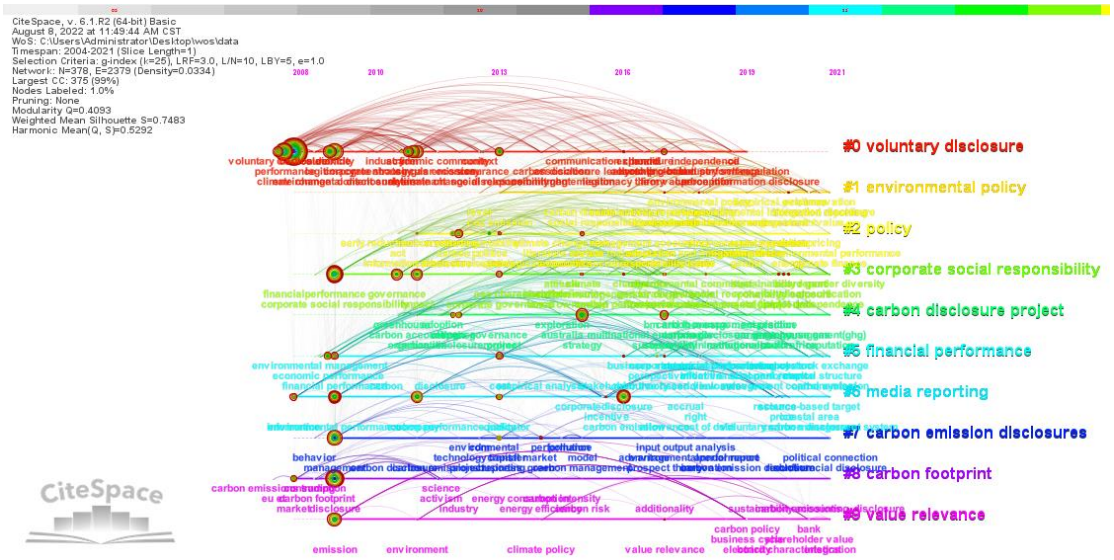

Figure 12 The knowledge map of the keywords clustering time line of CID

Cluster	Size	Silhouette	Representative keywords within clusters	Average Year
#0 voluntary disclosure	57	0. 691	voluntary disclosure (14. 25, 0. 001); legitimacy theory (11. 13, 0. 001); content analysis (8. 18, 0. 005); corporate strategy (6. 23, 0. 05); gri (6. 23, 0. 05)	2012
#2 policy	44	0. 738	policy (13. 78, 0. 001); politics (9. 18, 0. 005); asset pricing (9. 18, 0. 005); carbon (6. 1, 0. 05); information disclosure (5. 57, 0. 05)	2015
#3 corporate social responsibility	44	0. 653	corporate social responsibility (16. 77, 1. 0E-4); gender diversity (9. 08, 0. 005); firm performance (9. 08, 0. 005); governance (8. 97, 0. 005); corporate governance (8. 91, 0. 005)	2017
#5 financial performance	37	0. 758	financial performance (14. 08, 0. 001); istanbul stock exchange (10. 04, 0. 005); capital structure (10. 04, 0. 005); stakeholder theory (5. 33, 0. 05); climate change (5. 13, 0. 05)	2017

#7 carbon emission disclosures	29	0. 748	carbon emission disclosures (10. 2, 0. 005); carbon management (7. 15, 0. 01); carbon disclosure project (6. 55, 0. 05); environmental strategy (6. 55, 0. 05); event study (6. 55, 0. 05)	2015
#8 carbon footprint	27	0. 852	carbon footprint (20. 5, 1. 0E-4); energy efficiency (9. 95, 0. 005); sustainability accounting (6. 3, 0. 05); law and economics (4. 97, 0. 05); market price fundamentals (4. 97, 0. 05)	2011
#9 value relevance	23	0. 922	value relevance (23. 62, 1. 0E-4); climate policy (19. 49, 1. 0E-4); monetary stances (12. 16, 0. 001); fiscal redesign (12. 16, 0. 001); resource and conservation (12. 16, 0. 001)	2018

