The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2024

Volume 27, Pages 1-15

IConTech 2024: International Conference on Technology

The Trends in Carbon Emissions, Climate Change, Carbon Footprint, Carbon Tax, Green Technology Diffusion from 2015 to 2024: A Bibliometric and Visual Analysis

Hamide Ozyurek
OSTIM Technical University

Abstract: The aim of this study is to present a comprehensive review of carbon emissions, carbon footprint, carbon tax, carbon emissions pricing, trade openness, GDP per capita, R&D investment, green technology diffusion, urbanization, energy consumption, renewable energy, industrialization, and climate change research. Between 2015 and 2024 (limited to March 21st, 2024), we screened 5002 documents from the Web of Science and subjected them to analysis using the VOSviewer application and R programs. Biblioshiny (an R-based graphical interface of Bibliometrix) has been utilized to conduct performance and scientific mapping analyses for this study due to its proven effectiveness in building clear visualizations of literature using text mining functionality; and revealing the conceptual and intellectual structure of the field. The analysis revealed the publication trends and emerging themes in the research landscape. For the purposes of this research, the database was limited to open-access articles published in English, under the categories of business, business finance, economics, and environmental studies, indexed in the Social Sciences Citation Index (SSCI) and the Science Citation Index (SCI-Expanded). Advanced bibliometric techniques, such as co-citation analysis, co-occurrence of keywords, co-word analysis, scientometric mapping, are included in the methodology. The top five most frequently used keywords with the highest connection power are climate change, renewable energy, economic growth, energy, and sustainability respectively. This research has revealed that the journals with the highest number of articles in this field and the highest number of citations were Energy Policy, Energy Economics, Ecological Economics, Economic Research-Ekonomska Istrazıvanja, Environmental & Resource Economics, Technological Forecasting, and Social Change. In terms of the number of articles and citations by country in these fields, the USA, England, Germany, China, and the Netherlands ranked the highest. This research provides information gaps and research opportunities in the field, and contributes to shaping future research paths in this area.

Keywords: Carbon tax, Carbon emissions, Climate change, Carbon footprint, Green technology diffusion

Introduction

Climate change emerges as a pressing concern worldwide, evoking serious apprehensions. With its ramifications including global warming and the degradation of natural habitats, climate change stands as one of humanity's and the world ecosystem's most formidable challenges. In combating this global threat, strategies such as lowering carbon emissions, reducing carbon footprints, and embracing renewable energy sources are pivotal. These strategies form the foundational steps towards a sustainable future, crucial not only for environmental preservation but also for economic and social well-being.

In particular, the reduction of carbon emissions and carbon footprint aims to mitigate the effects of climate change by regulating greenhouse gas levels in the atmosphere. Research on this topic underscores the significance of policy measures geared towards lowering carbon emissions and promoting the utilization of renewable energy sources (Wang et al., 2020; Issa & In'airat, 2024).

Simultaneously, the concept of carbon footprinting has also garnered significant attention today. A carbon footprint serves as a metric to gauge the quantity of greenhouse gases generated by individuals, organizations, or nations, evaluating their environmental impacts. The escalating temperatures have a detrimental effect on the growth of gross domestic product (GDP) (Abidoye & Odusola, 2015).

The concept of renewable energy has been at the forefront of extensive debates due to its pivotal role and impacts on energy policies. There have been ongoing discussions even on the definition and framework surrounding renewable energy (Harjanne & Korhonen, 2019). Renewable energy is regarded as a focal point in global politics, with arguments suggesting that this transition could potentially bring about a structural transformation in the world order. It is emphasized that renewable energy has the potential to reshape models of economic growth and military competition. Scholars delve into how the shift towards renewable energy carries implications across various domains such as energy policy, economic growth, global politics (Xie et al., 2019), and climate change (Bastarrica et al., 2023; Grubler et al., 2021; Winkler et al., 2022). Therefore, comprehending the significant dimensions of the transition to renewable energy and evaluating its impacts play a crucial role in shaping future energy policies and societal transformations (Koirala et al., 2023)

In this context, this paper offers a thorough literature review and delves into critical concepts including carbon emissions, carbon footprint, carbon tax, emission pricing, trade openness, R&D investments, green technology diffusion, renewable energy, and climate change. These concepts are currently under intense debate in both academic circles and among policymakers, given their crucial roles in fostering both environmental sustainability and economic growth. 5002 documents from the Web of Science between 2015 and 2024 were analyzed using the VOSviewer application and R program. Biblioshiny, Bibliometrix's R-based graphical interface, was utilized to uncover trends and emerging themes in research concerning strategies to reduce carbon emissions and combat climate change. With its text mining functionality, Biblioshiny generates clear visualizations of the literature and is considered an effective tool for revealing the conceptual and intellectual structure of the field.

The research was carried out within the categories of business, business finance, economics, and environmental studies, which encompass open access English language articles. The methodology employed advanced bibliometric techniques including co-citation analysis, keyword co-occurrence frequency, word analysis, and scientific mapping. These techniques span a broad spectrum of studies focusing on policy strategies for carbon emissions, the diffusion of renewable energy sources, the relationship between economic growth and environmental sustainability, and other related topics.

Finally, this study aims to pinpoint the existing gaps in research concerning climate change, carbon emissions, green technology, and economic growth, and to outline a roadmap for future research directions. By offering a comprehensive review of the literature in this field, it seeks to contribute to the identification and implementation of effective policy strategies to combat climate change.

The study aims to address this need by discussing the following three broad research questions (RQs):

RQ1. What is the current state of research on Carbon Emissions, Climate Change, Carbon Footprint, Carbon Tax, Green Technology Diffusion?
RQ2. Which research contexts and themes in this area have been explored in the existing literature?
RQ3. What avenues or themes could be addressed in future research?

The findings of the study can facilitate the formation of a comprehensive understanding of this evolving research landscape and contribute to the advancement of both theory and practice. The results from the bibliometric analyses provide scholars with a deeper insight into the complexity and interdisciplinary character of previous research in the field. Additionally, through content analysis, various agendas for future research have been identified that scholars can explore.

Methodology

Database and Research Strategy

Bibliometric analysis, introduced by Pritchard (1969), has emerged as a valuable scientific method for comprehending the temporal evolution of a research field from a multidisciplinary standpoint. This method

enables a thorough understanding of a research field, mapping its boundaries, identifying influential authors, and highlighting new directions for future research (Tandon et al., 2021).

The selection of keywords was informed by a preliminary review of the existing literature. A search was conducted in Web of Science using the keywords 'Climate Change' and 'Carbon Footprint'. The first 1000 studies retrieved were then analyzed in VOSviewer to identify additional terms commonly employed in the literature. As a result of this initial search, terms such as 'carbon emissions', 'carbon emissions price', and 'carbon tax' were also deemed valid keywords. To further validate the selected keywords, we convened a panel of three experts from academia with extensive publications in the field of Climate Change, following the methodology outlined by Tandon et al. These experts were briefed on the research questions (RQs) and tasked with reviewing the relevance of the chosen keywords. Based on their recommendations, the following keywords were included in the database search: 'trade openness', 'GDP per capita', 'R&D investment', 'green technology diffusion', 'urbanization', 'energy consumption', 'renewable energy', and 'industrialization' (Figure 1). This information is summarized in Table 1, providing key details about the data.

