

# The Research Progress and Development Trend of Carbon Accounting: An Analysis Based on CiteSpace

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In this study, we analyzed the carbon accounting literature from 2015 to 2020 included in the Web of Science database to determine the current research status, hotspots, and trends of carbon accounting. CiteSpace visual analysis software and bibliometric method were used to analyze major countries, journals, research institutions, authors, keywords, and annual publication volume related to carbon accounting research. The results show that in recent years, the number of published papers has been increasing in recent years, and several major research institutions have been formed, such as the Chinese Academy of Sciences, the University of Leeds, and the Beijing Institute of Technology. Geoffrey P. Hammond, Paul W. Griffin, Connor C. Turvey, Jiahui Hong, et al. are the main contributors to carbon accounting publications. However, there is still a lack of cooperation between scholars and institutions. Currently, research on carbon accounting focuses on climate change, carbon emissions, and carbon footprints. This research will provide carbon accounting researchers and practitioners with the latest information on the current research status, hotspots, and trends in the field of carbon accounting research.

*Keywords:* carbon accounting, CiteSpace, visual analysis, bibliometric, Web of Science

## Introduction

The rapid economic development in the past century has brought not only economic prosperity but also rapid energy consumption and severe industrial carbon emissions. According to the International Energy Agency (IEA), the world's total final energy consumption increased from 4,243 Mtoe in 1973 to 9,938 Mtoe in 2018 (IEA, 2020). Meanwhile, the US Energy Information Administration (EIA) estimated that world energy consumption would increase 20% from 2015 to 2040 (Minh & Shirley Meng, 2019). This inevitably produces a large amount of CO<sub>2</sub> and other greenhouse gases, which causes the greenhouse effect, leading to more and more obvious signs of global warming. In such a harsh reality, countries have to find ways to reduce carbon emissions, thereby slowing down or even preventing the deterioration of the global climate, so a low-carbon economy is widely respected. How to quantify the environmental consequences of corporate actions in the context of a low-carbon economy has become a critical issue. Therefore, carbon accounting came into being. Hespeneide, Pavlovsky, and McElroy (2010) gave a broad definition of "carbon accounting", on the one hand,

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it is the measurement of emissions and removals; on the other hand, it is the financial impact. Carbon accounting has developed rapidly in the past 20 years and has become a broad research field. Discussions on accounting and processing standards for specific environmental issues (such as CO<sub>2</sub> emissions, trading, and emission reduction) have become more heated.

In the past two decades, many researchers have focused on carbon accounting and published a large amount of literature. Cherubini, Peters, Berntsen, Strømman, and Hertwich (2011) used the CO<sub>2</sub> impulse response function (IRF) from the C-cycle model to estimate the climate impact of CO<sub>2</sub> emissions from biomass combustion, which can be applied to CO<sub>2</sub> emissions from the combustion of all different biomass species. By comparing technologies and management practices in China with more advanced options worldwide, Zhang et al. (2013) found that the adoption of advanced technology could reduce nitrogen fertilizer-related emissions by 20-63%, equivalent to 102-357 Tg CO<sub>2</sub>-eq per year. Lin, Hu, Zhao, Shi, and Kang (2017) established a city-centric global multi-regional input-output model (CCG-MRIO) to evaluate the carbon footprint of urban consumption in the global supply chain. In recent years, the debate over consumption-based and production-based accounting for carbon dioxide emissions has raged. Ali (2017) analyzed the carbon emission of the two approaches in four world regions (European Union [EU], Organisation for Economic Co-operation and Development [OECD], Brazil, Russia, India, China [BRIC], and Rest-of-the-World [ROW]) from 1995-2009. The results showed that the carbon emissions were higher in the consumer approach than in the producer approach in the EU and OECD regions. At the same time, they were higher in the producer approach than in the consumer approach for BRIC countries and the rest of the world. Liu, Huang, Baetz, and Zhang (2018) compared production-based and consumption-based policies from the perspective of industries and found that production-based policies apply to the primary industry, while consumption-based policies apply to the industries at the end of the industrial chain.

However, the focus of scientific research changes over time, so it is difficult for scholars to directly understand the research progress, research frontiers, and hot spots in a specific field. It is essential to use scientometrics software to analyze this field (Chen, 2006). Knowledge mapping refers to a method of visually displaying knowledge in the subject area through a series of processes, such as data mining, information analysis, scientometrics, and graph rendering (Shiffrin & Börner, 2004). Since 2006, knowledge graph analysis has been widely used in many disciplines. Many tools are used by researchers for mapping the knowledge graph, such as VOSviewer, Copalred, BibExcel, SCI2, VantagePoint, and CiteSpace. For example, Chen, Cheng, Lian, Song, and Tian (2021) provided a bibliometric analysis of the status of research on the COVID-19 vaccine based on VOSviewer. Endler, Scarpin, and Steiner (2018) used BibExcel and Pajek software to conduct a quantitative analysis of the scientific production of lean supply from 1992 to 2016. Azam, Ahmed, H. Wang, Y. E. Wang, and Zhang (2021) visualized the knowledge background, research status, and the latest knowledge structure of wind power generation (WPG) related literature using CiteSpace based scientometrics investigation.

CiteSpace, a Java application for analyzing and visualizing co-citation networks, is the most influential visualization software developed by Professor Chaomei Chen of Drexel University in the United States (Chen, 2006). According to Chen (2017), CiteSpace can support multiple types of bibliometric research, including collaborative network analysis, co-word analysis, author co-citation analysis, document co-citation analysis, and text and geospatial visualization. It can create a series of visual maps to analyze the frontiers and trends of a knowledge field. Compared with other software, CiteSpace has the advantage of revealing the dynamic

development rules and discovering the research frontiers of disciplines. In recent years, more and more scholars have begun to use CiteSpace to analyze and describe knowledge pedigrees in fields including economy (Cao, 2020), technology (Chen & Liu, 2020), culture (Su, Li, & Kang, 2019), management (Li, Ma, & Qu, 2017), and environmental protection (Yang & Meng, 2020; Yao, Hui, Yang, Chen, & Xiao, 2020).