Table 8 keywords clustering table

Cluster # 0 is marked as “voluntary disclosure”. In terms of size, cluster # 0 is the largest, with a size of 57 and an average year of 2012. The silhouette value is 0. 691, which is near to 0. 7, it shows that the cluster has similarity and reliability. The highly cited papers in this cluster are briefly introduced below. Liao, L; L; Luo; and Q. Tang (2015) found that there are more independent directors, gender diversity, and the Environmental Committee's board is more inclined to voluntarily disclosure greenhouse gas information. The value of the company is negatively impacted by carbon emissions and voluntary disclosure of carbon emissions were found by Matsumura, E; R, Prakash (2014). According to Stanny, E. and K. Ely's 2008 research, a company's size, prior disclosures, and overseas sales all had an impact on whether it released the climate change data through the Carbon Disclosure Project. The consistency of GHG data voluntarily released by French listed firms using two distinct communication channels was researched by Depoers, F, Jeanjean, and T. Jerome in 2016. Siddique, M.; M. Akhtaruzzaman; A. Rashid; and H. Hammami (2021) found that carbon voluntary disclosure has a favorable impact on carbon performance, supporting the signal idea.

Cluster # 2 is marked as “policy”. The size of cluster # 2 is 44, and the average year is 2015. The silhouette value is 0. 738, greater than 0. 7, indicating that the cluster has sufficient similarity and reliability. Next, the high cited papers in this group are briefly introduced. Bento, N； G, Gianfrate（2020）shows that the comprehensive national program depends on national climate policy, national development, industry and corporate governance to a large extent. In addition, the uncertainty of national climate policy hinders carbon pricing in business. Andrew, J. ; C. Cortese(2013) explored the influence of neoliberalism on the development of global environmental regulation using the work of political geographers and political economists as a reference and believed that climate disclosure practices and regulation offered an opportunity to strengthen the ideological landscape of

neoliberalism. Nordenstam , L； D, Ilic；L, Odlund（2018）analyzed how enterprise standards and the EU framework can stimulate decisions on purchasing electricity and district heating, as well as decisions on cogeneration.

Cluster # 3 is marked as “corporate social responsibility”. The scale of cluster # 3 is 44, and the average year is 2017. The silhouette value is 0. 653, close to 0. 7, indicating that the cluster has a certain degree of similarity and reliability. The publications in this cluster that have received a lot of citations are briefly described below. Environmental legitimacy has a strong detrimental impact on an enterprise's ability to disclose carbon information, according to study by Li, D., et al.According to Calza, F;G, Profumo;I, Tutore (2016)the enterprises with a high proportion of state-owned enterprises show a high green initiative, and the ownership concentration seems to be negatively related to the positive environmental strategy. Yunus, S; Elijido-Ten, E; Abhayawansa,S(2016)demonstrates the critical roles internal organizational elements and corporate governance characteristics have in upholding organizational legitimacy (CMS).

Cluster # 5 is marked as “financial performance”. The scale of cluster # 5 is 37, and the average year is 2017. The silhouette value is 0. 758, greater than 0. 7, indicating that the cluster has sufficient similarity and reliability. The highly cited papers in this cluster are briefly introduced below. Financial performance is designated as cluster number 5. The average year is 2017, and cluster number five has a scale of 37. With a silhouette value of 0. 758, which is higher than 0. 7, the cluster is considered reliable and comparable enough. The publications in this cluster that have received a lot of citations are briefly described below. According to Gallego-Alvarez, I; Garcia-Sanchez, IM; Vieira (2014), there is a stronger correlation between environmental factors and financial performance during economic downturns. The link and causes between company economic performance, environmental information disclosure, and greenhouse gas emissions were explored by Hassan, OAG; Romilly, P (2018). As a result, improved economic performance and decreased emissions are strongly associated.

