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The Bibliometric Analysis of Low-Carbon Transition and Public Awareness

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Abstract: After the agreements of the Conference of the Parties, more and more countries announced plans to achieve net zero emissions over the coming decades and published new policies in response to the agreements. Public awareness is a crucial factor in achieving the goals of the agreements. Therefore, the study of public awareness/behavior toward the low-carbon transition is important. However, this topic lacks a comprehensive and systematic review. Thus, this study used bibliometric analysis, including performance analysis and scientific mapping analysis, to reveal research trends and clarify the status of studies in low-carbon transition and public awareness. We found that 95% of the literature on this topic was published from 2011 to 2022. Judging from keywords, the hotspots of this topic are "Sustainability", "Energy Transition", "Low-carbon Economy", and "Carbon Emission Reduction". Regarding the research field transition for this topic, environmental sciences have always been a core subject. Furthermore, economics, management, political science, and sociology have focused on this topic in recent years. Additionally, there are gaps between low-carbon policy and public awareness/behavior. Therefore, the frontier directions of low-carbon transition and public awareness include "low-carbon education", "policies with specific guidelines", and "worldwide collaboration".

Keywords: low-carbon transition; public awareness; low-carbon behavior

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1. Introduction

Climate change is the defining issue of our time on a global scale. The influence of climate change includes threats to food production and security [1–4], rising sea levels [5–7], increasing the risk of catastrophic flooding [8–10], reducing the ice sheet and glacier mass [11–13], and causing droughts [14–16]. According to the report from the Intergovernmental Panel on Climate Change (IPCC (Intergovernmental Panel on Climate Change)) and previous studies, human-induced climate change is also responsible for storms and extinctions [7,17–21]. In this urgent situation, we must take action.

"United Nations Framework Convention on Climate Change", "Kyoto Protocol", and "Copenhagen Accord" were formulated to prevent the threat and risks generated by climate change [22]. In order to mitigate climate change worldwide, the Paris Agreement was adopted by 196 parties at the UN Climate Change Conference (COP21) in 2015, which is a legally binding international treaty on climate change [23]. Its overarching goal is to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5 °C above pre-industrial levels" [23]. In order to limit global warming to 1.5 °C, greenhouse gas (GHG) emissions must decline by 43% by 2030 [23].

According to the UN (United Nations), carbon dioxide (CO_2) is the most abundant GHG, accounting for about two-thirds of all GHGs [15]. In recent years, many researchers have studied the possible options to reduce CO_2 emissions. Previous studies found that reducing CO_2 emissions is vital to mitigating climate change and achieving the low-carbon transition [24–32]. Studies found that CO_2 emissions from fossil fuel combustion are the main source of global climate change [33], and reducing demand for fossil fuels can directly contribute to the reduction of CO_2 emissions from waste disposal [34]. From an engineering point of view, CO_2 reduction options can be divided into three categories: (a) reduce energy intensity (energy saving) [35,36]; (b) reduce carbon intensity [37]; and (c) sequester carbon [37–41]. In addition, new energy is also a vital approach to achieving carbon neutrality [42]. Paustian et al. [43] found that reducing the frequency of bare fallow in crop rotations and increasing the use of perennial vegetation will increase the carbon stock of the soil. Lee et al. [44] found that green transportation and low-emission technology are the key aspects to balancing climate resilience and economic growth. Dietz et al. studied the influence of household low-carbon behaviors, and the results show that household actions can provide a behavioral wedge to reduce carbon emissions rapidly [45].

After the Paris Agreement, more and more countries announced their goal to achieve net zero emissions over the coming decades and also published new policies in response to the agreement. For example, the United Kingdom, Japan, and the Republic of Korea, along with 110 other countries, have pledged to reach carbon neutrality by 2050 [46–49], and China has pledged to achieve carbon neutrality by 2060 [50,51]. In order to achieve the carbon neutrality goal, the corresponding policies were formulated in many countries [52–54]. For example, China's energy policy promoted the social acceptance or public awareness of renewable energy [55,56].

As for the public's awareness/behavior response to policy, the "top-down" approach of telling the public "what to do" is confirmed to work ineffectively [57]. Although policy is a positive approach to encouraging low-carbon behavior, public awareness/behavior responses are also influenced by other factors [58,59]. That is to say, public awareness/behavior are variables that may delay the process of achieving the goal of the Paris agreement. In addition, there is a great gap between behavioral intention and actual actions [60]. A study found that awareness of climate change is widespread, but behavioral engagement is far lower [61]. Therefore, it is vital to study public awareness/behavior for the low-carbon transition.

