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The Evolution of Carbon Market: A Systematic Review and Bibliometric Study

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Abstract: The carbon market has emerged as a pivotal instrument in global climate policy, yet comprehensive analyses of its scholarly evolution remain limited. This study conducts a systematic review and bibliometric analysis of 491 Scopus-indexed publications (2000–2024) to map the intellectual structure and thematic trajectories of carbon market research. Using VOSviewer and Biblioshiny, we employ performance analysis and science mapping techniques to identify key trends, influential contributors, and research clusters. Results reveal exponential growth in publications post–Paris Agreement, with China, the USA, and Australia dominating output. Thematic evolution demonstrates a shift from early focus on Kyoto Protocol mechanisms to contemporary emphasis on carbon neutrality, pricing efficiency, and low-carbon technologies. Co-citation analysis identifies five research clusters: (1) carbon pricing policy design, (2) market efficiency and financialization, (3) international climate agreements, (4) corporate carbon strategies, and (5) technological innovation. Notably, critical perspectives on equity and governance remain marginalized, representing just 9% of high-impact studies. The geographic concentration of research (76% from OECD nations) highlights disparities in scholarly attention relative to Global South market implementations. Our findings yield three key policy insights: first, market designs must integrate dynamic cap-setting and price stabilization tools; second, governance frameworks require explicit equity safeguards; third, global harmonization of accounting standards is urgent. By synthesizing over 20 years of research, this paper highlights the importance of carbon markets in achieving global climate goals and identifies areas that require further exploration, including market design, equity, and environmental integrity.

Keywords: carbon pricing, emissions trading, market design, climate policy, bibliometric analysis and systematic review

1. Introduction

Climate change has necessitated the development of innovative economic instruments to mitigate greenhouse gas (GHG) emissions [1–3]. Among these mechanisms, carbon markets have emerged as a prominent policy tool, creating systems where emission allowances and credits are traded to achieve environmental objectives cost-effectively. Carbon market economics examines the structures, behaviors, and outcomes of both compliance and voluntary markets [4], focusing on how pricing mechanisms—particularly cap-and-trade systems and carbon taxes—internalize the external costs of emissions and incentivize decarbonization.

The evolution of carbon markets over the past two decades demonstrates their transition from theoretical constructs to operational policy instruments across diverse jurisdictions. The European Union Emissions Trading System (EU ETS), established in 2005, represents a landmark implementation, serving as the cornerstone of the EU's climate strategy through its cap-and-trade framework [5]. Similarly, China's national carbon market, launched in 2021, has rapidly become one of the world's largest systems as part of the country's decarbonization efforts [6]. In North America, regional initiatives such as the Western Climate Initiative and the Regional Greenhouse Gas Initiative (RGGI) illustrate collaborative approaches to environmental governance through market mechanisms [7]. This global proliferation has generated an expansive and multidisciplinary academic literature examining various aspects of carbon market economics, including market design, efficiency metrics, regulatory impacts, and socio-economic implications [8]. The growing complexity of this research landscape necessitates a systematic review to identify key trends, influential works, and emerging directions, which this study addresses through comprehensive bibliometric analysis.

Conceptually, carbon market economics builds upon the foundational principles of environmental economics, particularly the theory of externalities. GHG emissions represent a classic negative externality, where the social costs of pollution are distributed across society rather than borne by emitters [9]. Carbon pricing mechanisms seek to correct this market failure by assigning monetary value to emissions, thereby internalizing external costs and aligning private incentives with social welfare [10, 11]. Cap-and-trade systems operationalize this principle by establishing emissions caps, allocating or auctioning allowances, and enabling market-based trading to achieve cost-effective reductions [12]. Empirical research demonstrates that well-designed carbon markets can deliver significant emission reductions without excessive economic costs [13–15], as evidenced by the success of EU ETS in decarbonizing the power sector through clear price signals and regulatory certainty [5]. However, challenges such as allowance overallocation and inadequate enforcement can lead to price volatility and diminished environmental effectiveness [16].