At present, there are many research and review articles on carbon accounting. Still, there is no research to combine visualization software with literature reviews to study the development of the carbon accounting field. This research combines bibliometric methods with visualization tools, CiteSpace, to visually analyze carbon accounting research hotspots and trends, and aims to provide researchers with more accurate information about the progress and trends of carbon accounting research.

## **Data Collection and Methods**

### **Data Collection**

Web of Science is regarded as the preferred database site for CiteSpace analysis because it provides the most valuable and influential collections of papers (Falagas et al., 2008). Therefore, this paper's database selected for retrieval is the "Web of Science Core Database". The search conditions were as follows: AK = carbon accounting, language = (all languages), document types = (all document types), and the search time was 2015-2020. According to the above retrieval method, a total of 274 valid records were retrieved, including the authors, titles, keywords, abstracts, and cited references. These results are output as text format, named "download\_1-274". These records were exported and used as data samples for measurement and visual analysis in this study.

### **Research Method**

In this work, CiteSpace was used to analyze the data, such as institutions, authors, keywords, and references, from the number of published papers. Here, CiteSpace (5.7.R2) was used to visualize the raw data to obtain a visual knowledge map. The main steps are as follows:

- Firstly, the obtained 274 records of data were input into CiteSpace software, and then they were converted into data that CiteSpace can analyze. Articles, comments, and meeting minutes were screened out from the search results, and 268 valid documents were left after deleting duplicates.
- Secondly, the time slice was set from 2015 to 2020, and the "years per slice" was set to one year. The types of selected nodes were category, country, institution, author, cited journal, cited author, reference, and keywords; others were the default settings.
- Thirdly, in the "Node Type" setting, visual analysis was performed on Author, Institution, Country, Keyword, Category, Reference, Cited Author, and Cited Journal, respectively.
- Finally, carbon accounting knowledge maps were drawn through co-occurrence analysis and cluster analysis, which visually shows the hot spots and development trends of this research field.

## **Results**

### **Annual Publishing Trend**

It can be seen from Figure 1 that in the past six years, the number of research papers on carbon accounting has increased and then remained relatively stable. Specifically, the number of carbon accounting publications was increased from 35 in 2015 to 43 in 2016 and then dropped to 38 in 2017. Hereafter, it rose sharply to 53 in

2018 and then dropped slightly to 49 in 2020. In general, it is at a relatively stable level after 2018. Based on this analysis, it is clear that international attention to carbon accounting is increasing, but the specific content of the relevant research needs to be further analyzed.

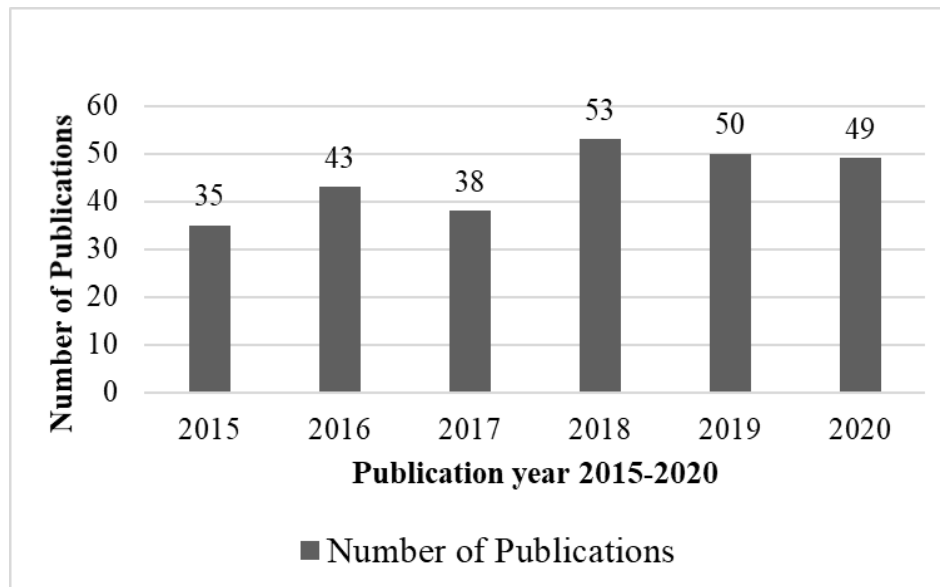


Figure 1. The trend of publication in carbon accounting.

### Web of Science Categories

Table 1

*Top 10 Research Areas by the Number of Articles*

WoS categories	Number of articles	%
Environmental Sciences & Ecology	145	54.104
Environmental Sciences	114	42.537
Science & Technology-Other Topics	67	25.000
Green & Sustainable Science & Technology	66	24.627
Engineering	59	22.015
Environmental Studies	51	19.030
Energy & Fuels	48	17.910
Engineering, Environmental	45	16.791
Business & Economics	41	15.299
Economics	21	7.836

According to the categories of Web of Science, the 268 articles in carbon accounting can be divided into 109 research fields. Table 1 lists the top 10 categories. Carbon accounting researchers published the most papers in the journal *Environmental Sciences & Ecology*, with 145 articles accounting for 54.10% of the total (Of the 145 publications, 114 were labeled Environmental Sciences only, not Ecology). The second most popular journal category was Science & Technology-Other Topics, with 67 publications. Moreover, the top 10 journal categories, including Green & Sustainable Science & Technology (66), Engineering (59), Environmental Studies (51), Energy & Fuels (48), Energy & Fuels (48), Engineering and Environmental (45), Business & Economics (41), Economics (21), are essential areas of carbon accounting research. A betweenness

centrality analysis found 108 nodes and 486 edges (see Figure 2), and the most common categories are well connected to the various parts of the network. According to the Web of Science, a single publication can be indexed in two or more different categories, which indicates that the journal category has the character of interdisciplinary in carbon accounting.