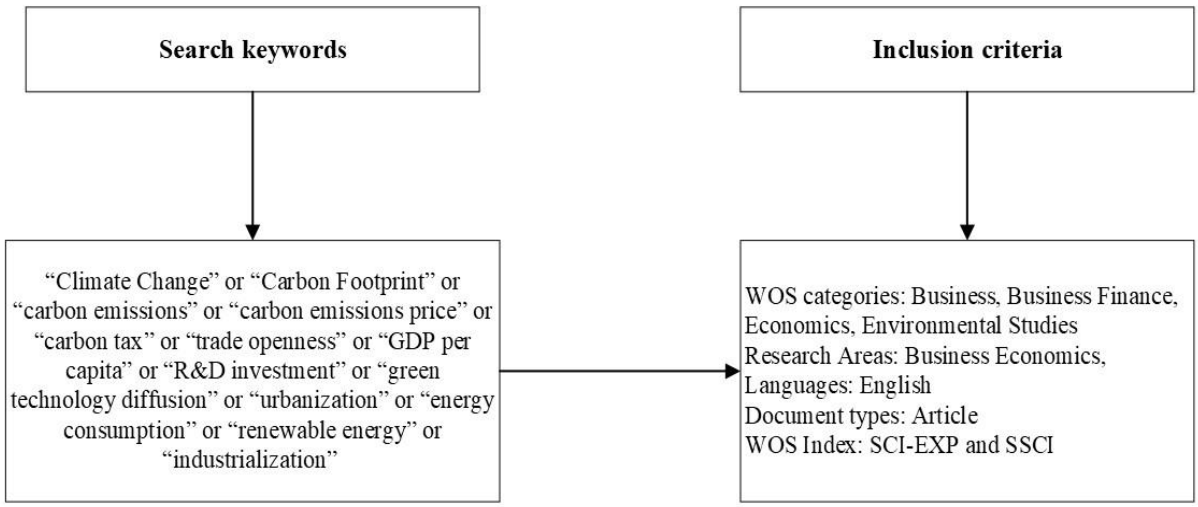

Figure 1. Search keywords and inclusion criteria

Table 1. Main information about data

Description	Results
Timespan	2015:2024
Sources (Journals, Books, etc)	433
Documents	5002
Keywords Plus (ID)	6395
Author's Keywords (DE)	12207
Average citations per doc	23.68
Authors	11572
Authors of single-authored docs	603
Article	4922
Book Chapter	23
Article; Proceedings Paper	57
References	213472
Single-authored docs	646
Co-Authors per Doc	3.01
International co-authorships %	46.12

Analysis and Findings

Publication by Year

The total number of studies in the Web of Science (WoS) database with the selected keywords is 5002, as depicted in Figure 2. It is evident that the number of studies in this field has been steadily increasing since 2015

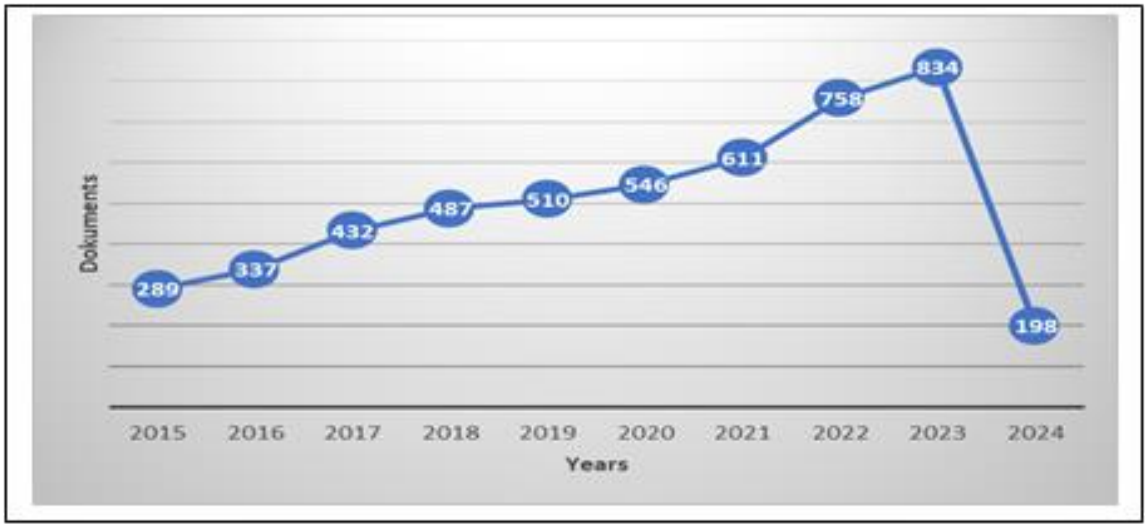

Figure 2. Annual scientific production

The techniques of bibliographic matching, co-occurrence, co-authorship, citation, and co-citation analyses were employed to address RQ1 and construct a comprehensive profile of the research landscape in this field.

Bradford Law and Journal Index Analysis

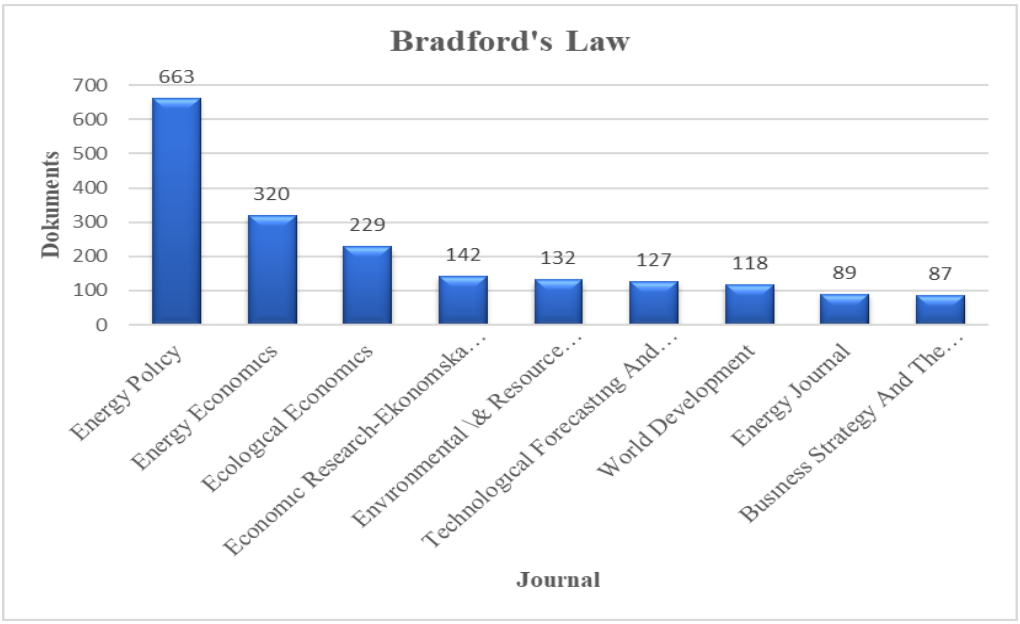

Figure 3. Bradford law

Table 2. Journal index

Journal	h_index	g_index	m_index	TC	NP
Energy Policy	76	112	7,6	23094	663
Energy Economics	59	100	5,9	12456	320
Ecological Economics	41	63	4,1	5751	229
World Development	41	63	4,1	4663	118
Technological Forecasting and Social Change	39	63	3,9	4554	127
Economic Research-Ekonomska Istrazivanja	28	40	2,8	2158	142
Business Strategy and The Environment	25	44	2,5	2144	87
Journal Of Environmental Economics and Management	25	42	2,5	2032	79
Environmental & Resource Economics	24	41	2,4	2127	132