Many studies have focused on the low-carbon transition and public awareness/behavior [62–70] However, this research topic lacks a comprehensive and systematic review. Therefore, this study analyzed the trends, progress, status, and hotspots of studies on low-carbon transition and public awareness/behavior through literature from the Web of Science (WoS) database, including countries/regions contribution analysis, institution contribution analysis, keyword analysis, and journal analysis. From the results of bibliometric analysis, this study obtains the countries/regions contributions, institution contributions, hot keywords, and highly productive journals of this research topic. Furthermore, this study indicated the gaps and future frontier directions for this research topic. These can contribute to comprehending the progress and content of this research topic and provide a guide, reference, and inspiration for low-carbon policies. Moreover, policymakers can formulate a suitable policy for low-carbon development based on the results of this study.

2. Data and Methods

2.1. Data

We collected the data for this study from the Web of Science Core Collection (WoSCC) database, which is one of the databases of the Web of Science (WoS). The WoSCC database includes Science Citation Index-Expanded (SCI-Expanded), Arts and Humanities Citation Index (AHCI), Emerging Sources Citation Index (ESCI), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index-Social Science and Humanities (CPCI-SSH), Book Citation Index-Science (BKCI-S), Book Citation Index-Social Sciences and Humanities

(BKCI-SSH), Conference Proceedings Citation Index-Science (CPCI-S), Emerging Sources Citation Index (ESCI), Current Chemical Reactions-Expanded (CCR-EXPANDED), and Index Chemicus (IC).

The literature data in this study were collected in February 2023. We selected and collected the literature data by using the following strategy: (a) The literature data was selected by the keywords that are related to "low-carbon transition" and "public awareness/behavior". The detailed search strategies were "TS = low-carbon AND awareness" OR "TS = low-carbon AND Lifestyle AND transition" OR "TS = low-carbon AND Lifestyle AND behavior" OR "TS = low-carbon AND behavior AND transition" OR "TS = low-carbon AND environmental education"; (b) only "Article" and "Review Article" literatures are included in this study; thus, only the literature data from peer-reviewed publications are collected; (c) only English literature publications were included in this study; and (d) this study obtained data from 1235 studies via the aforementioned process.

2.2. Methods

The bibliometric analysis in this study includes performance analysis and scientific mapping analysis, which can reveal research trends and clarify the current status of research. In this study, performance analysis evaluates the influence of studies from countries/regions, institutions, keywords, and journals. The scientific mapping analysis in this study encompasses the dynamics and relationships observed within the research. Therefore, this study conducted bibliometric analysis based on WoSCC data to evaluate publication trends, journal contributions, institutional contributions, and country contributions. Moreover, the frequency of specific keywords was analyzed through bibliometric analysis.

Microsoft Excel was used to analyze the general performance of publications. The results of the institution contribution analysis and highly productive journal analysis were obtained from the WoSCC. The analysis and visualization of keywords were conducted by Bibliometrix, which is an R-tool for comprehensive science mapping analysis. Countries/regions contribution analysis and visualization of the aforementioned studies were analyzed by CiteSpace 6.1 R3 (literature visual analysis software) Figure 1.

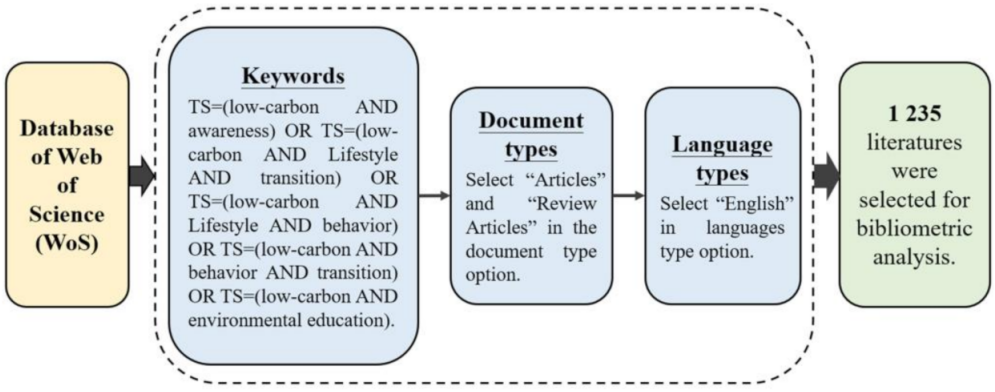

Figure 1. Flow chart of literature data collected for the study of low-carbon transition and public awareness/behavior. Note: TS means topic tag, which searches terms in title, abstract, author keywords, and keywords plus fields.

3. Results

3.1. General Performance of Publications

There were 1235 studies of low-carbon transition and public awareness/behavior collected from WoSCC. All the selected studies were cited 28,083 times in total. There were an average of 22.59 citations per piece of literature. Moreover, 33 studies were recorded as highly cited. The trend in the number of studies on the topics of low-carbon transition and public awareness/behavior can be seen in Figure 2.