Figure 2. Web of Science categories.

### Collaboration Network Analysis

Collaboration analysis can help learn more about the different countries, institutions, and authors that make the most remarkable contributions in the research of carbon accounting (Glänzel & Schubert, 2005).

**Country collaboration network analysis.** According to the literature on carbon accounting from the Web of Science Core Database, the top 10 countries were ranked based on the number of publications in each country (see Table 2). In terms of the number of publications per node, the United States contributed the most (65 articles), accounting for 24.25% of the total data collected, which indicates that the United States is the most active in carbon accounting research, which is followed by China (63 articles), accounting for 23.51% of the collected data. Australia and the United Kingdom ranked third and fourth, with 38 and 31 articles, respectively. The centrality of a node is an attribute of graph theory, which can quantify the importance of the node's position in the network. According to Table 2, the United States has the highest degree of centralization (centrality = 0.32), followed by Australia (centrality = 0.29), and Germany (centrality = 0.25). It reveals that these countries play an obvious intermediary role in carbon accounting research. They conducted more research through these nodes, which greatly impacts the structure of the research network. The United States ranks first in the number and concentration of research papers published in carbon accounting, which shows that the United States has made important research achievements and made great contributions in the field of carbon accounting. Although China ranks second in the number of publications, its centrality is only 0.05, much lower than other countries. It shows that China has a place in carbon accounting research, but China's international influence is relatively weak compared with other countries.

Table 2

*Top 10 Countries by Number of Articles*

Countries	Centrality	Number of articles	%
USA	0.32	65	24.254
China	0.05	63	23.507
Australia	0.29	38	14.179
England	0.16	31	11.567
Germany	0.25	27	10.075
Italy	0.13	18	6.716
Spain	0.19	17	6.343
Canada	0.14	16	5.970
France	0.01	13	4.851
Austria	0.03	10	3.731

**Institution collaboration network analysis.** CiteSpace software was used to visually analyze 268 records to obtain a network map of institutional cooperation. We selected the parameter “Institution” in CiteSpace and got the knowledge map of institution collaboration in carbon accounting. As shown in Figure 3, the node size represents the number of journal articles published by the research institution and the relationship between the two. Nodes represent the strength of cooperation between different institutions. In the analysis of institutional cooperation networks, universities are the leading research institutions for carbon accounting. Chinese Academy of Sciences, University of Leeds, Beijing Institute of Technology, University of Queensland, Aarhus University, University of Bath, Beijing Normal University, Australian National University, Monash University, and Lund University is the top 10 contributors. Among them, Chinese and Australian institutions each accounted for 30%. The collaborative network consists of 176 nodes and 210 connections, with a density of 0.0136. The University of Queensland ranks first in terms of centrality (centrality = 0.05), indicating less cooperation between institutions, and there is still much room for improvement in horizontal collaboration between institutions.

**Author collaboration network analysis.** The analysis of author distribution is the prerequisite for mastering the research field and research trend of a specific subject. We run the parameter “Author” in CiteSpace, and the knowledge map of the authors’ cooperation in carbon accounting is present in Figure 4. According to the selected 268 documents, a total of 187 scholars have researched this area. The results of the author's collaborative network analysis are shown in Figure 4. Nodes represent authors, and links between nodes represent the collaborative relationship between authors. The author who has contributed the most to the frequency of cooperation was Geoffrey P. Hammond, who has completed the most publications with other collaborators (frequency = 5). Based on the cooperation relationship between authors, several main research groups were established: (1) Griffin’s team from the University of Bath in the UK analyzed the energy demand of the steel industry (Griffin & Hammond, 2019a), and the energy use and carbon emission reduction of the steel sector and chemicals sector (Griffin & Hammond, 2019b; Griffin, Hammond, & Norman, 2018); (2) Turvey’s group from Monash University in Australia focused on calculating the CO<sub>2</sub> storage capacity of ultramafic iron mines (Turvey, Wilson, Hamilton, & Southam, 2017; Turvey, Hamilton, & Wilson, 2018; Turvey et al., 2018); and (3) Yang’s team from the South China University of Technology mainly studied the calculation model of carbon footprint in the urban distribution system and the choice of urban distribution mode

under the conditions of a low-carbon economy (Yang, Cai, Hong, Shi, & Zhang, 2016). However, the author's collaboration network is not very centralized, and many vital nodes are scattered.