Cluster # 7 is labeled “carbon emission disclosures”. The scale of cluster # 7 is 29, and the average year is 2015. The silhouette value is 0. 748, greater than 0. 7, indicating that the cluster has sufficient similarity and reliability. Next, the high cited papers in this group are briefly introduced. According to Kilic, M; Kuzey, C (2019), the degree and tendency of disclosure of carbon emissions are significantly influenced positively by the diversity of countries represented on the board of directors and the establishment of the sustainable development committee. Kurnia, P; Darlis, E; Putra, AA（2020）shows that carbon emission information disclosure and good corporate governance have no direct impact on corporate value. According to Hardiyansah, M; Agustini, AT; Purnamawati, I's research (2021), the enterprise value is positively and significantly impacted by the disclosures of carbon emission information. Because the carbon emission information disclosure is a concern of the enterprise for the environment, which has received a positive response from the

market and has become the basis for investors to evaluate the sustainability of the company.

Cluster # 8 is labeled as “carbon footprint”. The size of cluster # 8 is 27, and the average year is 2011. The silhouette value is 0. 852, greater than 0. 7, indicating that the cluster has sufficient similarity and reliability. The following is a brief introduction to the highly cited papers in this cluster.Hrasky, S（2012）show that the footprint related disclosure rate of large Australian listed companies is increasing, and the signal of disclosure is more and more obvious. Nansai, K; Kagawa, S; Kondo, Y; Suh, S; Inaba, R; Nakajima, K (2009) using a global linked input-output model that took into account 804 economic sectors in Japan and 230 other nations and regions. A technique to include the three ranges of carbon footprint into the data envelopment analysis model to assess environmental performance was created by Chang, DS; Yeh, LT; Liu, WR (2015). MAHAPATRA, S； T, SCHOENHERR； J, JAYARAM（2021）conducted an inductive analysis using second-hand data collected from CDP to understand the role of non-financial companies in the global top 500 in reducing their carbon footprint.

Cluster # 9 is marked as “value correlation”. The size of cluster # 2 is 23, and the average year is 2018. The silhouette value is 0. 922, which is much higher than 0. 7, demonstrating the excellent similarity and dependability of the cluster. The following is a brief introduction to the highly cited papers in this group. Baboukardos, D（2017）rovided evidence to illustrate the potential benefits of mandatory environmental reporting on the market valuation of listed companies. The research of Liesen, A; Hoepner, AG; Patten, DM; Figge, F (2017) shows that the quantitative GHG emissions and carbon performance disclosed by the company are related to company value. Mandatory and standardized carbon emission performance information can not only improve market efficiency, but also improve capital allocation in the real economy. According to Jiang, Y; Luo, L; Xu, JF; Shao, XR(2021), the value of the corporation increases when more carbon information is released. In developing countries, the positive correlation between company value and voluntary carbon disclosure is stronger.

3. 4. 4 Keywords burst analysis

The identification of burst keywords can study the frontier dynamics and development trend of a field, as well as the time change and dynamic distribution of word frequency (E. Zhu, Q. Qi, and M. Sha,2021). When a keyword quickly rises in popularity, it means that within a short period of time, study interest in that area has unexpectedly increased (Youping Teng et al). Burst keyword analysis is better suited for examining the newly developing theme of discipline development than the prior keyword analysis (Chen, 2015). To use CiteSpace based on keyword co-occurrence, choose standalone refresh and view under burstness in the control panel. Figure 13's created keyword burst displays 18 burst words from 2004 through 2021 along with their intensities, start and finish times, and other details (sorted by burst duration).

Whereas, from beginning to end, the red bar depicts the time sequence of the keywords.

From the perspective of burst intensity, the intensity of "organization" is the highest, with 3.14, followed by “perspective”, with 2.94. Additionally, "environmental management" and "CSR disclosure"—the other two crucial frontiers in this area—have very high intensities, at 2.55 and 2.51, respectively. The keywords "content analysis (2010-2018), "environmental management (2009-2015), " and "politics (2013-2018)" have long occurrence times and long outbreak periods, respectively, which suggests that the research on these keywords has a longer-lasting effect on the research field of carbon information disclosure. "CSR disclosure", "perception" and "corporate social performance" appeared in the latest time, representing the academic frontier in the field of carbon information disclosure.