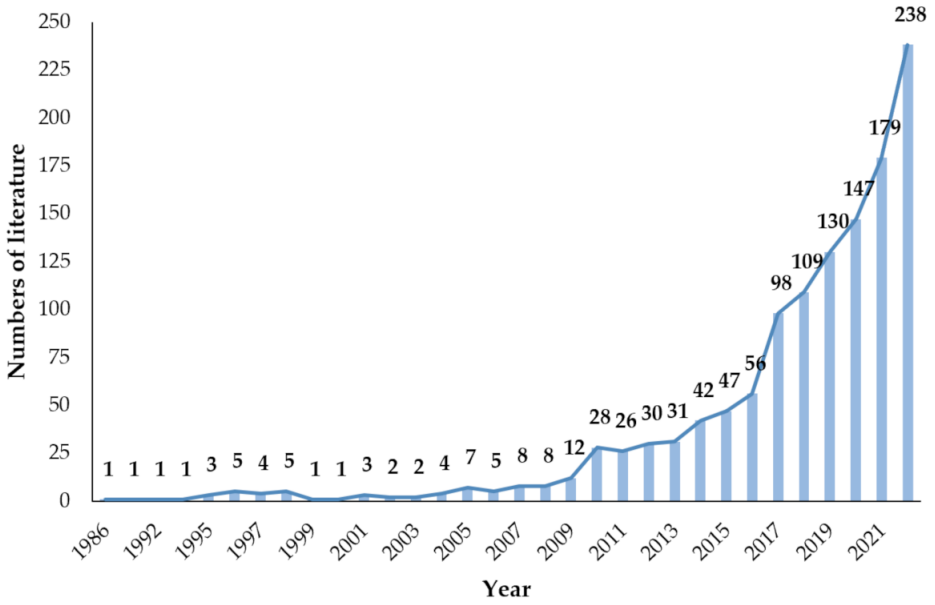

Figure 2. The trend of the number of annual publications for the study of low-carbon transition and public awareness/behavior.

As we can see in Figure 2, the study of low-carbon transition and public awareness/behavior drew a small amount of attention between 1994 and 1997 and 2000 and 2003. The number of publications has increased gradually since 2004. There has been a rapid growth trend in publications since 2016. In addition, there was the largest increase in the number of publications from 2021 to 2022. It is indicated that studies on the topics of low-carbon transition and public awareness/behavior have gradually become more popular since 2004. Since 2010, the study of low-carbon transition and public awareness/behavior has drawn high amounts of attention and become a popular research topic in the field of low-carbon.

3.2. High-Productivity Journal Analysis

Academic journals play an important role in the inheritance and dissemination of scientific achievements. Thus, they are essential for scientific research. There are 202 academic journals that published low-carbon transition and public awareness/behavior-related papers in this study. The top 10 journals on the study of low-carbon transition and public awareness/behavior are listed in Table 1, which includes the impact factors, SCImago journal rank, journal citation reports (JCR), and categories. Eight out of the top 10 journals were in JCR's first quarter.

Table 1. Top 10 journals for the study of low-carbon transition and public awareness/behavior.

Rank	Publications	Number of Publications	IF 2022	SJR 2022	JCR 2022	Categories
1	*Journal of Cleaner Production*	90	11.072	Q1	Q1	Environmental Science (SCIE)
2	*Sustainability*	74	3.889	Q2	Q1	Environmental Science (SSCI)
3	*Energy Policy*	52	7.576	Q1	Q1	Environmental Science (SCIE)
4	*Energies*	31	3.252	Q2	Q3	Energy and Fuels (SCIE)
5	*Materials Science and Engineering A: Structural Materials: Properties, Microstructure, and Processing*	29	6.044	Q1	Q1	Metallurgy and Metallurgical Engineering (SCIE)
6	*Energy Research and Social Science*	26	8.514	Q1	Q1	Environmental Science (SSCI)
7	*Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science*	25	2.726	Q1	Q2	Metallurgy and Metallurgical Engineering (SCIE)
8	*International Journal of Environmental Research and Public Health*	23	4.614	Q1	Q1	Public, Environment, and Occupational Health (SSCI)
9	*Renewable and Sustainable Energy Reviews*	21	16.799	Q1	Q1	Multidisciplinary Sciences (SCIE)
10	*Applied Energy*	18	11.466	Q1	Q1	Energy and Fuels (SCIE)

Note: IF: impact factors; SJR: SCImago journal rank; JCR: journal citation reports.

3.3. Keywords and Hotspot Analysis

The focus and content of the study of low-carbon transition and public awareness/behavior are analyzed through keyword analysis. The top 20 keywords for the study of low-carbon transition and public awareness/behavior can be seen in Figure 3. Additionally, Table 2 shows the top 20 keywords and their frequency, which is based on the study of low-carbon transition and public awareness/behavior. Moreover, Figure 4 illustrates the top 20 keywords with the strongest citation bursts and their popular periods.