TC: Total Citation; **NP:** Number of Production

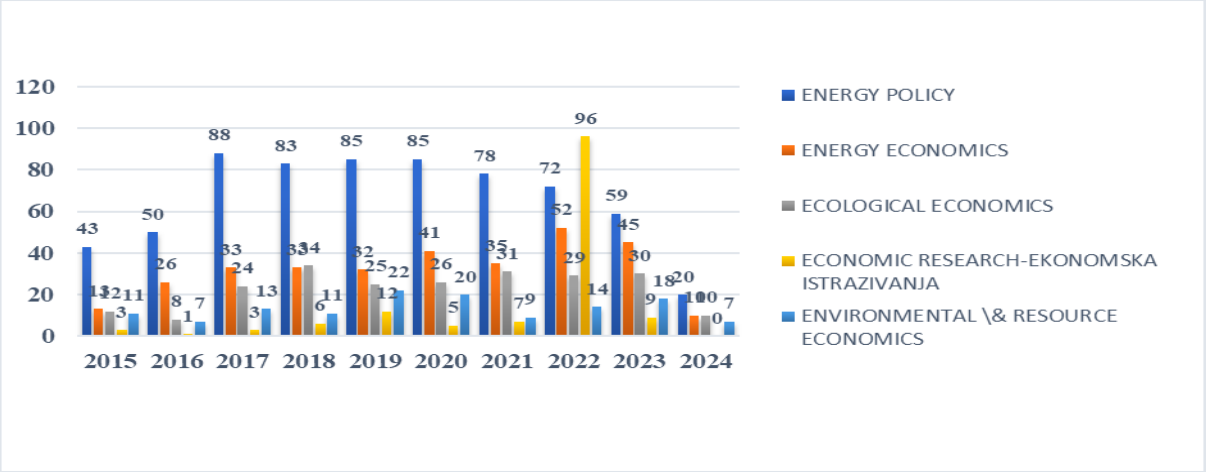

Figure 4. Number of articles published in sources by years

Author and Organization Publishing Trends

Table 3 displays the most cited institutions and authors. Out of 4,119 institutions that published in the research area, 596 institutions have contributed more than 5 publications

Table 3. Citation analysis for top 10 organizations and authors

Id	Organization	Documents	Citations	Author	Documents	Citations
1	Oxford University	96	2693	Shahbaz, Muhammad	26	4774
2	Cambridge University	84	2506	Sovacool, Benjamin K.	17	862
3	Swiss Fed Inst Technol	76	1954	Paramati, Sudharshan Reddy	16	804
4	Vrije Univ Amsterdam	74	1424	Van Der Ploeg, Frederick	16	246
5	UCL	72	2363	Shi, Xunpeng	14	650
6	Utrecht University	69	2028	Managi, Shunsuke	12	652
7	World Bank	61	1288	Apergis, Nicholas	11	560
8	NBER	59	2714	Rausch, Sebastian	11	213
9	Sussex University	59	2543	Edenhofer, Ottmar	10	146
10	Leeds University	56	2211	Mahalik, Mantu Kumar	10	1382

Publishing Activity by Country

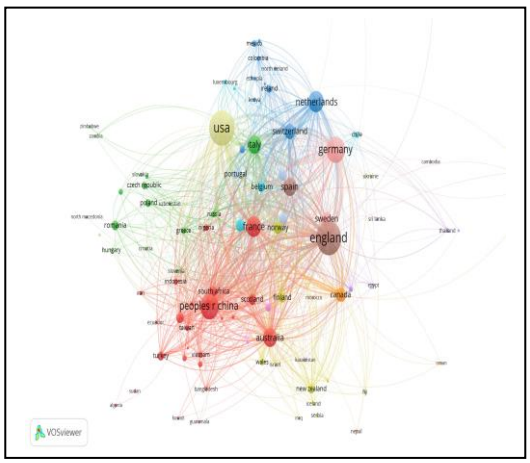

Figure 5. Countries analysis

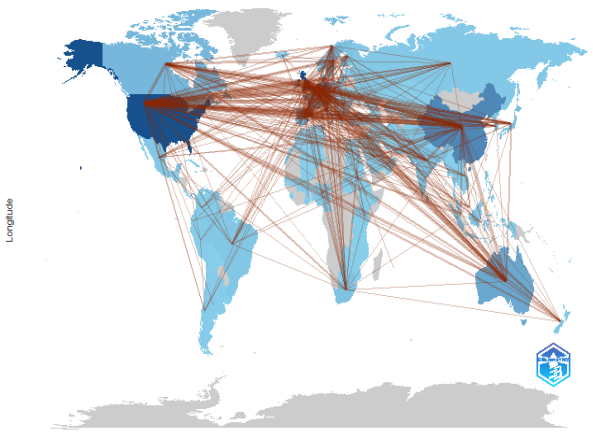

Figure 6. Countries' Collaboration

Within the scope of this research, the countries involved in studies with international co-authors were examined (Figure 5). Figure 6 displays the world map of international co-authorships in the 5,002 studies subjected to bibliometric analysis. Among the 34 countries that contributed to this topic, 23 countries produced only one publication. Table 4 presents the top 25 countries with the highest number of publications, with Turkey ranking 25th. Collaboration among the top 10 countries is outlined in Table 4.

Table 4. Citation analysis for countries

Id	Country	Documents	Citations	Total Link Strength	Id	Country	Documents	Citations	Total Link Strength
1	Usa	1145	33737	2877	13	Norway	156	3020	325
2	England	1075	35122	2900	14	Denmark	136	3831	333
3	Germany	645	14590	1695	15	Japan	135	3402	218
4	Peoples R China	609	15967	1254	16	Austria	128	2768	419
5	Netherlands	416	9916	1218	17	Scotland	119	3636	409
6	France	392	13085	1317	18	India	107	3930	361
7	Australia	330	8863	836	19	Belgium	99	2968	294
8	Italy	323	7142	973	20	Finland	96	2049	188
9	Spain	314	8502	697	21	South Africa	93	2670	229
10	Switzerland	221	5346	699	22	Portugal	91	2047	147
11	Sweden	197	5157	436	23	Romania	88	610	79
12	Canada	194	5525	615	24	Pakistan	81	2869	361
					25	Turkey	80	2359	224

Table 5. Collaboration for top 10 countries

From	To	Frequency
Usa	Unıted Kıngdom	179
Unıted Kıngdom	Chına	128
Unıted Kıngdom	Germany	125
Usa	Germany	104
Unıted Kıngdom	Netherlands	100
Germany	Netherlands	91
Usa	Chına	89
Unıted Kıngdom	Italy	74
Usa	Italy	69

Dynamic co-citation and common word analyses were conducted to comprehend the evolution of this field and to discern the focal areas investigated by previous scholars (RQ2). PageRank and citation analyses were performed to identify the 10 most influential publications in each focus area or research theme. Content analysis was utilized to delineate the key topics within each area.

Keyword Analysis: The most frequently recurring words in the author's keywords (a), titles keywords (b), abstract keywords (c), and keywords plus (d) sections of the studies examined in the research are shown in the word cloud in Fig7.