Top 18 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2004 - 2021
institutional investor	2004	2.43	**2008**	2012	
environmental management	2004	2.55	**2009**	2015	
content analysis	2004	1.79	**2010**	2018	
organization	2004	3.14	**2011**	2014	
legitimacy	2004	1.85	**2011**	2012	
carbon reporting	2004	2.16	**2012**	2016	
management	2004	1.77	**2012**	2016	
assurance	2004	2.48	**2013**	2014	
politics	2004	2.37	**2013**	2018	
carbon	2004	2.2	**2013**	2015	
perspective	2004	2.94	**2017**	2019	
kyoto protocol	2004	2.2	**2017**	2019	
sustainability	2004	2.12	**2017**	2018	
adaptation	2004	1.88	**2017**	2018	
control system	2004	1.88	**2017**	2018	
csr disclosure	2004	2.51	**2018**	2019	
perception	2004	2.09	**2018**	2019	
corporate social performance	2004	2.09	**2018**	2019	

Figure 13 Top 18 Keywords with the strongest citation burst

4 Conclusions and limitations

In this paper, CiteSpace is used to conduct bibliometric analysis of carbon information disclosure literature. 502 effective articles in the web of science database

and 2894 relevant references were visually inspected to study and reveal the development of carbon information disclosure research from 2004 to 2021. By employing statistical maps and tables, co-authorship maps, co-occurrence maps, co-citation maps, clustering maps, time zone map, emergent words map, we were able to identify significant publications, authors, journals, institutions, nations and provide a comprehensive description of the evolution history, current hotspots and future trends of carbon information disclosure research. The conclusions are as follows:

①Carbon information disclosure research has become a hot topic in recent years. The first phase, from 2004 to 2010, produced less than five articles per year, indicating that it was still in its infancy. The next budding phase produced articles ranging from 2011 to 2016, more than four times the number of the previous phase. In the last phase, from 2017 to 2021, publications show a sharp increase, which represents a boom in this period.

②The study identifies the main outcome contributions of carbon disclosure research through co-authorship analysis from three dimensions: country, institution, and author.

Country: the United States is the country with the most publications, followed by Australia, Britain and China.

Institutions: Western Sydney University, Newcastle University, Macquarie University, Griffith University and Hunan University of commerce are the main research institutions.

Authors: TANG Q、LUO L、FREEDMAN M、ZORIO-GRIMA A and KUMAR P are the main contributors of carbon information disclosure publications.

Although there are several academics and organizations engaged in carbon accounting research, there is little substantial international collaboration. The collaboration between various authors, institutions, or nations has to be strengthened in order to advance the development of carbon disclosure research.

③From the results of the co-citation analysis, scholars such as Ans Kolk, Clarkson, Peter M., Luo, Le, Deegan, Craig, and Patten, Dennis M. are the most cited scholars, and published the most influential articles in the academic community. The most cited journal is *Journal of Business Ethics*, followed by *Business Strategy and Environment*、*Journal of Cleaner Production*、*Accounting Organizations and Society* and *Accounting Auditing & Accountability Journal*.

④To examine research hotspots and frontiers, this study uses keyword co-occurrence, clustering, a time zone map, and emergent words analysis. We found that the most intensive keywords were "climate change, " "disclosure, " "performance, " and "emissions, " and the longest-lasting keywords were "content analysis, " "environmental management, " and "politics. " CSR disclosure, " "perception, " and "corporate social performance" emerged the latest and represent the academic frontier.

This study provides a systematic, bibliometric review and visual analysis of the

literature on carbon disclosure research using CiteSpace. It provides a foundational understanding for future researchers and fills the gap between carbon disclosure research and bibliometric analysis. However, it is important to recognize the limitations of this study. First off, only one database was used in our investigation. Despite the fact that WoS is a database of generally high-quality publications, many findings that have been published in other journals are not present in WoS and were not gathered for this investigation. Second, only two categories of publications were used for data gathering in this study to assure the high quality of publications (articles and reviews). Future studies might broaden the data collection to include other kinds of publications (like conference papers and working papers), which could yield more information and conclusions. In conclusion, there is still much to learn about the disclosure of carbon information, and researchers might widen their scope by utilizing other factors, approaches, and viewpoints.