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The global carbon market landscape reflects diverse regional approaches shaped by distinct policy priorities, economic structures, and political contexts [17–19]. As of 2023, carbon pricing initiatives have been implemented or scheduled in 46 national and 35 subnational jurisdictions, covering approximately 23% of global GHG emissions [20]. In North America, the RGGI—a cooperative effort among several U.S. states since 2009—has successfully reduced power sector emissions while generating clean energy investment through its market-based design [7]. California's multisector cap-and-trade program, linked with Quebec's system, demonstrates subnational leadership with innovative features to mitigate price volatility [21]. Parallel to compliance markets, voluntary carbon markets have expanded rapidly, driven by corporate sustainability commitments and net-zero targets, with the global market valued at $821 billion (including both compliance and voluntary markets) in 2023 and projected to reach $1.75 trillion by 2030 [22].

Despite their potential, carbon markets face significant challenges and critiques [23–25]. Concerns about environmental integrity plague voluntary markets, particularly regarding overestimated emission reductions, questionable additionality, and permanence issues in offset projects [26]. Price volatility in systems such as the EU ETS has necessitated stabilization mechanisms such as the Market Stability Reserve [27]. Furthermore, equity concerns persist regarding the distributional impacts of carbon pricing on vulnerable populations and its ability to address root causes of emissions [28]. These complexities, combined with the rapid expansion of the field, create an urgent need for systematic assessment of the academic literature. This study addresses that need through bibliometric analysis of carbon market economics publications from 2000 to 2024, utilizing Scopus data and VOSviewer visualization to map research trends, patterns, and trajectories in this critical domain of climate policy. This paper is structured as follows. Section 2 explains the data and methods. Section 3 presents the results. Section 4 discusses these results, and, last, Section 5 concludes with policy implications and future directions.

2. Data and Methodology

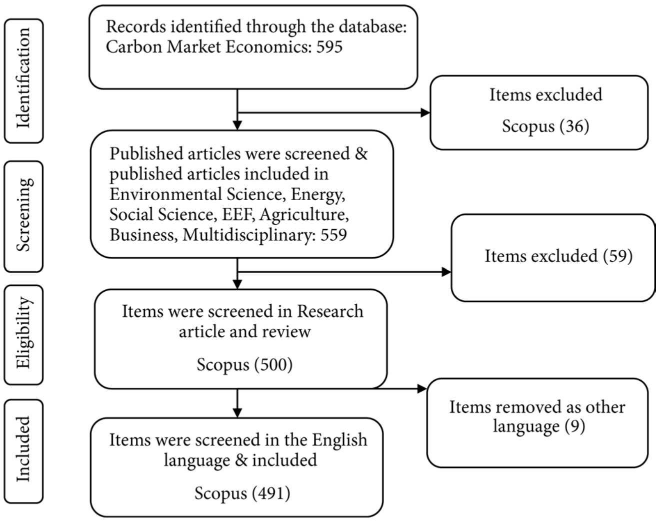
This study uses a bibliometric analysis approach to explore the research landscape of the carbon market. The data extraction process is based on Scopus, the biggest abstract and citation database, covering more than 80 million documents across all fields [29]. Scopus was used as the source because of its high-impact journal coverage. The initial search strategy is to retrieve all the relevant documents from Scopus using the keywords "carbon market" and "economics." Table 1 lists the search syntax used to extract the data, which yielded 595 publications worldwide. A systematic filtering process was performed to refine the dataset.