Thematic Map

Climate change stands as one of the paramount environmental challenges of our time. Effectively addressing this challenge necessitates the consideration and implementation of a blend of policies, technologies, and societal approaches across various domains. In order to grasp the ontological and epistemological foundations of the field, a coupling analysis clustering has been conducted (Tandon et al., 2021; Kaur, 2024). The selected keywords are determined to best reflect the content of the articles, offering insights into the topics covered in the publications. Furthermore, through network and text analysis, the embedded keywords and patterns within these words can illuminate the composition of the publications. In this context, a Conceptual Structure Factorial Analysis, based on Multiple Correspondence Analysis, was conducted using the Bibliometrix package integrated into Biblioshiny user interfaces. The resulting thematic structures are depicted in Figure 8. Based on

the analysis, four thematic areas were delineated corresponding to the four clusters identified through dynamic co-citation analysis (Table 6). The most influential articles published in each cluster (Table 7) serve as indicators of the thematic focus within this domain. Consequently, the top 10 most influential articles from each cluster were subjected to content analysis to extract the primary insights and objectives of each analyzed article (Tandon et al., 2021).

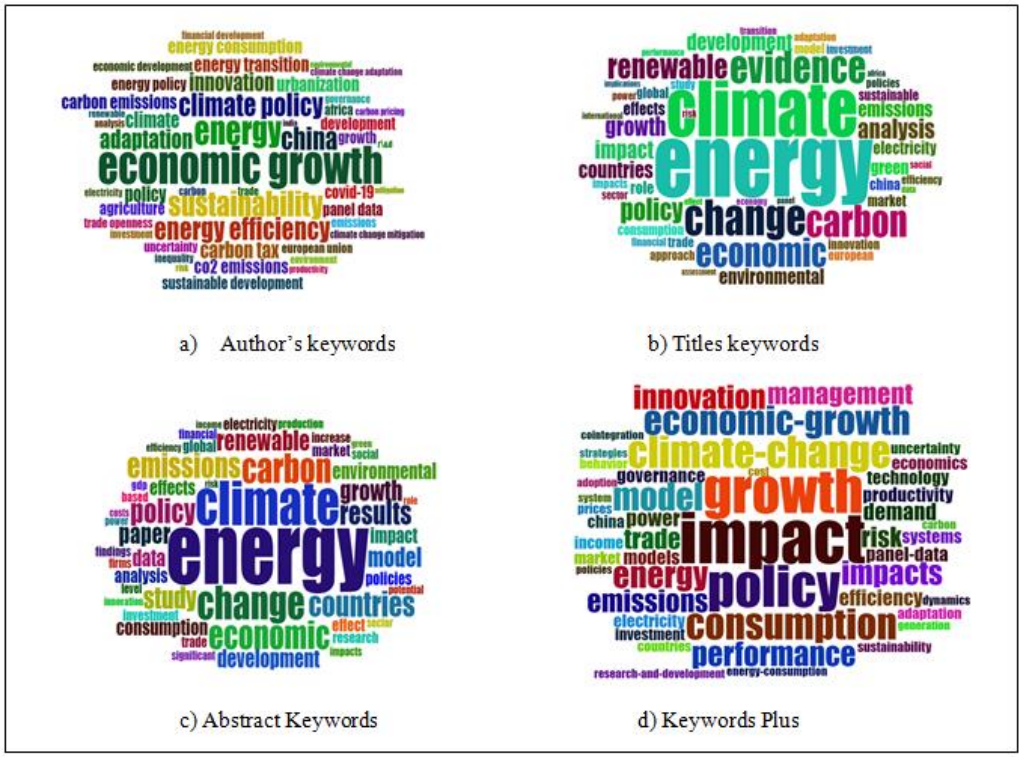

Figure 7. Keyword analysis

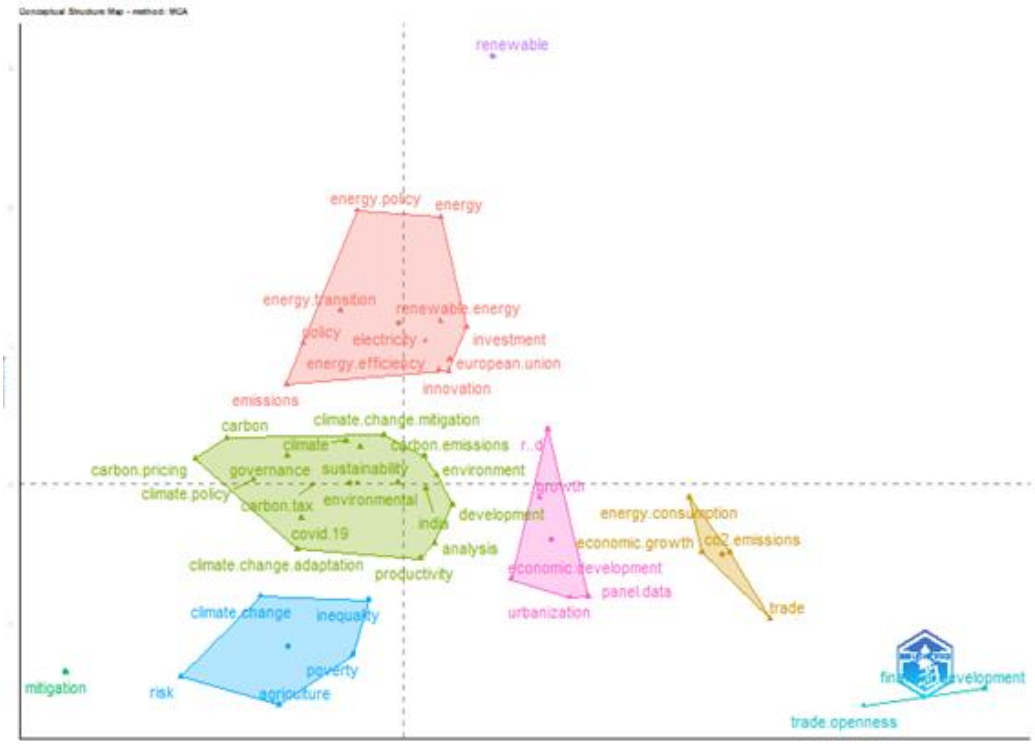

Figure 8. Factorial analysis

Table 6. Clusters analysis

Cluster	CallonCentrality	CallonDensity	RankCentrality	RankDensity	ClusterFrequency
Climate Change	0,01750499	1,43511606	2	1	1207
Renewable Energy	0,02663892	1,45768705	4	2	1056
Climate Policy	0,01044803	1,70783574	1	3	436
Economic Growth	0,01931001	1,82951589	3	4	847

Table 7. Top 10 prestigious publications according to thematic clusters.

S. No	Authors	Pagerank	Authors	Pagerank
	Cluster 1 Climate Change		**Cluster 2 Renewable Energy**	
1	Pleegıng et al. (2021)	0,107325	Mecu et al. (2023)	0,131724
2	Ferreıra et al. (2020)	0,103048	Harjanne and Korhonen (2019)	0,101646
3	Gosslıng et al. (2016)	0,100224	Albert (202)2	0,101313
4	Berner et al. (2022)	0,097934	Bastarrıca et al. (2023)	0,098734
5	Abidoye and Odusola (2015)	0,096986	Hılber et al. (2019)	0,093551
6	Nippa et al., 2021	0,095855	Handayanı et al. (2019)	0,092754
7	Duran-Romero et al, 2020	0,088611	Ghadge et al.(2020)	0,092754
8	Andrade and De Olıveıra (2015)	0,088204	Cao et al. (2017)	0,092754
9	Steınbuks and Hertel (2016)	0,088179	Baum et al. (2023)	0,092754
10	Belaia et al. (2021)	0,085668	Mclaughlin et al. (2019)	0,082495
	Cluster 3 Climate Policy		**Cluster 4 Economic Growth**	
1	Macaluso et al. (2018)	0,092925	Leitao and Balogh (2020)	0,14526
2	Mukanjarı and Sterner (2020)	0,091128	Salari et al. (2021)	0,113742
3	Klenert et al. (2020)	0,089271	Jınqıao et al.(2022)	0,107228
4	Budolfson et al.(2019)	0,087594	Kuzemko et al., 2019	0,09197
5	Kornek et al. (2021	0,080638	Desmet and Rossi-Hansberg (2015)	0,091876
6	Andersson (2023)	0,078078	Ansell and Cayzer (2018)	0,091239
7	Dıng et al. (2023)	0,076525	Casey (2024)	0,091239
8	Lahcen et al. (2020)	0,076297	Fernandes et al. (2021)	0,088478
9	Balint et al. (2017)	0,075954	Kahn et al. (2021)	0,088478
10	Tol (2019)	0,075954	Rezai (2018)	0,088478