REFERECES

Adhikari, A; Zhou, HY(2022), Voluntary disclosure and information asymmetry: do investors in US capital markets care about carbon emission?, SUSTAINABILITY ACCOUNTING MANAGEMENT AND POLICY JOURNAL, 13(1), 195-220

Albort-Morant, G., & Ribeiro-Soriano, D. (2016). A bibliometric analysis of international impact of business incubators. Journal of Business Research, 69(5), 1775–1779.

Andrew, J; Cortese, C(2013), Free market environmentalism and the neoliberal project: The case of the Climate Disclosure Standards Board, CRITICAL PERSPECTIVES ON ACCOUNTING, 24 (6), 397-409

Antonini, C; Olczak, W; Patten, DM(2021), Corporate climate change disclosure during the Trump administration: evidence from standalone CSR reports, ACCOUNTING FORUM, 45(2), 118 -141

Anwar, M; Rahman, S; Kabir, MN(2021), Does national carbon pricing policy affect voluntary environmental disclosures? A global evidence, ENVIRONMENTAL ECONOMICS AND POLICY STUDIES, 23(2), 211 -244

Baboukardos, D(2017), Market valuation of greenhouse gas emissions under a mandatory reporting regime: Evidence from the UK, ACCOUNTING FORUM, 41(3), 221-233

Bellis, N. D. (2009). Bibliometrics and citation analysis: From the science citation index to Cybermetrics. Lanham: Scarecrow Press.

Ben-Amar, W; Chang, M; McIlkenny, P(2017), Board Gender Diversity and Corporate Response to Sustainability Initiatives: Evidence from the Carbon Disclosure Project, JOURNAL OF BUSINESS ETHICS, 142(2), 369 -383

Blanco, C; Caro, F; Corbett, CJ(2016), The state of supply chain carbon footprinting: analysis of CDP disclosures by US firms, JOURNAL OF CLEANER

PRODUCTION, 135, 1189-1197

Borghei, Z(2021), Carbon disclosure: a systematic literature review, ACCOUNTING AND FINANCE, 61(4), 5255-5280

Calza, F; Profumo, G; Tutore, I(2016), Corporate Ownership and Environmental Proactivity, BUSINESS STRATEGY AND THE ENVIRONMENT, 25(6), 369-389

Carpineto, C., Osiński, S., Romano, G., & Weiss, D. (2009). A survey of web clustering engines. ACM Computing Surveys, 41(3), Article 17.

Chang, DS; Yeh, LT; Liu, WR(2015), Incorporating the carbon footprint to measure industry context and energy consumption effect on environmental performance of business operations, CLEAN TECHNOLOGIES AND ENVIRONMENTAL POLICY , 17(2), 359-371

Chen, C. (2003). Mapping scientific frontiers. London, England: Springer-Verlag.

"Chen, C. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. Journal of the American Society for Information Science and Technology,

57, 359-377."

Chen, C. (2010). Information visualization. Wiley Interdisciplinary Reviews: Computational Statistics, 2, 387-403.

Chen, C. (2015). How to use CiteSpace. Victoria, British Columbia, Canada: Leanpub.

Chen, C. (2016). CiteSpace: A practical guide for mapping scientific literature. New York, NY: Nova Science Publishers.

Chen, C. (2017). Expert review. Science mapping: A systematic review of the literature. Journal of Data and Information Science, 2(2), 1-40.

"Chen, C., Cribbin, T., Macredie, R., & Morar, S. (2002). Visualizing and tracking the growth of competing paradigms: Two case studies. Journal of the American Society for Information

Science and Technology, 53, 678-689."