The study used a structured search methodology to select high-quality and relevant documents. The filtering process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework [30–32], as shown in Figure 1. The filtering steps were document type filtering, where the initial search yielded 595 documents of various document types [33]. The search focus is on publications in environmental science, energy, social science, agricultural business, and multidisciplinary fields to match our research objective and reduced the dataset to 559 publications. We retained only journal articles and review papers to ensure academic rigor and reduced the dataset to 500 publications. The final language-based filtering removed non-English papers and ultimately yielded 491 publications. The selected documents were re-examined to confirm relevance, accuracy, and alignment with our research focus. The bibliometric analysis used quantitative methods to examine research trends, author contributions, institutional affiliations, and keyword co-occurrence [34]. Descriptive analysis looked into annual publication trends, country-wise contributions, and subject-area distributions. Co-authorship analysis mapped research collaboration networks at the author, institution, and country levels [35]. Co-word analysis analyzed frequently used keywords to identify emerging themes and knowledge clusters. Citation and impact analysis found highly cited papers, influential authors, and top journals. Bibliometric analysis was performed using VOSviewer [36] and Biblioshiny [37], two popular tools for visualizing and interpreting bibliometric data [29].

Table 1
Databases and search syntax

Databases	Search syntax
Scopus	(TITLE-ABS-KEY ("carbon market") AND TITLE-ABS-KEY (economics)) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (EXCLUDE (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))

Figure 1
Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)



A PRISMA-based systematic approach was used to ensure transparency and reproducibility of the data selection process. The PRISMA flow diagram shows the inclusion-exclusion process to ensure methodological rigor [38]. This structured methodology ensures that the dataset is comprehensive, reliable and aligned with the objective of the study so we can get robust bibliometric insights into carbon market economics research.

3. Results

A typical literature review includes performance analysis of bibliometric data, looking at sources/journals, authors, and documents. This section covers various descriptive analytics. In this study, we have extended this to include performance analysis, science mapping, and network analysis. Several authors such as Zhang et al. [6] and Wang et al. [39] categorize bibliometric analysis into two main sections: 1) performance analysis and 2) science mapping. In this context, our study follows this classification and combines performance analysis and science mapping to cover the literature. The study includes 491 documents, of which 78 are single-author documents. The average number of citations per document is 31.38. Likewise, papers written by 1,303 authors used 24,048 references and 1,467 keywords, showing the strength of collaboration among the authors in carbon market economics research. Table 2 shows the summary of our extracted dataset.

3.1 Performance analysis

The purpose of performance analysis in bibliometrics is to thoroughly examine the activities of different scientific actors within a bibliographic dataset. These actors can be countries, universities, scholars, or departments [40]. The study focuses on four specific keywords related to carbon market economics: carbon market, climate change, carbon price, and emission trading. Its scope is not limited to these four keywords but includes a range of related terms such as cap and trade, carbon sequestration, carbon trading, and others. The scope was expanded to include a broader range of words associated with carbon market, climate change, carbon price, and emission trading. Figure 2 shows the number of articles published on the carbon market from 2000 to 2024. The data shows a significant increase over the years, with the peak in 2024. The trend shows growing interest and research output in the field, with fluctuations but an overall upward trend in the number of documents per year. The publication trend of the article showed a good fit ($R^2 = 0.8007$) with the exponential trend line. The trend indicates that more research publications will likely be in the field of the carbon market and economics.

Table 2
Summary of the extracted dataset

Description	Results
Main Information About Data	
Timespan	2000–2024
Sources (journals, books, etc.)	184
Documents	491
Annual growth rate %	13.29
Document average age	7.52
Average citations per doc	48.98
References	24,048
Document Contents	
Keywords plus (ID)	2,707
Author's keywords (DE)	1,467
Authors	
Authors	1,303
Authors of single-authored docs	71
Authors Collaboration	
Single-authored docs	78
Co-authors per doc	3.34
International co-authorships %	30.75
Document Types	
Article	462
Review	29