Cluster 1. Climate Change

The ten most influential publications on climate change are outlined in Table 7. These studies were subjected to content analysis, revealing a common theme emphasizing the pivotal roles of policy, technology, and societal interactions across various domains in combating climate change. The findings underscore the necessity of considering policy, technology, and societal approaches collectively to effectively address climate change. Furthermore, these studies delve into topics such as climate change and economic growth in Africa, carbon emissions and the policies of multinational corporations, circular economy practices, the role of the private sector in global climate and energy governance, and global land use and solar geoengineering.

Abidoye and Odusola (2015) demonstrate that rising temperatures have a detrimental effect on gross domestic product (GDP) growth, particularly highlighting the African continent's vulnerability to the adverse effects of climate change on economic growth. The role of the private sector in global climate and energy governance is expanding. This research underscores the private sector as a pivotal stakeholder in the development and implementation of climate and energy policies. Engaging the private sector is crucial for the effective functioning of climate and energy regimes. Global land use dynamics involve a complex interplay of economic, agricultural, and biophysical factors. Steinbuks and Hertel (2016) explored various modeling and analytical methods to comprehend the impacts of climate change on global land use. Among various sectors, the agricultural sector is particularly experiencing significant impacts due to climate change.

The transportation sector stands out as a significant contributor to climate change, emphasizing the crucial importance of policies in this domain. In an assessment of climate policies within the European Union and Gossling et al. (2016) delved into mitigation targets and policy effectiveness, focusing on twelve policy officials from three Directorates General. This research sheds light on differing and common perspectives regarding climate policy objectives and challenges in policy implementation. Multinational corporations have emerged as integral players in carbon mitigation efforts. According to Nippa et al. (2021), multinational companies demonstrate more consistent carbon reductions and overall better carbon performance compared to domestic

firms. National and international carbon regulations play a pivotal role in shaping companies' carbon policies. Incentives for green energy, policies for technology transfer, climate regulations in the transportation sector, and measures to enhance energy efficiency are all critical components in the effective fight against climate change.

The promotion of green energy stands as a pivotal step in combating climate change Pleeging et al. (2021) reveal that individuals with a hopeful outlook are generally more inclined to pay a premium for green energy. In this context, it is underscored that hopeful individuals exhibit an enhanced willingness to invest in green energy, while acknowledging the gravity of the issue. Research on technology transfer and the impact of environmental patents in Europe yields significant insights. Ferreira et al. (2020), in their investigation of technology transfer within the European continent, explored the effects of environmental water-related adaptation technologies and climate change mitigation patents on economic growth. These studies shed light on the influence of environmental patents on Europe's economic performance and how geographical location determines levels of entrepreneurial activity. Enhancing energy efficiency has emerged as a crucial avenue for reducing greenhouse gas emissions.

A study conducted by Berner et al. (2022) delved into the economy-wide recovery effects of energy efficiency improvements and their long-term impact on energy use. This study underscores that innovations in energy efficiency can offer limited assistance in curbing future energy consumption and may be associated with economic growth. The concept of Circular Economy (CE) is emerging as a pivotal strategy in the fight against climate change. Research by Durán-Romero et al. (2020) demonstrates that CE eco-innovations can make substantial contributions to climate change mitigation objectives. Evaluating the interplay between CE and climate policies represents a crucial stride towards sustainability. Solar geoengineering (SE) and carbon dioxide removal (CDR) technologies hold significant promise as methods for mitigating climate change. Studies by Belaia et al. (2021) reveal that the integration of SE and CDR technologies can serve as an effective strategy for reducing greenhouse gas emissions. The contributions of these technologies to climate policies underscore their vital role in decreasing the carbon intensity of energy systems and industrial processes.

Cluster 2. Renewable Energy

The research within this cluster underscores that the shift towards renewable energy carries significant implications across various domains such as energy policy, economic growth, global geopolitics, and climate change. Within this context, these studies bring the attention of policymakers and society towards a more sustainable energy future. By centering on renewable energy, this body of research urges contemplation on the reformation of energy policies and its multifaceted economic, social, and environmental aspects. It also serves as a crucial reference point for comprehending the ramifications of the energy transition on global politics and economy, thus shaping future policies and strategies. These studies hold the potential to enhance awareness and galvanize pertinent stakeholders into action, offering insights into the opportunities and challenges stemming from the transformation of the energy sector. Hence, grasping the pivotal dimensions of the transition to renewable energy and evaluating its impacts stand as integral components in steering future energy policies and fostering societal transformation.

The concept of renewable energy has been a subject of extensive debate due to its central role and impact on energy policies. Harjanne and Korhonen (2019) shed light on this discourse by providing a theoretical analysis of the definition and framework of renewable energy. Within the realm of global politics, the transition to renewable energy emerges as a pivotal focal point, with arguments suggesting it could precipitate a structural transformation in the world order. Albert (2022) and other scholars underscore that renewable energy has the potential to reshape patterns of economic growth and military competition. Significant revisions in strategies to combat climate change have been observed within the European Union. Studies within this context have unveiled that ambitious targets set forth in energy policies prove effective in curbing greenhouse gas emissions and bolstering economic growth (Mecu et al., 2023).

The decarbonization of electricity supply stands out as a crucial step in the battle against climate change. Bastarrica et al. (2023) highlight the welfare implications of scenarios aimed at reducing CO2 emissions from electricity generation, alongside the substantial costs associated with the deployment of renewable energy. Studies have also delved into the effects of historic preservation policies on energy efficiency. Hilber et al. (2019) investigate the impact of these policies on energy costs and the social costs of carbon, specifically examining the influence of national energy prices on household energy efficiency installations. Moreover, the significance of technological learning in the diffusion of renewable energy is underscored. Handayani et al. (2019), in their examination of the electricity system, demonstrate that investments considering technological

learning can diminish the costs of electricity generation, rendering renewable energy competitive with other energy sources.

Bioethanol production emerges as a pivotal issue concerning its impacts on climate change. Ghadge et al. (2020) underscore that bioethanol supply chains hold the potential to mitigate the risks of climate change, emphasizing the criticality of sustainable feedstock utilization. Addressing the nexus between fossil fuel consumption, climate change, and bioenergy solutions, Cao et al. (2017) assert that bioenergy technologies can offer substantial contributions through carbon sequestration. Furthermore, the study delves into the role of advanced technologies such as solar radiation management and carbon dioxide removal in climate response strategies. Baum et al. (2023) elaborate on the impacts and viability of these technologies, accentuating their significance in confronting the climate challenge. Finally, the literature also includes studies on the role of accounting professionals on carbon taxes and energy companies' compliance with these taxes. McLaughlin et al. (2019) summarize the research on this topic and assess what role accounting and tax policies can play in the field of renewable energy.