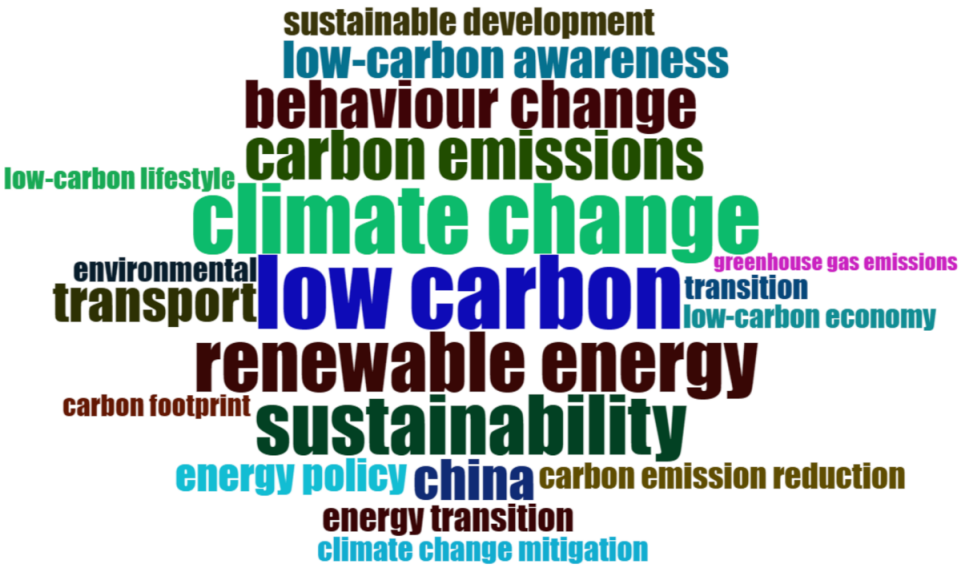

Figure 3. Word cloud of keywords for the study of low-carbon transition and public awareness/behavior. Note: the keyword font size in the diagram represents the frequency of the keywords during searches.

Table 2. Top 20 keywords for the study of low-carbon transition and public awareness/behavior.

Rank	Keywords	Frequency	Rank	Keywords	Frequency
1	Low Carbon	77	11	Energy Transition	29
2	Climate Change	73	12	Sustainable Development	29
3	Renewable Energy	62	13	Carbon Emission Reduction	27
4	Sustainability	62	14	Climate Change Mitigation	25
5	Carbon Emissions	51	15	Environmental	25
6	Behavior Change	50	16	Transition	25
7	China	43	17	Low-carbon Economy	24
8	Transport	43	18	Carbon Footprint	23
9	Low-carbon Awareness	39	19	Low-carbon Lifestyle	23
10	Energy Policy	34	20	Greenhouse Gas Emissions	18

The top 20 keywords on the study of low-carbon transition and public awareness/behavior include "Low Carbon", "Climate Change", "Sustainability", "Energy Transition", "Low-carbon Awareness", "Energy Policy", "Behavior change", "Low-carbon Economy", "Transport", "Environmental", "Renewable Energy", "Carbon Emission Reduction", "Sustainable Development", "Transition", "Climate Change Mitigation", "Carbon Footprint", "Carbon Emissions", "China", "Low-carbon Lifestyle", and "Greenhouse Gas Emissions".

According to the top 20 keywords, the focus of the study on low-carbon transition includes energy transition and economic transition, which should be guided by related policy. In order to decrease carbon emissions and mitigate climate change, researchers explored possible solutions, which include electric vehicles, introducing renewable energy, adapting to a low-carbon economy, and enhancing energy efficiency. In addition, researchers also focused on sustainability and biodiversity.