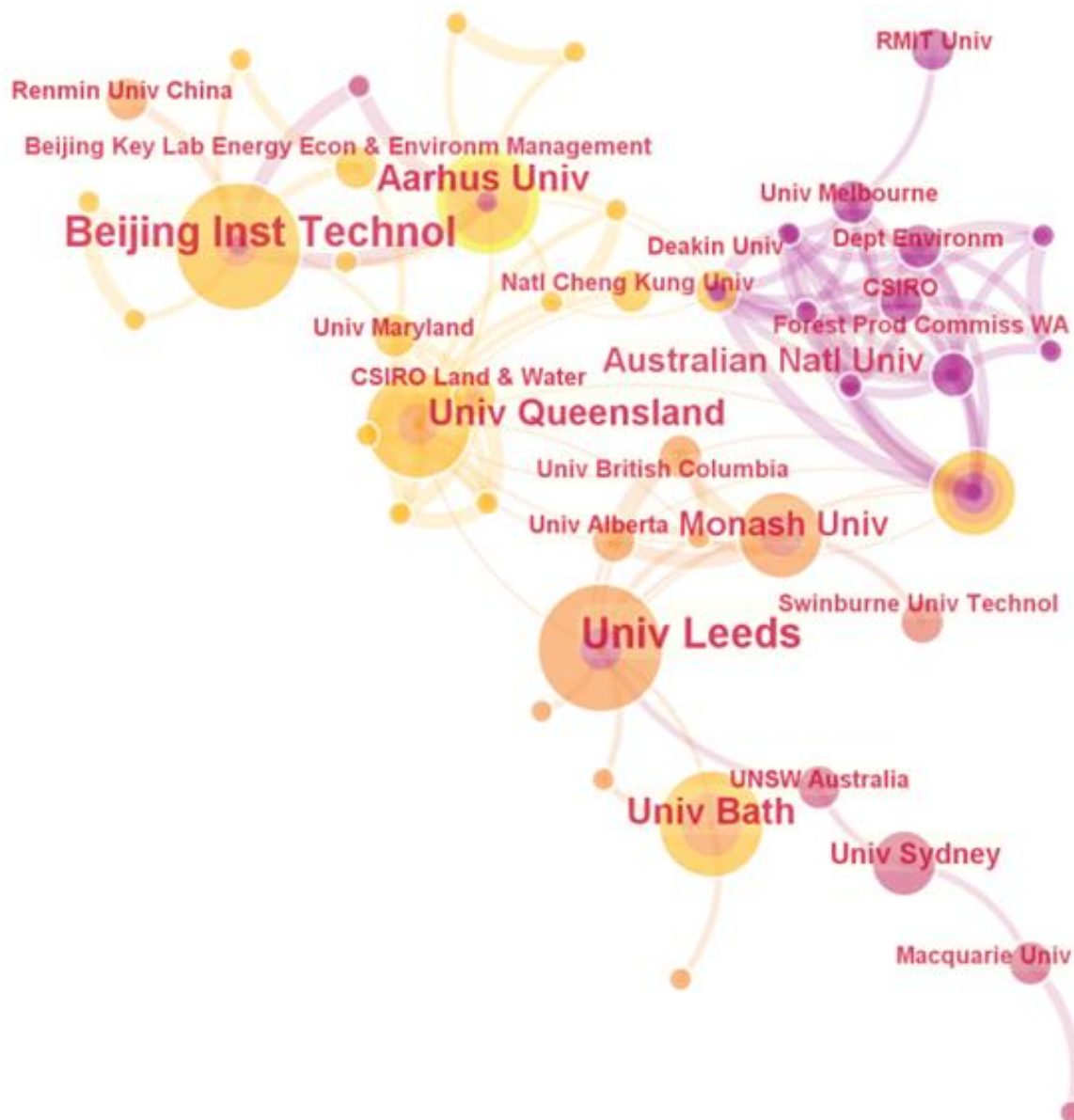


Figure 3. Knowledge map of institution collaboration in carbon accounting.

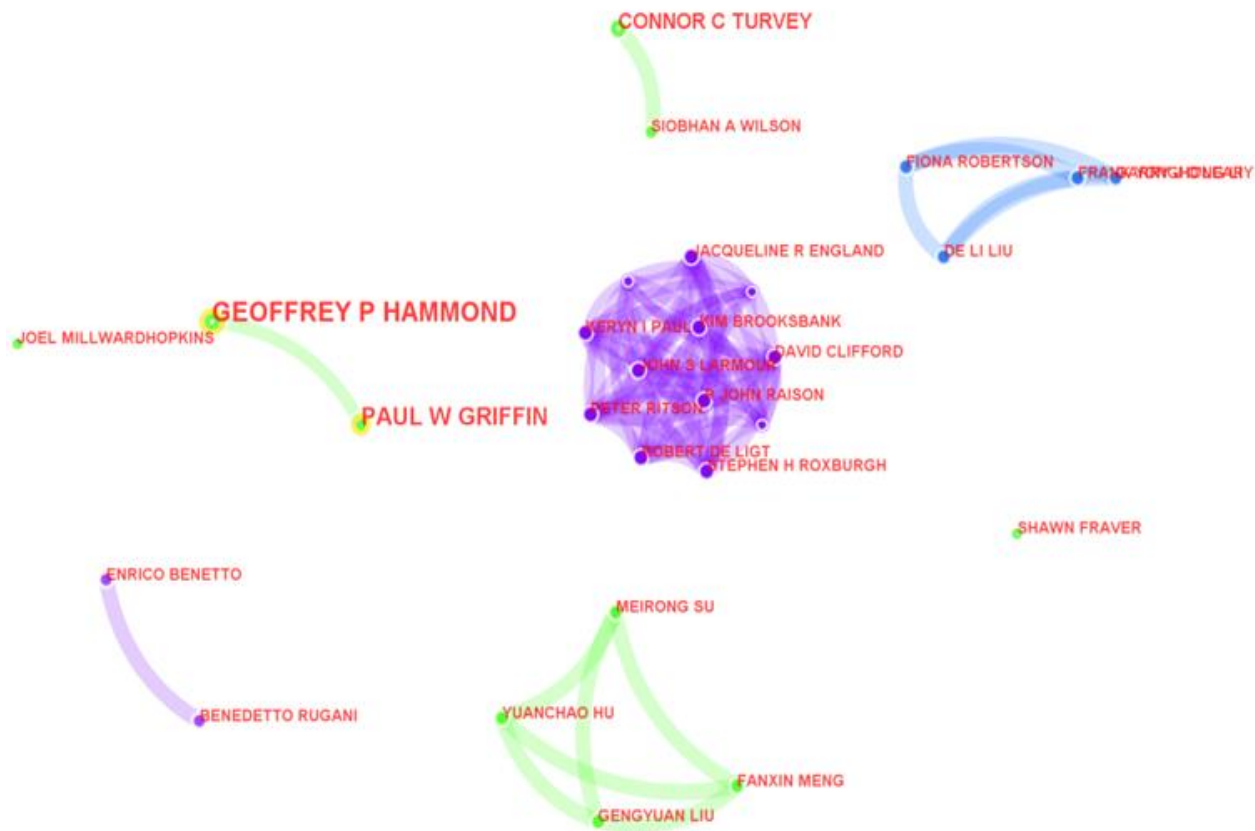


Figure 4. Knowledge map of author collaboration in carbon accounting.