Cluster 3. Climate Policy

The papers within this cluster provide an intricate analysis of the multifaceted effects of carbon tax scenarios on sectoral output, energy consumption, and the broader US economy. The analyses aim to discern how differences in trajectories of carbon tax and various revenue utilization options impact sectoral-level patterns (Macaluso et al., 2018). Furthermore, these studies delve into the potential impacts of the COVID-19 crisis on the green economy, the corporate environmental responsibility, and diverse facets of carbon emissions. Additionally, they explore the potential effects of environmentally friendly construction projects on both the economy and the environment (Mukanjari and Sterner, 2020).

When assessing the relationship between income inequality and carbon emissions over time, it is important to consider the potential effects of environmentally friendly construction projects on both the economy and the environment. This examination suggests that this relationship should be thoroughly understood and taken into account in policy-making (Andersson, 2023). There is a notable emphasis on the economic and social dimensions of climate change, global inequality, and the feasibility of climate policies. It is argued that by drawing lessons from the COVID-19 crisis, there is a necessity to enhance the applicability of climate policies and prepare for future crises (Klenert et al., 2020). In the evaluation of various scenarios regarding the relationship between the COVID-19 pandemic and the green economy, the impacts of investments in environmentally friendly construction projects to stimulate the economy are analyzed (Lahcen et al., 2020). Additionally, carbon tax scenarios are examined with a focus on changes in sectoral output and energy consumption, assessing their impact on the competitiveness of the US economy (Macaluso et al., 2018)

In considering the implications of the COVID-19 crisis for climate change policies, ethical considerations arise regarding how much future generations should be expected to sacrifice to reduce carbon emissions today (Budolfson et al., 2019). Ding et al. introduce optimal taxation models that account for the social cost of carbon, addressing the distributive aspect of climate policies. They also highlight the importance of increased climate-related disclosure for companies with high carbon emissions, aiming to enhance their environmental responsibility (Ding et al., 2023). Furthermore, the study delves into the role of complex systems models in the fight against climate change and their economic implications. It examines national climate change impact functions used to estimate the social costs of carbon in poorer countries, as well as the sensitivity of these models to economic growth. The recommendation is made to estimate the national social costs of carbon in impoverished nations and assess the impacts of climate policies on a global scale (Tol, 2019).

The articles in cluster 3 provide recommendations for companies, governments and researchers in combating climate change in a wide range of areas:

There are several important steps that companies can take to fulfill their environmental responsibilities and reduce carbon emissions. These steps include setting decarbonization targets that aim to reduce carbon emissions over a certain period of time (Ding et al., 2023). At the same time, transitioning to green energy use by meeting their energy needs from green and renewable energy sources (Mukanjari and Sterner, 2020) stands out as an effective way to reduce carbon emissions.

Decarbonizing production processes or investing in technological innovations to reduce carbon emissions (Macaluso et al., 2018) can assist companies in achieving their sustainability objectives. Furthermore,

collaborating with sustainable suppliers, considering environmental impacts in supply chain management (Andersson, 2023), implementing waste management policies, and initiating recycling programs all contribute significantly to reducing companies' environmental footprint. Training employees in environmentally friendly practices and fostering environmental awareness within the organization are crucial steps in promoting environmental responsibility (Balint et al., 2017). Lastly, regular reporting and maintaining transparency regarding their environmental performance (Ding et al., 2023) are essential tools for companies to monitor their progress toward achieving environmental goals. These strategies collectively enable companies to fulfill their environmental responsibilities and establish a sustainable business model for the future.

States can adopt various policies and strategies to play a crucial role in combating climate change. These include implementing a range of economic instruments and incentives to promote reductions in carbon emissions and the adoption of green energy (Klenert et al., 2020). For instance, efforts to reduce carbon emissions can be incentivized through mechanisms such as carbon taxes or emissions trading (Macaluso et al., 2018). Additionally, states can offer financial support and incentives to encourage investments in renewable energy sources (Mukanjari and Sterner, 2020).

States can introduce various standards and regulations to enhance energy efficiency (Andersson, 2023), which can both reduce energy consumption and lower carbon emissions. Additionally, they can accelerate the transition to a carbon-free economy by investing in green infrastructure projects and developing environmentally sustainable transportation systems (Lahcen et al., 2020). National and international cooperation is also crucial in the fight against climate change. By participating in international climate agreements and setting common goals on climate change, states can facilitate the implementation of effective policies globally (Kornek et al., 2021). Finally, raising awareness and mobilizing society on climate change through environmental education and awareness campaigns is another crucial step that states can take (Tol, 2019). The combination of these policies and strategies can empower states to effectively combat climate change and pave the way for a sustainable future.

Researchers can play a pivotal role in combatting climate change through their scientific endeavors. Initially, they can engage in interdisciplinary studies aimed at better understanding the causes and ramifications of climate change. These endeavors might involve the development of climate models, analysis of the carbon cycle, research into the economic and social impacts of climate change, and related areas (Balint et al., 2017). Additionally, researchers can focus on research and development efforts to cultivate green technologies and enhance efficiency (Klenert et al., 2020). Providing policymakers and companies with precise data and analyses to inform effective climate change policies and strategies is also among the responsibilities of researchers (Mukanjari and Sterner, 2020). Furthermore, they can contribute to communication and advocacy campaigns to raise awareness and educate the public about climate change (Tol, 2019).

Moreover, researchers can disseminate their knowledge and findings at international conferences, prepare reports assessing the impact of climate policies, and collaborate with policymakers to help shape evidence-based policies (Kornek et al., 2021). Finally, they can contribute to mobilizing the public and influencing policy demands by presenting information about climate change in a clear and accessible manner (Andersson, 2023). All of these endeavors can empower researchers to play a significant role in combatting climate change and make a valuable contribution to a more sustainable future.

Cluster 4. Economic Growth

In the fourth cluster, research delves into the impacts of diverse economic and environmental factors on climate change, alongside policy measures. Studies within this cluster delve into the effects of variables such as energy consumption, financial policies, technological innovations, trade dynamics, and CO2 emissions on both economic growth and environmental sustainability across different countries and regions. These inquiries underscore crucial factors and potential solutions that policymakers and economists must take into account when addressing the challenges of climate change.

The European Union's endeavors to attain its 20% reduction target in greenhouse gas emissions by 2020, aimed at addressing climate change, are bolstered by research assessing the environmental ramifications of factors such as energy consumption, agriculture, and trade (Fernandes et al., 2021). Similarly, the correlation between CO2 emissions, energy consumption, and economic growth in U.S. states has been scrutinized utilizing state-level data, with a particular emphasis on the influences of various energy consumption types on CO2 emissions (Salari et al., 2021). Within the Emerging Seven Countries, investigations into the impacts of financial

development and technological innovation on climate change have been conducted using dynamic panel data models, showcasing that while financial development holds a direct adverse effect, its impact turns positive through technological innovation (Jinqiao et al., 2022).

These studies illustrate that sustainable technology transfer and innovation promote green growth, and this green growth, in turn, positively influences economic growth (Fernandes et al., 2021). The long-term impacts of climate change on economic activities have been investigated on a global scale, revealing that the global temperature rise negatively affects world GDP, with these effects varying significantly among countries (Kahn et al., 2021). Furthermore, the effects of energy policies and the role of technological innovations in energy use have been explored, with a focus on the dynamics of energy consumption following increases in energy efficiency and the impacts of incentivizing policies (Casey, 2024). These studies underscore crucial factors and solutions that policymakers and economists must consider in the fight against climate change. Researchers have explored the relationship between climate change and economic growth, aiming to discern the impacts of financial development and technological innovation on climate change (Jinqiao et al., 2022).