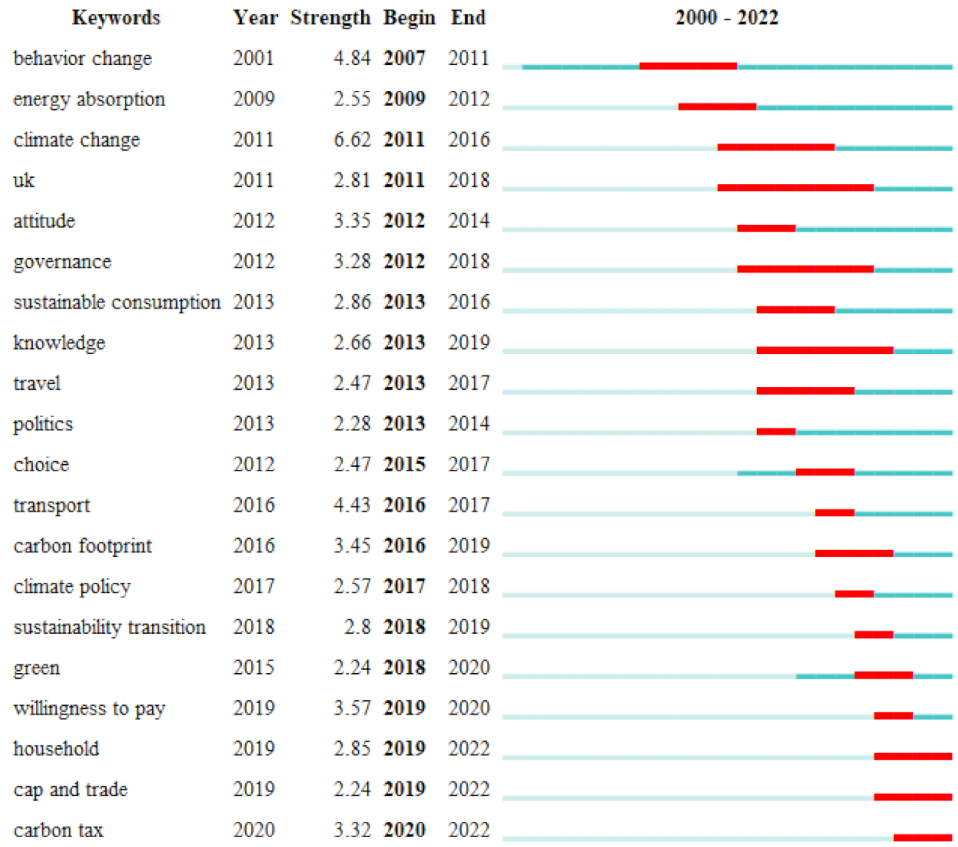

Figure 4. Top 20 keywords with the strongest citation bursts. Note: the year represents the starting year when keywords are mentioned.

3.4. Institution Contribution Analysis

Institutional contributions are critical to understanding the research intensity and composition of studies in specific fields. The performance of the top 10 institutions with the most publications on the study of low-carbon transition and public awareness/behavior is shown in Table 3. Research achievements in this field predominantly come from research institutes and universities. In addition, the top three institutions with high publications are as follows: the Chinese Academy of Sciences, the University of London, and Tianjin University.

Table 3. Performance of the top 10 institutions with the most publications within the study of low-carbon transition and public awareness/behavior.

Rank	Institution	Country	Number of Publications				Total
			1900–2005	2006–2010	2011–2015	2016–2022	
1	Chinese Academy of Sciences	China	0	4	6	30	38
2	University of London	UK	0	0	6	21	27
3	Tianjin University	China	0	0	8	19	27
4	Centre National de la Research Scienfique	Spain	2	3	1	17	23
5	Northeastern University	China	1	2	0	17	20
6	Tsinghua University	China	0	3	4	14	21
7	University College London	UK	0	1	4	14	19
8	United States Department of Energy	USA	4	0	5	10	19
9	Indian Institute of Technology System	India	0	2	3	13	18
10	University of Oxford	UK	0	0	4	14	18

3.5. Countries/Regions Contribution Analysis

The status of the low-carbon transition and public awareness/behavior were studied in various countries/regions. The geographical distribution and co-citation network for

the study of low-carbon transition and public awareness/behavior are illustrated, as seen in Figure 5. According to the result, the top three countries with the highest number of research publications are China, the United Kingdom (UK), and the United States (US). Moreover, as for research collaboration, China, the US, the UK, Australia, the Netherlands, and Germany have exhibited strong causal links with other countries. This shows that, on these research topics, researchers in these six countries collaborated closely with researchers in other countries, which further contributed to the increase in publications.

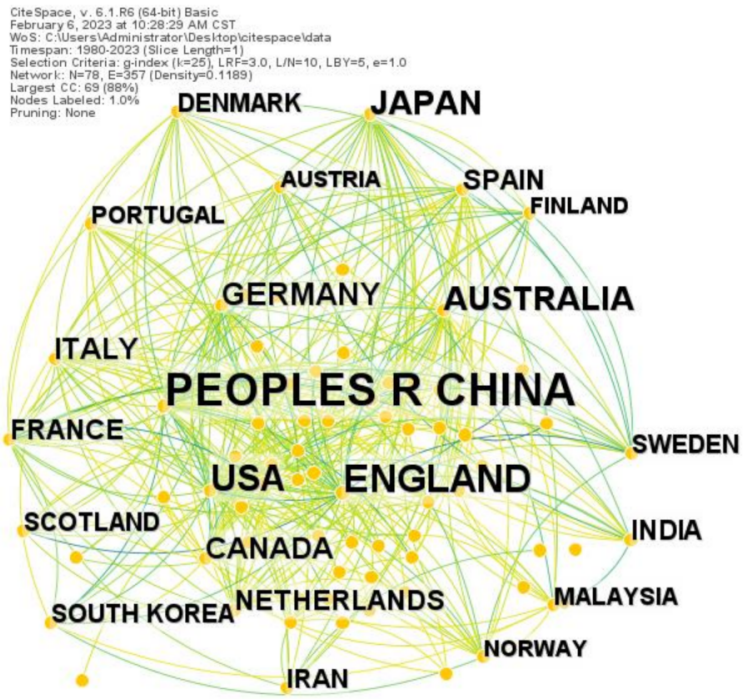

Figure 5. The geographical distribution and co-citation network for the study of low-carbon transition and public awareness/behavior. Note: the size of the label font in the figure represents the number of published documents, and the link between nodes represents the cooperative relationship between countries/regions.