### Co-citation Analysis

The occurrence network provides an appropriate scientific tool to assess the academic level of journals, literature, and authors and help scholars and institutions find valuable information (Small, 1973).

**Journal co-cited analysis.** By studying journal co-citation, we can investigate a specific field's subject structure and research topic. Table 3 lists the prominent journals of carbon accounting research publications. The most cited journals are *Journal of Cleaner Production* with 106 papers, followed by *Energy Policy* (97), *Environmental Science & Technology* (94), *Ecological Economics* (90), *Proceedings of the National Academy of Sciences of the United States of America* (83), *Nature* (73), *Science* (70), *Journal of Industrial Ecology* (64), *Environmental Research Letters* (62), and *Applied Energy* (61). These ten journals can serve as authoritative reference materials for research on carbon accounting. As can be seen in Table 3, the *Journal of Cleaner Production* has been cited the most times and has a high centrality. It is an international, interdisciplinary journal focused on research and practice in cleaner production, the environment, and sustainability, and it is an important academic journal to help societies become more sustainable. In terms of the critical research fields of the cited journals, the research of carbon accounting is closely related to the research fields of Management Sciences, Environmental Sciences, Meteorology & Atmospheric Sciences, etc. Moreover, three journals with an impact factor of more than nine were cited: *Nature* (42.799), *Science* (41.845), and *Proceedings of the National Academy of Sciences of the United States of America* (9.412). The impact factor measures the average number of papers published in the journal in the previous two years that were cited in a given year. This high



impact factor indicates that there are plenty of core journals in the field of carbon accounting.

Table 3

*Top 10 Journals by the Number of Publications*

Journals	Frequency	Centrality	Impact factor
<i>Journal of Cleaner Production</i>	113	0.13	7.246
<i>Energy Policy</i>	97	0.02	5.042
<i>Environmental Science &amp; Technology</i>	94	0.03	4.363
<i>Ecological Economics</i>	90	0.02	4.482
<i>Proceedings of the National Academy of Sciences of the United States of America</i>	83	0.05	9.412
<i>Nature</i>	73	0.06	42.779
<i>Science</i>	70	0.02	41.845
<i>Journal of Industrial Ecology</i>	64	0.03	6.539
<i>Environmental Research Letters</i>	62	0.07	6.096
<i>Applied Energy</i>	61	0.02	8.848

**Authors co-cited analysis.** The author's co-citation analysis can help us to understand the important scholars and their fields. We analyze the authors according to citation frequency and centrality (see Table 4). The results show that [Anonymous], Glen P. Peters, Intergovernmental Panel on Climate Change (IPCC), Manfred Lenzen, Thomas Wiedmann had high citation frequency, indicating that their research results had produced a wide range of social media influence in this field. These most co-cited authors are engaged in carbon accounting research from different scientific perspectives: Glen P. Peters is a member of Centre for International Climate and Environmental Research (CICERO), who has made significant contributions to the research of climate change, emerge& fuels, environmental sciences & ecology and forestry; the main research content of Manfred Lenzen from the University of Sydney is Ecological Economics. He focuses on the input-output model and carbon footprint. From the University of New South Wales Sydney, Thomas Wiedmann mainly engaged in research on cleaner production, environmental sustainability, and input-output analysis. However, centrality scores show different results: Food and Agriculture Organization (FAO), \*\*European Commission, R. Core Team, Stefan Schaltegger, Ana Cláudia Dias are the top five authors with the highest centrality, indicating that they are connecting different networks of co-authors. The above tracking and analysis of key researchers can help us fully grasp the key scholars in carbon accounting and related topics.

Table 4

*Top 5 Authors by the Number of Publications & Centrality*

Authors	Frequency	Authors	Centrality
[Anonymous]	73	FAO	0.36
Glen P. Peters	52	**European Commission	0.31
IPCC	50	R. Core Team	0.3
Manfred Lenzen	37	Stefan Schaltegger	0.24
Thomas Wiedmann	33	Ana Cláudia Diass	0.2

**Reference co-citation analysis.** Co-citation analysis can reflect the knowledge base and theoretical knowledge base of related research. We have selected the "reference" parameter in the CiteSpace analysis software, and the knowledge map of the co-cited documents in "carbon accounting" is shown in Figure 5. The

co-citation network of carbon accounting research consists of 272 nodes and 909 edges. Among the 272 references, this paper selects the top five key nodes with the greatest impact (see Table 5). These scholars have used consumption-based accounting methods in their research to allocate all emissions in the entire production chain to products and final consumption locations.