Chen, C., Dubin, R., & Kim, M. C. (2014). Emerging trends and new developments in regenerative medicine: A scientometric update (2000-2014). Expert Opinion on Biological Therapy, 14, 1295-1317.

Clarkson, PM; Li, Y; Pinnuck, M; Richardson, GD(2015), The Valuation Relevance of Greenhouse Gas Emissions under the European Union Carbon Emissions Trading Scheme, EUROPEAN ACCOUNTING REVIEW, 24(3), 551-580

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. Journal of the American Society for Information Science & Technology, 62(7), 1382–1402.

Cordova, CR; Zorio-Grima, A; Garcia-Benau, M(2018), New trends in corporate

reporting: Information on carbon footprint in Spain, RAE-REVISTA DE ADMINISTRACAO DE EMPRESAS, 58(6), 537-550

Deegan, C; Islam, MA(2012), Corporate Commitment to Sustainability - Is it All Hot Air? An Australian Review of the Linkage between Executive Pay and Sustainable Performance, AUSTRALIAN ACCOUNTING REVIEW, 22 (4), 384-397

Depoers, F; Jeanjean, T; Jerome, T (2016) Voluntary Disclosure of Greenhouse Gas Emissions: Contrasting the Carbon Disclosure Project and Corporate Reports, JOURNAL OF BUSINESS ETHICS, 134(3), 445-461

Fang, Y., Yin, J., & Wu, B. (2017). Climate change and tourism: A scientometric analysis using CiteSpace. Journal of Sustainable Tourism, 26, 108-126

Freedman, M; Jaggi, B,(2004) CARBON DIOXIDE EMISSIONS AND DISCLOSURES BY ELECTRIC UTILITIES, RE-INVENTING REALITIES,10 ,105 -129

Gallego-Alvarez, I; Garcia-Sanchez, IM; Vieira, CD(2014), Climate Change and Financial Performance in Times of Crisis, BUSINESS STRATEGY AND THE ENVIRONMENT, 23(6), 361-374

Ganda, F(2022), The influence of carbon performance on the financial debt of listed companies in an emerging economy: Does company size matter?, BUSINESS STRATEGY AND DEVELOPMENT, 5(1), 44-58

Gaviria-Marin, M., Merigó, J. M., & Baier-Fuentes, H. (2019). Knowledge management: A global examination based on bibliometric analysis. Technology. Forecasting & Social Change, 140, 194-220.

Glänzel, W., & Schubert, A. (2005). Analysing scie ntific networks through co-authorship. In H. F. Moed, W. Glänzel, U. Schmoch (Eds.), Handbook of quantitative science and technology research: The use of publication and patent statistics in studies of S & T systems (pp. 257-276). Netherlands, Dordrecht: Springer.

Griffin, PA; Lont, DH; Sun, EY (2017) The Relevance to Investors of Greenhouse Gas Emission Disclosures, CONTEMPORARY ACCOUNTING RESEARCH, 34(2), 1265-1297

Hardiyansah, M; Agustini, AT; Purnamawati, I(2021), The Effect of Carbon Emission Disclosure on Firm Value: Environmental Performance and Industrial Type, JOURNAL OF ASIAN FINANCE ECONOMICS AND BUSINESS, 8(1), 123-133

Hassan, OAG; Romilly, P(2018), Relations between corporate economic performance, environmental disclosure and greenhouse gas emissions: New insights, BUSINESS STRATEGY AND THE ENVIRONMENT, 27(7), 893-909

He, R; Luo, L; Shamsuddin, A; Tang, QL(2022), Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement, ACCOUNTING AND FINANCE, 62(1), 261-298

Hrasky, S(2012), Carbon footprints and legitimation strategies: symbolism or

action?, ACCOUNTING AUDITING & ACCOUNTABILITY JOURNAL,25(1), 174-198

ICAP (2022), Emissions Trading Worldwide: Status Report 2022 ,Berlin:International Carbon Action Partnership.

IPCC (2021), Climate Change 2021: The Physical Science Basis- Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change , (Cambridge University Press).