The top 20 countries/regions with the most publications on the study of low-carbon transition and public awareness/behavior, as well as their whole and per capita publication numbers in 2022, are shown in Table 4. There were more than 100 publications each in China, the UK, and the US. Additionally, the top five countries with the highest number of publications are China, the UK, the US, Australia, and Japan. These results indicate that these countries have a wealth of high intensity focus on this research field and also have lots of publications. In addition, judging by the starting year of the research publications, the UK, the US, Japan, France, Spain, Denmark, and Finland all started the research on low-carbon transition and public awareness/behavior before 2000. This reflects the fact that these seven countries started research on this study topic much earlier than other countries. According to the per capita number of publications in 2022, the top three are Australia, the Netherlands, and the UK, which indicates that a relatively high percentage of researchers pay attention to this study topic in these countries.

Table 4. Top 20 countries/regions with the most publications surrounding the study of low-carbon transition and public awareness/behavior.

Rank	Country	Number of Publications	Starting Year	Number of Publications in 2022	Per Capita Number of Publications in 2022 (N/Million People)
1	China	499	2005	133	0.093
2	UK	195	1998	25	0.369
3	USA	142	1998	16	0.047
4	Australia	68	2008	13	0.492
5	Japan	66	1995	11	0.089
6	Germany	60	1998	7	0.084
7	Canada	42	2010	7	0.180
8	Italy	40	2008	6	0.102
9	France	38	1997	7	0.180
10	Netherlands	38	2001	8	0.454

Note: N represents the number of publications.

Figure 5 and Table 4 show the geographical distribution of publications for the study of the low-carbon transition and public awareness/behavior. According to the results, seven of the top ten countries/regions are located in North America and Europe, which indicates that this topic of study is conducted on these continents. Excepting the continents of North America and Europe, China (499), Australia (68), and Japan (66) are another three countries with a high number of publications on these research topics. Furthermore, within their respective continents, the quantity of research publications in China, Australia, and Japan is higher than in other countries.

4. Discussion

4.1. Research Trends, Development, and Hotspots

According to the bibliometric analysis results, studies on the topic of low-carbon transition and public awareness/behavior gradually became more popular in 2004, received high amounts of attention in 2016, and thereafter became a popular research topic in the fields of low-carbon. This may be because of the Paris Agreement in 2015, which drew strong attention to climate change worldwide, and then low-carbon became a popular topic in many fields.

According to the number of research publications, China, the UK, the US, Australia, and Japan have a wealth of high intensity focus on this research field. This may be in response to the Paris Agreement. For example, the United Kingdom, Japan, and many other countries have pledged to reach carbon neutrality by 2050 [46–49], and China has pledged to achieve carbon neutrality by 2060 [50,51]. In order to achieve the carbon neutrality goal, the corresponding policies were also formulated in many countries [52–54]. For example, China's energy policy promoted social acceptance or public awareness of renewable energy [55,56]. In addition, researchers are supported to study low-carbon transitions and public awareness/behavior in these countries. For example, researchers in China were encouraged and rewarded to study this topic and apply the findings to the policy-making process, which is a benefit to the low-carbon transition. Therefore, there are more publications than in any other country. However, publication numbers cannot represent the actual achievements of carbon emissions reduction in these countries since the benefits of low-carbon actions take time to be shown.

Additionally, according to the starting year of research publications, the UK, the US, Japan, France, Spain, Denmark, and Finland all started the research on low-carbon transition and public awareness/behavior earlier than other countries. According to the results of keyword analysis, energy transition and economic transition were the main study foci of the low-carbon transition.

According to Figure 4, behavior change was focused on by researchers in 2001, and it became a study hotspot between 2007 and 2011. In addition, researchers paid constant attention to behavior change from 2001 to the present day. Thus, behavior change should

be the key to achieving a low-carbon transition. As we can see, since climate change started becoming a popular study topic, researchers from the United Kingdom paid attention to it in the same year and studied the low-carbon transition and public awareness/behavior actively from 2011 to 2018. Since 2012, governments have been involved in this topic, and low-carbon policies have been formulated. Low-carbon technologies were studied soon after, such as low-carbon transport/travel, low-carbon education, carbon footprint reduction, and sustainability transition. Additionally, the public's willingness to pay for low-carbon products is also studied. From 2019 to 2022, household carbon emissions, carbon cap and trade, and carbon tax became the study hotspots.