In a separate study, which focused on energy consumption and CO2 emissions, the environmental impacts in U.S. states were analyzed, investigating the effects of various forms of energy consumption on CO2 emissions (Salari et al., 2021). Moreover, research on the enduring consequences of global warming has revealed that the global rise in temperature detrimentally affects economic activities on a global scale, with considerable variation among countries based on climatic conditions (Kahn et al., 2021). Researchers have put forth recommendations to improve the efficacy of climate change policies and advance sustainable growth based on these insights. Additionally, research on the correlation between green growth and economic expansion underscores that sustainable technology transfer and innovation foster green growth, ultimately benefiting economic advancement (Fernandes et al., 2021). These studies underscore critical factors and solutions that policymakers and economists should take into account when addressing the challenge of climate change.

Among the critical considerations for economists are the following: First, the heterogeneous economic impacts of climate change, which vary across countries, sectors, and income groups, must be acknowledged (Kahn et al., 2021). Hence, these distinctions are crucial when crafting policies to adapt to and mitigate the effects of climate change. Second, the influence of environmental factors such as energy consumption and CO2 emissions on economic growth warrants examination (Salari et al., 2021). It is noted that policies promoting green growth positively affect economic advancement while bolstering environmental sustainability. Third, the ramifications of financial development and technological innovation on climate change should be factored in (Jinqiao et al., 2022).

Certainly, the promotion of sustainable technology transfer and innovation should be highlighted, as they stimulate green growth and exert a positive influence on economic advancement. Lastly, comprehending the enduring impacts of global warming on economic activities and discerning the variability of these effects across diverse geographical regions and income groups is crucial (Desmet & Rossi-Hansberg, 2015; Rezai et al., 2018). All these factors collectively aid economists and policymakers in formulating effective policies and strategies to combat climate change.

Future Research Directions

Based on the outcomes of dynamic co-citation, coupling, and citation analyses, several promising avenues for future research have been suggested in response to RQ3. These potential areas of exploration aim to further enhance our understanding of the complex interplay between climate change, economic growth, and policy interventions. Here are some proposed avenues:

1. Environmental factors and economic growth: Delving deeper into the effects of environmental factors, such as energy consumption and CO2 emissions, on economic growth can offer valuable insights. Future research could explore the nuanced relationships between these variables, considering various policy interventions and their effectiveness.
2. Financial development and technological innovation: The role of financial development and technological innovation in climate change mitigation and adaptation strategies presents a rich area for exploration. Investigating how these factors interact and influence each other, particularly in the context of green growth, could provide actionable policy recommendations.
3. Sustainable technology transfer and innovation: A focus on the promotion and dynamics of sustainable technology transfer and innovation can significantly contribute to green growth. Future studies might delve

into the mechanisms, drivers, and barriers to effective technology transfer, especially in the context of developing economies.
4. Long-term effects of global warming: Understanding the enduring repercussions of global warming on economic activities remains crucial. Future research could aim to forecast and model these effects, considering different climate scenarios and their implications for economic sectors and regions.
5. Policy evaluation and effectiveness: Continual assessment of the effectiveness of climate change policies is essential. Future studies could focus on evaluating existing policies, identifying best practices, and proposing innovative policy frameworks that integrate economic growth with environmental sustainability.

Conclusion

This paper offers an evaluation of global research trends in publications on carbon emissions, climate change, carbon footprint, carbon tax, and green technology diffusion from 2015 to 2024. These subjects have constituted a comprehensive research field since 2015, characterized by a marked growth in publication output. This field of study is divided into four main research areas: (1) Climate Change, (2) Renewable Energy, (3) Climate Policy, and (4) Economic Growth. These studies, subjected to content analysis, have revealed a common theme emphasizing the pivotal roles of policy, technology, and societal interactions across various domains in combating climate change. The findings underscore the necessity of considering policy, technology, and societal approaches collectively to effectively address climate change.

Several positive aspects can be drawn from bibliometric analysis. Firstly, since multi-authored publications constitute approximately three-quarters of all publications, it can be concluded that there is a considerable amount of collaborative research in this field. Secondly, there is a wide variety of journals publishing on the subject, with diverse topic categories allocated to the publications in the field, indicating a broad range of research themes and the interdisciplinary nature of the field. This research has revealed that the journals with the highest number of articles in this field and the highest number of citations were Energy Policy, Energy Economics, Ecological Economics, Economic Research-Ekonomska Istrazıvanja, Environmental & Resource Economics, Technological Forecasting, and Social Change. In terms of the number of articles and citations by country in these fields, the USA, England, Germany, China, and the Netherlands ranked the highest.

Finally, it is important to note some limitations of this bibliometric study. Firstly, the search was limited to publications listed in the Web of Science. While Web of Science is one of the largest global databases, it does not encompass all publications in the field of carbon emissions, climate change, carbon footprint, carbon tax, and green technology diffusion. Other international databases such as Scopus could have also been utilized.

Recommendations

The author of this study recommends examining carbon emissions, climate change, carbon footprint, carbon tax, and green technology to acquire guidance and insight into the topics that future researchers may focus on in their own studies. Additionally, they suggest finding journals, countries, and other authors that may be interested in their work.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the author.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology (www.icontechno.net) held in Alanya/Turkey on May 02-05, 2024.

References

Abidoye, B. O., & Odusola, A. F. (2015). Climate change and economic growth in Africa: An econometric analysis. *Journal of African Economies*, *24*(2), 277-301.

Albert, M. J. (2022). The global politics of the renewable energy transition and the non-substitutability hypothesis: towards a 'great transformation'?. *Review of International Political Economy*, *29*(5), 1766-1781.

Andersson, F. N. (2023). Income inequality and carbon emissions in the United States 1929–2019. *Ecological Economics*, *204*, 107633.

Andrade, J. C. S., & Puppim de Oliveira, J. A. (2015). The role of the private sector in global climate and energy governance. *Journal of Business Ethics*, *130*, 375-387.

Ansell, T., & Cayzer, S. (2018). Limits to growth redux: A system dynamics model for assessing energy and climate change constraints to global growth. *Energy Policy*, *120*, 514-525.

Balint, T., Lamperti, F., Mandel, A., Napoletano, M., Roventini, A., & Sapio, A. (2017). Complexity and the economics of climate change: A survey and a look forward. *Ecological Economics*, *138*, 252-265.

Bastarrica, L. A. G., Esquinas, E. M. B., Pou, M. Á. C., & Ovando, R. Y. (2023). An ıntegrated assessment model for comparing electricity decarbonisation scenarios: The case for Spain. *Energy Policy*, *178*, 113592.

Baum, C. M., Low, S., & Sovacool, B. K. (2023). Coupling for climate intervention: Sectoral and sustainability couplings for carbon removal and solar geoengineering pathways. *Technological Forecasting and Social Change*, *194*, 122734.

Belaia, M., Moreno-Cruz, J. B., & Keith, D. W. (2021). Optimal climate policy in 3D: Mitigation, carbon removal, and solar geoengineering. *Climate Change Economics*, *12*(3), 2150008.

Berner, A., Bruns, S., Moneta, A., & Stern, D. I. (2022). Do energy efficiency improvements reduce energy use? Empirical evidence on the economy-wide rebound effect in Europe and the United States. *Energy Economics*, *110*, 105939.