IPCC (2022), Climate Change 2022: Impacts, Adaptation and Vulnerability-Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change , (Cambridge University Press).

IPCC (2022), Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change , (Cambridge University Press).

Jiang, Y; Luo, L; Xu, JF; Shao, XR(2021), The value relevance of corporate voluntary carbon disclosure: Evidence from the United States and BRIC countries, JOURNAL OF CONTEMPORARY ACCOUNTING & ECONOMICS , 17(3)

Jung, J; Herbohn, K; Clarkson, P(2018), Carbon Risk, Carbon Risk Awareness and the Cost of Debt , Financing JOURNAL OF BUSINESS ETHICS, 150(4), 1151-1171

Kilic, M; Kuzey, C(2019), Determinants of climate change disclosures in the Turkish banking industry, INTERNATIONAL JOURNAL OF BANK MARKETING, 37(3), 901-926

Kolk, A. and Pinkse, J. (2005) Business responses to climate change: identifying emergent strategies, California Management Review, 47(3), 6-20.

Kolk, A; Levy, D; Pinkse, J(2008), Corporate Responses in an Emerging Climate Regime: The Institutionalization and Commensuration of Carbon Disclosure, EUROPEAN ACCOUNTING REVIEW, 17(4), 719-745

Kurnia, P; Darlis, E; Putra, AA(2020), Carbon Emission Disclosure, Good Corporate Governance, Financial Performance, and Firm Value, JOURNAL OF ASIAN FINANCE ECONOMICS AND BUSINESS, 7(12), 223-231

Lee, SY; Park, YS; Klassen RD (2015), Market Responses to Firms' Voluntary Climate Change Information Disclosure and Carbon Communication, CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT, 22(1), 1-12

Lemma, TT; Shabestari, MA; Freedman, M; Mlilo, M(2020), Corporate carbon risk exposure, voluntary disclosure, and financial reporting quality, BUSINESS STRATEGY AND THE ENVIRONMENT, 29(5), 2130-2143

Li, DY; Huang, M; Ren, SG; Chen, XH; Ning, LT(2018), Environmental Legitimacy, Green Innovation, and Corporate Carbon Disclosure: Evidence from CDP China 100, JOURNAL OF BUSINESS ETHICS, 150(4), 1089-1104

Liang, C. C., Luo, A. J. and Zhong, Z. Q.(2018), Knowledge mapping of medication literacy study: a visualized analysis using CiteSpace. SAGE Open Med. 6, 1–10.

Liao, L; Luo, L; Tang, QL (2015) Gender diversity, board independence, environmental committee and greenhouse gas disclosure, BRITISH ACCOUNTING REVIEW, 47(4), 409-424

Liesen, A; Hoepner, AG; Patten, DM; Figge(2015), F Does stakeholder pressure influence corporate GHG emissions reporting? Empirical evidence from Europe, ACCOUNTING AUDITING & ACCOUNTABILITY JOURNAL, 28(7), 1047-1074

Luo, L (2019) The influence of institutional contexts on the relationship between voluntary carbon disclosure and carbon emission performance, ACCOUNTING AND FINANCE, 59(2), 1235-1264

Luo, XY; Zhang, RM; Liu, W(2022), Environmental legitimacy pressure, political connection and impression management of carbon information disclosure, CARBON MANAGEMENT , 13(1), 90-104

Matsumura, EM; Prakash, R; Vera-Munoz, SC (2014) Firm-Value Effects of Carbon Emissions and Carbon Disclosures, ACCOUNTING REVIEW, 89(2), 695-724

McCain, K. W. (1991). Mapping economics through the journal literature: An experiment in journal co-citation analysis. Journal of the American Society for Information Science, 42(4), 290–296.

Merigó, J. M., & Yang, J. B. (2017). A bibliometric analysis of operations research and management science. Omega, 73, 37-48.