Table 5

*Top 10 Most Cited References of Carbon Accounting*

Authors	Frequency	The title of articles
Feng,Hubacek, Sun, &Liu (2014)	14	Consumption-based CO <sub>2</sub> accounting of China's megacities: The case of Beijing, Tianjin, Shanghai, and Chongqing
Steininger et al. (2014)	11	Justice and cost-effectiveness of consumption-based versus production-based approaches in the case of unilateral climate policies
Mi et al. (2016)	11	Consumption-based emission accounting for Chinese cities
Lin,Liu, Meng, Cui, & Xu (2013)	8	Using a hybrid method to evaluate the carbon footprint of Xiamen City, China
Timmer, Dietzenbacher, Los, Stehrer, & de Vries(2015)	8	An illustrated user guide to the world input-output database: The case of global automotive production

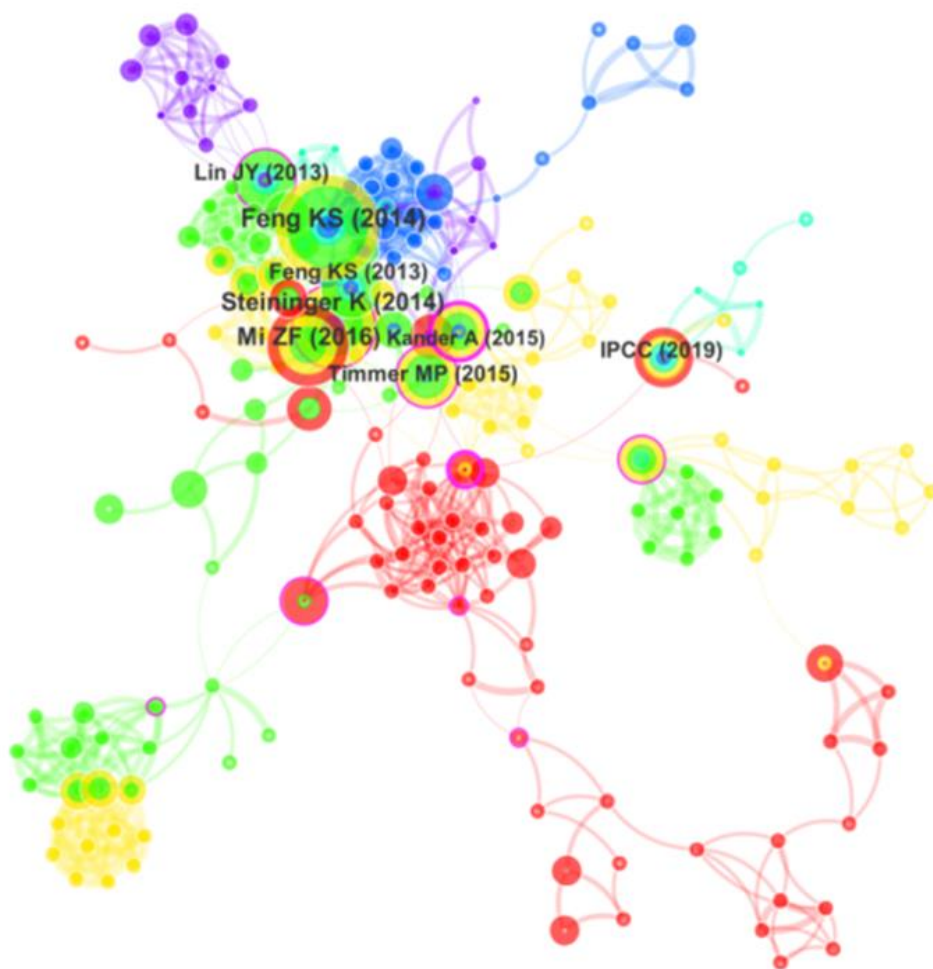


Figure 5. Knowledge map of co-citation literature in carbon accounting.

**Key-Word Network and Time Zone Chart Analysis**

**Co-occurrence of keywords.** Keyword co-occurrence analysis can directly reflect the research situation in the subject field. In the CiteSpace software, the data from 2015 to 2020 are sliced within one year to obtain the keyword co-occurrence network diagram shown in Figure 6 and the keyword table shown in Table 6.

In Figure 6, nodes represent the keywords for carbon accounting research, and the size of nodes is positively correlated to the frequency of keywords. The lines between the nodes represent the degree of connection between keywords. As shown in Figure 6, the network consists of 254 nodes and 1,254 edges. Among which, the higher the frequency of keywords, the larger the nodes. Table 6 shows the top 10 keywords that appear simultaneously and collectively. The more citations, the more keywords scholar's study. The higher the centrality of a node, the more media it provides to other non-central nodes. The higher the centrality of a node, the more media it provides to other non-central nodes. If the centrality is greater than 0.1, it indicates that a lot of research has been carried out through this node, and the node has great influence (Chen, 2006). Therefore, the citation frequency and centrality of keywords were selected as indicators for chart interpretation.

Table 6

*Top 10 Keyword Co-occurrence of Carbon Accounting*

Keywords	Frequency	Keywords	Centrality
Carbon accounting	113	Climate change	0.16
Climate change	43	Emission	0.13
Emission	35	Footprint	0.13
Carbon footprint	35	Forest	0.13
Greenhouse gas emission	31	Consumption	0.11
Sequestration	29	Carbon sequestration	0.11
Life cycle assessment	24	Co <sub>2</sub> emission	0.1
Carbon	24	Sequestration	0.09
Consumption	24	Carbon	0.09
Co <sub>2</sub> emission	23	China	0.09

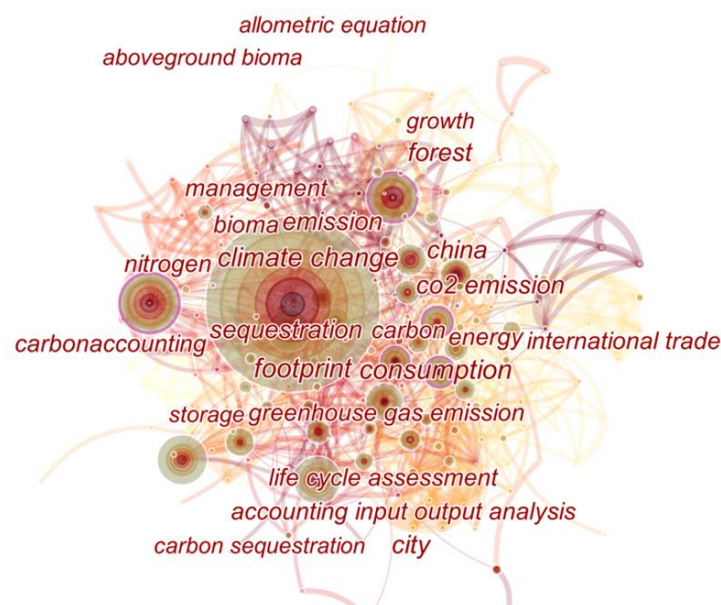


Figure 6. Knowledge map of keywords co-occurrence in carbon accounting.