Regarding the research filed for the study of low-carbon transition and public awareness/behavior (Figure 6), from 1900 to 2000, there were not many research fields paying attention to low-carbon transition and public awareness/behavior studies, just economics and environmental studies, and each only had one publication. From 2001 to 2010, the number of research fields increased, and environmental studies/sciences (19) ranked first. Some fields that did not appear in rankings from 1900 to 2000 were added to the ranking, including energy fuels, green sustainable science and technology, engineering environmental sciences, business, geography, management, and transportation. Thus, the main study focus of this period is new energy, carbon emissions reduction, low-carbon policy, and transportation footprint. From 2011 to 2022, environmental studies/sciences (638) still ranked the highest and have increased massively in number. Green sustainable science and technology ranked second (229); the following two are engineering environmental (111), and economics (90). Additionally, public environmental occupational health, urban studies, political science, sociology, educational research, communications, and development studies were added to the rankings. As we can see, the study of low-carbon transition and public awareness/behavior is getting more attention in environmental studies/sciences and has become a study topic in so many other fields in recent years.

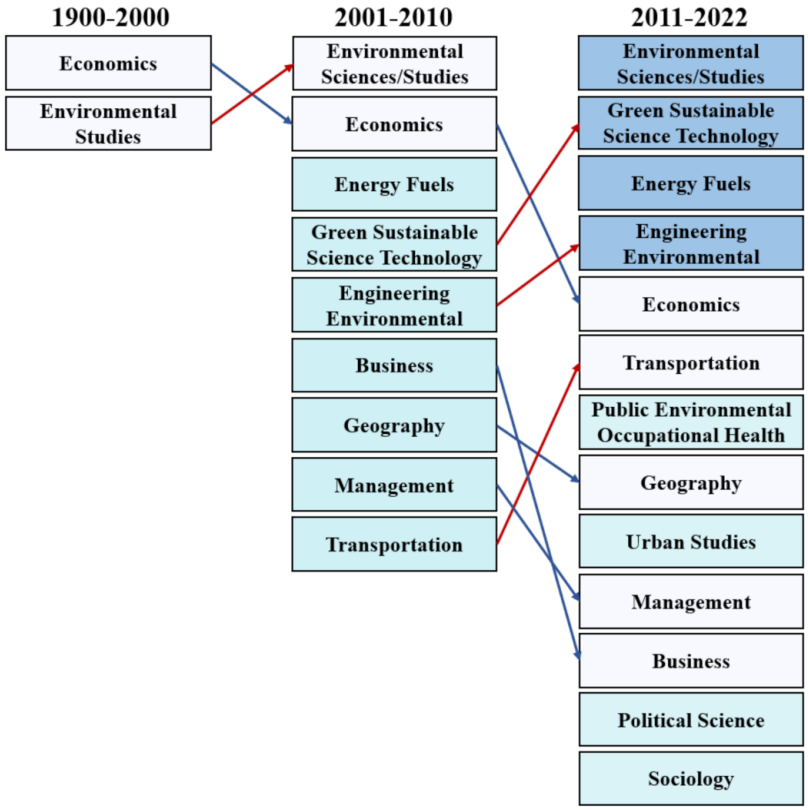

Figure 6. Research filed on transition for the study of low-carbon transition and public awareness/behavior.

A low-carbon energy transition is important to mitigate climate change impacts and temperature rises [62]. Adopting alternative technologies for fossil energy and improving energy efficiency are possible technical directions and options to reduce carbon emissions [33]. Previous studies found that 70% of CO_2 emissions (directly and indirectly) are from households; energy use at home, transportation options, and diets will have an effect on households' CO_2 footprint [63]. Peng et al. analyzed neighborhood residents' cognition of and participation in low-carbon behaviors. The results showed that neighborhood residents get involved in low-carbon behaviors through home energy conservation (HEC), efficient resource consumption (ERC), and recycling habits (RH) [64].

Environmental education has a positive impact on low-carbon behavior through pollution control and enhances green consumption intentions through residents' environmental awareness [65]. Previous studies found that the influence of awareness and personal/social norms is as important as monetary factors [63]. Hu et al. also found that attitude, perceived behavior control, environmental concern, and perceived moral obligation have a positive impact on low-carbon travel behavioral intention [66]. Thus, environmental education is a great approach to improving people's awareness of low-carbon behaviors. Additionally, personal and social norms have a significant influence on low-carbon behaviors. Niamire et al. found that behavioral factors (e.g., knowledge and awareness) have an effect on personal norms; a higher level of knowledge and awareness about environmental and climate issues comes along with a higher level of personal norms [63]. Chen and Li investigated the influence factors of low-carbon behavior and found that personal and social norms had a stronger impact on public low-carbon behavior than private low-carbon behavior [67]. Moreover, demographic factors (i.e., gender, education, and income) will impact low-carbon behavior [67]. Additionally, although some people have an awareness of low-carbon behavior, it is still hard for them to take proper action if they do not have knowledge of the carbon footprint of their behavior. Thus, there should be information provided to inform people of the carbon footprint of their decisions [71].