Figure 2
Production of document over the year

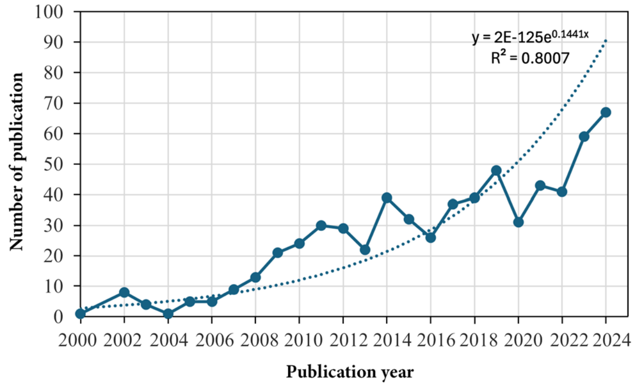


Table 3 presents the most influential authors in carbon market research based on three key metrics: total citations (TC), publication frequency, and citations per year. Li, J. leads with 393 citations (56.1/year) from just 7 papers, showing high impact per study. Zhang, W. and Zhang, X. also have strong influence with 8 papers each (320 and 296 citations). Wang, Y. published the most (11 papers) but with fewer citations, suggesting broader but less-cited work. Others such as Dargusch, P. and Wang, H. show more modest contributions. The data reveals a trade-off between publication volume and citation impact in this field.

Table 4 lists the most influential carbon market research papers (2000–2024), ranked by TC. Timilsina [41] leads with 488 citations (37.5/year), reflecting its foundational role in renewable energy policy. Recent works such as Zhang et al. [6] and Liao [42] show high annual citation rates (51.8 and 39.0 per year, respectively), indicating growing relevance. Older studies (e.g., work by Olsen [43]) remain impactful but with lower yearly citations. The normalized TC (accounting for citation disparities across fields) highlights Liao [42] as the most influential (9.45). Notably, Green [44] and Ren et al. [45] demonstrate rapid recent impact. Table 4 highlights enduring themes (climate policy, energy economics) and emerging trends (carbon neutrality, market mechanisms).

Table 5 highlights key papers frequently cited within carbon market research ("local citations"), alongside their broader academic impact ("global citations"). Chevallier [54] and Fan and Todorova [56]

Table 3
Most relevant authors

Row Labels	Sum of TC	Sum of frequency	Citation per year
Li, J.	393	7	56.14286
Wang, X.	314	7	44.85714
Li, Y.	290	7	41.42857
Zhang, W.	320	8	40
Zhang, X.	296	8	37
Zhang, J.	235	8	29.375
Wang, Y.	173	11	15.72727
Li, H.	82	6	13.66667
Dargusch, P.	86	7	12.28571
Wang, H.	35	6	5.833333

Table 4
Most relevant papers in the carbon market worldwide (2000–2024)

Paper	DOI	Total Citations	TC per Year	Normalized TC
Timilsina [41]	10.1016/j.rser.2011.08.009	488	37.54	8.34
Olsen [43]	10.1007/s10584-007-9267-y	298	16.56	4.59
Liao [42]	10.1016/j.enpol.2018.05.020	273	39.00	9.45
Zhang et al. [6]	10.1016/j.energy.2020.117117	259	51.80	8.41
Fahey [46]	10.1890/080169	245	16.33	5.49
McAfee [47]	10.1111/j.1467-7660.2011.01745.x	227	17.46	3.88
Dong et al. [48]	10.1016/j.scitotenv.2018.10.395	221	36.83	7.20
Wang et al. [49]	10.1016/j.energy.2014.11.009	214	21.40	6.80
Oberndorfer [50]	10.1016/j.ecolecon.2008.07.026	187	11.69	3.56
Zhang et al. [51]	10.1016/j.enpol.2014.08.006	179	16.27	4.10
Wen et al. [52]	10.1016/j.eneco.2019.104627	173	34.60	5.61
MacKerron [53]	10.1016/j.enpol.2008.11.023	167	10.44	3.18
Chevallier [54]	10.1016/j.eneco.2011.07.012	153	10.93	3.37
Green [44]	10.1088/1748-9326/abdae9	150	37.50	5.01
Tan et al. [55]	10.1016/j.eneco.2020.104870	137	27.40	4.45
Fan and Todorova [56]	10.1016/j.apenergy.2017.09.007	136	17.00	3.98
Lin [57]	10.1016/j.apenergy.2019.01.194	122	20.33	3.97
Locatelli [58]	10.1007/s13280-014-0530-y	122	11.09	2.79
Ren et al. [45]	10.1016/j.techfore.2022.121611	118	39.33	5.49