According to the joint analysis of Figure 6 and Table 6, it can be seen that the “carbon accounting” has the

largest number of nodes, with the highest frequency being 113 times. It is the key to start the literature retrieval. However, its centrality is only 0.03. It can be seen that although it is a research hotspot, it provides less media for other non-central nodes. The second and third places were climate change and emissions, with the centrality of 0.16 and 0.13, respectively. According to the centrality of keywords, the main research nodes in the field of carbon accounting include keywords, such as “climate change (0.16)”, “emission (0.13)”, and “footprint (0.13)”. According to Figure 6, in carbon accounting research, high-frequency keywords, such as carbon footprint, CO<sub>2</sub> emission, and storage coexist with other keywords, forming a closely related research hotspot symbiosis network.

**Time zone chart analysis.** To better grasp the hotspots and development trends of carbon accounting research, and more directly show the time distribution and interrelationships of hotspots in this field, CiteSpace was used to draw a time zone view of the keyword co-occurrence network diagram (see Figure 7).

It can be seen from Figure 7 that research on carbon accounting appeared in early 2015 and became the focus of research in subsequent years. In 2015, there were many keywords. These studies mainly focused on climate change, emission, carbon footprints, greenhouse gas emission, etc. In 2016, Model, Impact, Input-Output Analysis, and China became research hotspots. In 2017 and 2018, keywords began to decrease, and the main research topics were international trade and policy, which indicated that the carbon accounting research gradually reached a stable stage after a period of rapid expansion. At the beginning of 2019, there was a new keyword “ecosystem service”, which attracted much attention.



Figure 7. Keyword time zone line map.

## Research Trends Analysis

### Keyword Burst Analysis

Keyword burst analysis can help us understand the changes in research hotspots in this field over some time, and identify cutting-edge trends. Therefore, we conduct burst analysis on keywords and obtain 20 burst terms from 2015 to 2020. Figure 8 shows a chart of emerging keywords for carbon accounting research, including burst terms, intensity, start and end times, and other information (sorted by burst duration).

From the perspective of burst intensity, “policy” is the strongest keyword within an intensity of 3.61. It is

mainly related to the carbon accounting policy, which has attracted widespread attention and has become a relatively influential research frontier hotspot. In addition, the intensity of “carbon emission” and “low-carbon economy” is also very high, at 2.58 and 2.13, respectively, which are two other important frontiers of carbon accounting research.

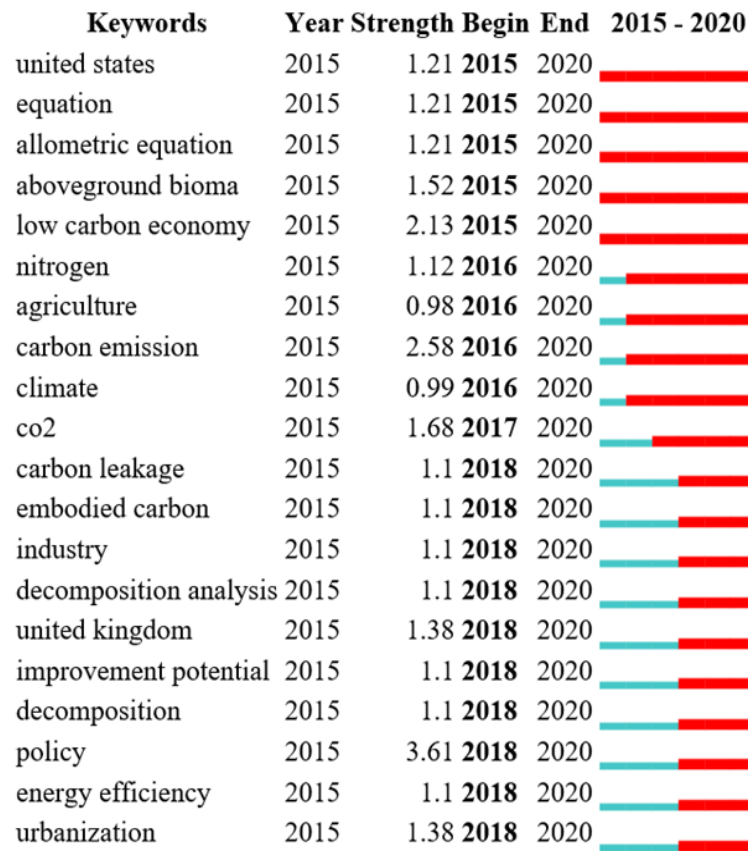


Figure 8. Keywords with the strongest citation burst in carbon accounting.

From the perspective of the time of the outbreak, the keyword with a long appearance and long outbreak cycle include “United States (2015-2020)”, “Equation (2015-2020)”, “Allometric Equation (2015-2020)”, and “Low-Carbon Economy (2015-2020)”, indicating that research related to these keywords has a more lasting impact on the field of carbon accounting research.

Besides, combined with the latest published literature research, it can be found that emissions accounting methods, industrial energy use, and carbon sequestration are also the frontier areas of current research.