Nansai, K; Kagawa, S; Kondo, Y; Suh, S; Inaba, R; Nakajima, K(2009), IMPROVING THE COMPLETENESS OF PRODUCT CARBON FOOTPRINTS USING A GLOBAL LINK INPUT-OUTPUT MODEL: THE CASE OF JAPAN, ECONOMIC SYSTEMS RESEARCH, 21(3), 267-290

Nordenstam, L; Ilic, DD; Odlund, L(2018), Corporate greenhouse gas inventories, guarantees of origin and combined heat and power production - Analysis of impacts on total carbon dioxide emissions, JOURNAL OF CLEANER PRODUCTION, 186, 203-214

Noyons, E. C., Moed, H. F., & Luwel, M. (1999). Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. Journal of the American Society for Information Science, 50(2), 115-131.

Qian, W; Schaltegger, S (2017) Revisiting carbon disclosure and performance: Legitimacy and management views,BRITISH ACCOUNTING REVIEW, 49(4), 365-379

Saha, AK; Al-Shaer, H; Dixon, R; Demirag, I(2021), Determinants of Carbon Emission Disclosures and UN Sustainable Development Goals: The Case of UK

Higher Education Institutions, AUSTRALIAN ACCOUNTING REVIEW, 31 (2), 79-107

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. Journal of American Society for Information Science, 24(4), 265–269.

Stanny, E; Ely, K(2008), Corporate Environmental Disclosures about the Effects of Climate Change, CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT, 15(6), 338-348

Tadros, H; Magnan, M; Boulianne, E(2020), Is corporate disclosure of environmental performance indicators reliable or biased information? A look at the underlying drivers, JOURNAL OF FINANCIAL REPORTING AND ACCOUNTING, 18(4) , 661-686

Tan, DJ; Bilal; Gao, S; Komal, B(2020), Impact of Carbon Emission Trading System Participation and Level of Internal Control on Quality of Carbon Emission Disclosures: Insights from Chinese State-Owned Electricity Companies, SUSTAINABILITY, 12(5)

Tang, QL(2019), Institutional Influence, Transition Management and the Demand for Carbon Auditing: The Chinese Experience, AUSTRALIAN ACCOUNTING REVIEW, 29(2), 376-394

Thelwall, M. (2008). Bibliometrics to webometrics. Journal of Information Science, 34(4), 605-621.

White, H. D. & Mccain, K. W. (1998). Visualizing a discipline: An author co-citation analysis of information science, 1972–1995. Journal of the American Society for Information Science, 49(4), 327–355.

Xiying Luo, Ruimin Zhang & Wei Liu (2022) , Environmental legitimacy pressure,political connection and impression management of carbon information disclosure, Carbon Management, 13(1), 90-104,

Xue WZ, Li H, Rizwan A, Ramiz Ur ORCID R (2020) Knowledge Mapping of Corporate Financial Performance Research: A Visual Analysis Using Cite Space and Ucinet. Sustainability 12:35–54

Y.Chen, C. M. Chen, and Z. Y. Liu, “The methodology func- tion of CiteSpace mapping knowledge domains,” Studies in Science of Science, vol. 33, no. 2, pp. 242–253, 2015.

Youping Teng, Yue Huang , Shuai Yang(2022), Applying Knowledge Graph to Analyze the Historical Landscape Based on CiteSpace, Wireless Communications and Mobile Computing, Volume 2022, Article ID 3867541, 12 pages

Yunus, S; Elijido-Ten, E; Abhayawansa, S(2016), Determinants of carbon management strategy adoption Evidence from Australia's top 200 publicly listed firms, MANAGERIAL AUDITING JOURNAL , 31(2), 156-179

Yuwei Du, Songsheng Chen, Luyao Tang(2021), The Research Progress and

Development Trend of Carbon Accounting: An Analysis Based on CiteSpace, China-USA Business Review, 20(4), 185-201

Z.Y. Liu, Mapping of Scientific Knowledge: Methods and Appli- cations, People's Press, Beijing, China, 2008.

Zhang, YJ; Liu, JY(2020), Overview of research on carbon information disclosure, FRONTIERS OF ENGINEERING MANAGEMENT ,7(1), 47-62