Table 5
Locally cited documents

Document	DOI	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations (%)	Normalized Global Citations
Chevallier [54]	10.1016/j.eneco.2011.07.012	2011	15	153	9.80	8.37	3.37
Fan and Todorova [56]	10.1016/j.apenergy.2017.09.007	2017	13	136	9.56	8.67	3.98
Wang et al. [49]	10.1016/j.energy.2014.11.009	2015	13	214	6.07	13.90	6.80
Tuerk et al. [59]	10.3763/cpol.2009.0621	2009	12	96	12.50	4.00	1.83
Lo [60]	10.1080/14693062.2014.991907	2016	10	100	10.00	7.00	3.40
Fan et al. [61]	10.1016/j.enpol.2017.01.008	2017	10	82	12.20	6.67	2.40
Oberndorfer [50]	10.1016/j.ecolecon.2008.07.026	2009	10	187	5.35	3.33	3.56
Dong et al. [48]	10.1016/j.scitotenv.2018.10.395	2019	9	221	4.07	13.18	7.20

have the highest local citations (15 and 13), showing strong influence in this specific field, despite moderate global citations (153 and 136). Notably, Wang et al. [49] and Dong et al. [48] have high global citations (214 and 221, respectively) but lower local citation ratios (6.07% and 4.07%, respectively), indicating their broader relevance beyond carbon markets. The LC/GC ratio reveals niche impact Fan and Todorova [56] are cited more proportionally within carbon market literature (12.5% and 12.2%). Normalized metrics adjust for citation biases, with Wang et al. [49] and Dong et al. [48] excelling in global influence (6.80 and 7.20, respectively), while Chevallier [54] and Fan and Todorova [56] dominate locally (8.37 and 8.67, respectively). Table 5 highlights that some works (e.g., Oberndorfer [50]) are widely cited but less pivotal in carbon market discussions, whereas others (e.g., Tuerk et al. [59]) are specialized touchstones.

Figure 3 shows several academic journals in the work, employment, and related fields, with number of published documents, TC received, and rank according to citation. *Energy Policy* has the most with 1858 citations, so it is the most influential in energy policy research. *Climate Policy* (1215 citations) and *Energy Economics* (1086 citations) are also very influential in their respective fields of climate policy and energy economics. Journals such as *Applied Energy, Renewable and Sustainable Energy Reviews*, and *Ecological Economics* also show high impact, so sustainable energy and ecological economic research is important. The variety of topics shows the interdisciplinary nature of influential research in environmental and economic fields.

Figure 4 shows the number of papers on carbon market economics that are published in various countries. China has 205, demonstrating its high attention and capabilities in environmental policy research.