Budolfson, M., Dennig, F., Fleurbaey, M., Scovronick, N., Siebert, A., Spears, D., & Wagner, F. (2019). Optimal climate policy and the future of world economic development. *The World Bank Economic Review*, *33*(1), 21-40.

Cao, X., Chih-Chun, K. U. N. G., & Wang, Y. (2017). An environmental and economic evaluation of carbon sequestration from pyrolysis and biochar application in China. *Agricultural Economics/Zemědělská Ekonomika*, *63*(12).

Casey, G. (2024). Energy efficiency and directed technical change: implications for climate change mitigation. *Review of Economic Studies*, *91*(1), 192-228.

Desmet, K., & Rossi-Hansberg, E. (2015). On the spatial economic impact of global warming. *Journal of Urban Economics*, *88*, 16-37.

Ding, D., Liu, B., & Chang, M. (2023). Carbon emissions and TCFD aligned climate-related information disclosures. *Journal of Business Ethics*, *182*(4), 967-1001.

Durán-Romero, G., López, A. M., Beliaeva, T., Ferasso, M., Garonne, C., & Jones, P. (2020). Bridging the gap between circular economy and climate change mitigation policies through eco-innovations and Quintuple Helix Model. *Technological Forecasting and Social Change*, *160*, 120246.

Fernandes, C. I., Veiga, P. M., Ferreira, J. J., & Hughes, M. (2021). Green growth versus economic growth: do sustainable technology transfer and innovations lead to an imperfect choice?. *Business Strategy and the Environment*, *30*(4), 2021-2037.

Ferreira, J. J., Fernandes, C. I., & Ferreira, F. A. (2020). Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries. *Technological Forecasting and Social Change*, *150*, 119770.

Ghadge, A., van der Werf, S., Kara, M. E., Goswami, M., Kumar, P., & Bourlakis, M. (2020). Modelling the impact of climate change risk on bioethanol supply chains. *Technological Forecasting and Social Change*, *160*, 120227.

Gössling, S., Cohen, S. A., & Hares, A. (2016). Inside the black box: EU policy officers' perspectives on transport and climate change mitigation. *Journal of Transport Geography*, *57*, 83-93.

Handayani, K., Krozer, Y., & Filatova, T. (2019). From fossil fuels to renewables: An analysis of long-term scenarios considering technological learning. *Energy Policy*, *127*, 134-146.

Harjanne, A., & Korhonen, J. M. (2019). Abandoning the concept of renewable energy. *Energy Policy*, *127*, 330-340.

Hilber, C. A., Palmer, C., & Pinchbeck, E. W. (2019). The energy costs of historic preservation. *Journal of Urban Economics*, *114*, 103197.

Issa, A., & In'airat, M. (2024). From words to action: unpacking the real impact of sustainability initiatives on carbon emissions reduction. *Social Responsibility Journal*, *20*(3), 585-604.

Jinqiao, L., Maneengam, A., Saleem, F., & Mukarram, S. S. (2022). Investigating the role of financial development and technology innovation in climate change: evidence from emerging seven countries. *Economic Research-Ekonomska İstraživanja*, *35*(1), 3940-3960.

Kahn, M. E., Mohaddes, K., Ng, R. N., Pesaran, M. H., Raissi, M., & Yang, J. C. (2021). Long-term macroeconomic effects of climate change: A cross-country analysis. *Energy Economics*, *104*, 105624.

Kaur, V. (2024). Neurostrategy: A scientometric analysis of marriage between neuroscience and strategic management. *Journal of Business Research*, *170*, 114342.

Klenert, D., Funke, F., Mattauch, L., & O'Callaghan, B. (2020). Five lessons from COVID-19 for advancing climate change mitigation. *Environmental and Resource Economics*, *76*, 751-778.

Kornek, U., Klenert, D., Edenhofer, O., & Fleurbaey, M. (2021). The social cost of carbon and inequality: When local redistribution shapes global carbon prices. *Journal of Environmental Economics and Management*, *107*, 102450.

Kuzemko, C., Lawrence, A., & Watson, M. (2019). New directions in the international political economy of energy. *Review of International Political Economy*, *26*(1), 1-24.

Lahcen, B., Brusselaers, J., Vrancken, K., Dams, Y., Da Silva Paes, C., Eyckmans, J., & Rousseau, S. (2020). Green recovery policies for the COVID-19 crisis: modelling the impact on the economy and greenhouse gas emissions. *Environmental and Resource Economics*, *76*, 731-750.

Leitão, N. C., & Balogh, J. M. (2020). The impact of intra-industry trade on carbon dioxide emissions: The case of the European Union. *Agricultural Economics (Zemědělská ekonomika)*, *66*(5), 203-214.

Macaluso, N., Tuladhar, S., Woollacott, J., Mcfarland, J. R., Creason, J., & Cole, J. (2018). The impact of carbon taxation and revenue recycling on US industries. *Climate Change Economics*, *9*(01), 1840005.

McLaughlin, C., Elamer, A. A., Glen, T., AlHares, A., & Gaber, H. R. (2019). Accounting society's acceptability of carbon taxes: Expectations and reality. *Energy Policy*, *131*, 302-311.

Mecu, A. N., Chiţu, F., Marin, G. I., & Hurduzeu, G. (2023). Analysis of the ımpact of energy efficiency and renewable energy on greenhouse gas emissions and economic growth in EU member states. *Amfiteatru Economic*, *25*, 1149-1163.

Mukanjari, S., & Sterner, T. (2020). Charting a "green path" for recovery from COVID-19. *Environmental and Resource Economics*, *76*(4), 825-853.

Nippa, M., Patnaik, S., & Taussig, M. (2021). MNE responses to carbon pricing regulations: Theory and evidence. *Journal of International Business Studies*, *52*, 904-929.

Pleeging, E., van Exel, J., Burger, M. J., & Stavropoulos, S. (2021). Hope for the future and willingness to pay for sustainable energy. *Ecological Economics*, *181*, 106900.

Rezai, A., Taylor, L., & Foley, D. (2018). Economic growth, income distribution, and climate change. *Ecological Economics*, *146*, 164-172.

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO2 emissions, energy consumption, and economic growth in the US. *Economic Analysis and Policy*, *69*, 182-194.

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: the effects of FDI, financial development, and energy innovations. *Energy Economics*, *74*, 843-857.

Steinbuks, J., & Hertel, T. W. (2016). Confronting the food–energy–environment trilemma: Global land use in the long run. *Environmental and Resource Economics*, *63*, 545-570.

Tandon, A., Kaur, P., Mäntymäki, M., & Dhir, A. (2021). Blockchain applications in management: A bibliometric analysis and literature review. *Technological Forecasting and Social Change*, *166*, 120649.

Tol, R. S. (2019). A social cost of carbon for (almost) every country. *Energy Economics*, *83*, 555-566.

Wang, G., Liao, M., & Jiang, J. (2020). Research on agricultural carbon emissions and regional carbon emissions reduction strategies in China. *Sustainability*, *12*(7), 2627.

Author Information

Hamide Ozyurek
OSTIM Technical University
Ankara, Turkey
Contact e-mail: *hamide.ozyurek@ostimteknik.edu.tr*

To cite this article:

Ozyurek, H. (2024). The trends in carbon emissions, climate change, carbon footprint, carbon tax, green technology diffusion from 2015 to 2024: A bibliometric and visual analysis. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)*, *27*, 1-15.