In sum, environmental education is a great way to improve society's awareness of low-carbon behavior [68,69]. Thus, there should be some environmental education projects conducted in the whole society and in such groups as neighborhoods and households.

4.2. Future Work and Frontier Directions

According to previous research, there are gaps between low-carbon-related policy and public awareness/behavior, which will postpone the progress of the low-carbon transition. First of all, there are many low-carbon policies formulated, but it is still a challenge to put them into action. For example, many policies are top-down demands within abstract and general concepts and usually aim for the benefits of the whole country or a larger range of populations, which seem remote from public personal life. Thus, it is difficult for the public to accept changes that are not closely related to their own interests. Therefore, low-carbon education needs to be invested in to let the public learn about their close relationship with the low-carbon transition and to explain the policy for guiding the public's low-carbon behavior. Additionally, policies are also expected to be more precise, such as providing specific carbon emission reduction measures and low-carbon behavior guidelines. Secondly, new low-carbon technologies should be introduced to the public more efficiently. For example, provide new low-carbon products with purchase discounts and reward the company for using low-carbon energy so as to guide the public to accept new energy or low-carbon technology products. Finally, the low-carbon transition needs collaboration worldwide. It is not the mission of one industry, country, or continent, but a human mission. Thus, the low-carbon transition is a revolution within the co-thinking, co-design, and co-action of every person, household, industry, country, and continent. In general, the frontier issues/directions of low-carbon transition and public awareness include "low-carbon education", "policies with specific guidelines", and "worldwide collaboration".

4.3. Strengths and Limitations

This study analyzed the trends and status of the research on low-carbon transition and public awareness/behavior through bibliometric analysis. In addition, this study systematically summarized the research progress on low-carbon transition and public awareness/behavior in previous studies, including factors that have an effect on low-carbon behavior, low-carbon transition mechanisms, and so on.

Finally, because English is the most widely used language for academic publications worldwide, this study only included publications in English. The limitation of this study is that it only analyzed English literature collected from the WoSCC database. Moreover, this study only considered peer-reviewed publications (i.e., "Article" and "Review Article") on low-carbon transition and public awareness/behavior. In addition, the search terms might have excluded other relevant literature.

5. Conclusions

After the Paris agreement, studies on low-carbon transition and public awareness/behavior became research hotspots in the low-carbon field. As a response, this study conducted bibliometric analysis to analyze the trends, progress, status, and hotspots of studies on low-carbon transition and public awareness/behavior, including country/region contribution analysis, institution contribution analysis, keyword analysis, and highly productive journal analysis.

This study analyzed the trends and status of the research on low-carbon transition and public awareness/behavior through bibliometric analysis. In addition, this study systematically summarized the research progress on low-carbon transition and public awareness/behavior in previous studies, including factors that have an effect on low-carbon behavior, low-carbon transition mechanisms, and so on. For example, researchers paid constant attention to behavior change from 2001 to the present day. Since 2012, governments have been involved in this topic, and low-carbon policies have been formulated. From 2019 to 2022, household carbon emissions, carbon cap and trade, and carbon tax became the study hotspots. From 1900 to 2000, there were not many research fields that paid attention to low-carbon and public awareness/behavior studies. From 2001 to 2010, there were publications in environmental studies/sciences, energy fuels, green sustainable science and technology, engineering environmental sciences, business, geography, management, and transportation fields. From 2011 to 2022, the publication numbers of low-carbon transition and public awareness/behavior studies have increased massively. Moreover, public environmental and occupational health, urban studies, political science, sociology, educational research, communications, and development studies were also focused on this topic.

Policymakers need to advocate for the carbon reduction benefits of urban forms and lifestyles and formulate implementable policies accordingly. A low-carbon society is feasible if widespread awareness is achieved. This is also in line with the trends in "public participation", "co-design", and "act locally". Regarding the frontier issues/directions of low-carbon transition and public awareness, low-carbon education needs to be invested in to let the public learn about their close relationship with low-carbon transition and to explain the policy for guiding the public's low-carbon behavior. Additionally, policies are also expected to be more precise, such as providing specific carbon emission reduction measures and low-carbon behavior guidelines. Moreover, new low-carbon technologies should be introduced to the public more efficiently. Finally, the low-carbon transition needs collaboration worldwide.

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