### Co-citation Literature Burst

The burst test is also an indicator of co-citation research. Higher citations provide evidence, rather than intuitive premises (Kleinberg, 2003), indicating that a particular publication is related to a large number of citations (Chen, 2014). In other words, related literature has attracted attention in a certain field. Figure 9 shows the top 20 most cited references (sorted by the year of the outbreak). References with strong values in the “Strength” column are usually important to research milestones (Chen, 2017). It can be seen that the most influential reference is the study of the tension and contradiction between different concepts of carbon

accounting meaning (Ascui & Lovell, 2011), with the highest intensity of 3.02. The second milestone is carbon accounting for sustainable development and management (Schaltegger & Csutora, 2012), with an intensity of 2.35. Other milestones include establishing a global input-output database (Lenzen, Moran, Kanemoto, & Geschke, 2013) and tracking urban carbon footprints (Lin, Hu, Cui, Kang, & Ramaswami, 2015).

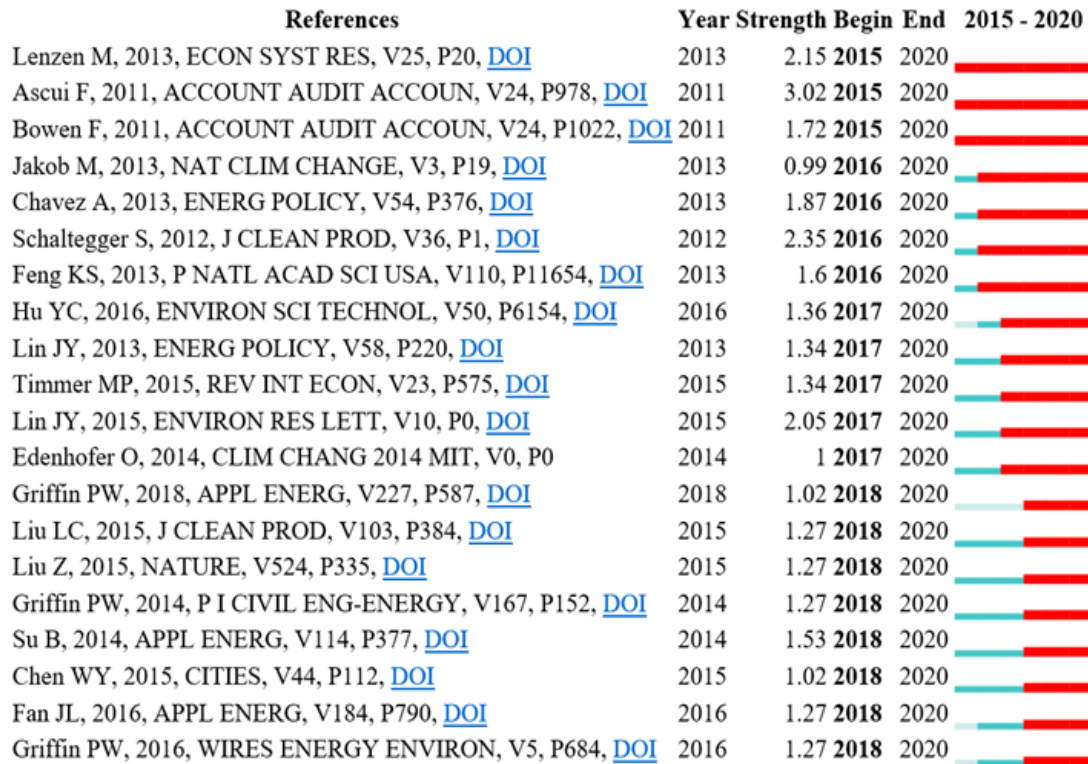


Figure 9. Co-citation articles burst in carbon accounting.

## Conclusions and Deficiencies

Based on the theoretical knowledge and methods of scientometrics, in this study, CiteSpace software was used to visually analyze the journal papers published in the Web of Science core database from 2015 to 2020 with the keyword “carbon accounting”, and draw the following conclusions:

1. In terms of the number of published papers, despite some fluctuations, the research literature on carbon accounting has shown an upward trend in recent years.

2. This study used collaborative analysis to determine the main strengths of carbon accounting research.

- Countries: The results showed that the United States, China, Australia, and other countries published the most papers.

- Institutions: Chinese Academy of Sciences, The University of Leeds, and The Beijing Institute of Technology were major research institutes.

- Journals: The most cited journal was *Journal of Cleaner Production*, followed by *Energy Policy*, *Environmental Science & Technology*, *Ecological Economics*, and *Proceedings of the National Academy of Sciences of the United States of America*.

- Authors: Some collaborative teams that made great contributions were formed, such as Griffin's team



from the University of Bath in England, Turvey's team from Monash University in Australia, Yang's team from the South China University of Technology.

Although there are a large number of scholars and institutions dedicated to carbon accounting, there is a lack of cooperation between authors and institutions. Therefore, the cooperation between authors should be strengthened to promote the development of carbon accounting research.

3. This study uses keyword bursts and co-cited literature bursts to analyze research hotspots and frontier research. The results show that the most intense keywords are "Policy", "Carbon Emissions", and "Low-Carbon Economy", and the longest keywords are "The United States", "Equation", "Allometric Equation" and "Low-Carbon Economy". We found that Policy, Low-Carbon Economy, and other topics represent the academic frontier.

In the future, this study still has some room for improvement: (1) Since only the core database of Web of Science is used and the source of the literature is not comprehensive, the analysis of this article is limited. Therefore, the data source will be further improved in future research; (2) The parameter setting may be insufficient during software operation; and (3) This research is only preliminary work, and further research should be conducted to fully understand the research progress and development trend of carbon accounting research.

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