Figure 3
Most popular journals according to citations

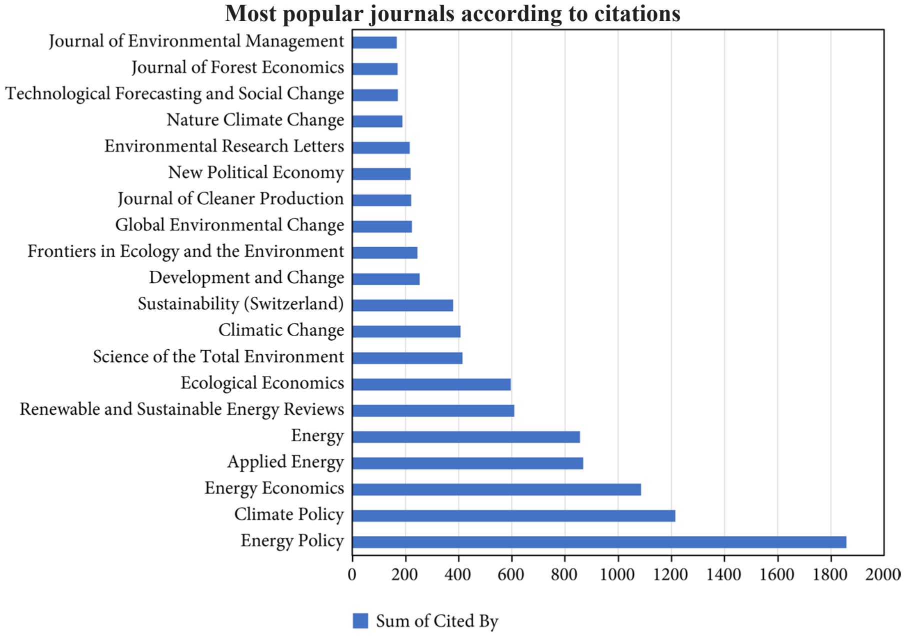
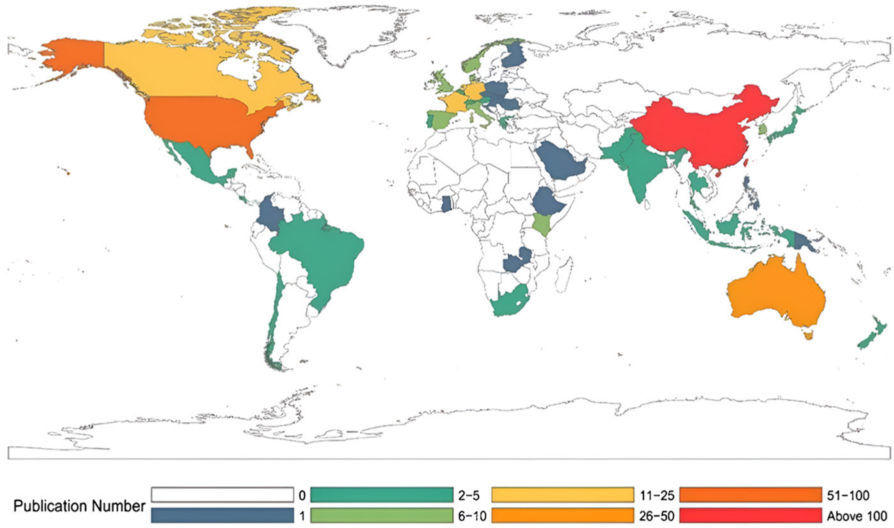


Figure 4
Country's contribution to scientific production



The United States of America has 198, reflecting its strong support for climate research in the academia and government. Australia, the United Kingdom, and Germany also have 28, 21, and 11, respectively. This reflects global interest in understanding carbon markets through research with contributions from countries such as France, Canada, Italy, the Netherlands, and Brazil.

3.2 Science mapping

Science mapping involves several steps: data extraction, cleaning, processing, network mining, plotting, investigation. and visualization, as described by Du et al. [62]. The main questions that science mapping addresses in bibliometric analysis are identifying, examining, and producing social networks around research topics. The complexity of science mapping comes from the need to use different software tools [63]. Practices in science mapping include citation analysis, co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis, which can be combined with network analysis to understand intellectual structures [35]. It helps researchers to understand the research landscape comprehensively and make informed decisions on research priorities.

The co-citation network in this research illustrates the relationships between documents based on how often these are cited together by other publications. When two documents are frequently co-cited, it suggests a thematic or conceptual link between them. These networks often reveal shared research themes, key contributors, and emerging areas within a specific field—such as the carbon market. Figure 5 presents a co-citation network map in which each node represents a cited reference, and the size of each node indicates the number of citations it has received. Using VOSviewer, the analysis identified 51 references from a total of 41,024 that were co-cited at least 15 times. The five thematic clusters within the network offer insight into major research areas: Cluster I (red) comprises 16 items focused on carbon pricing mechanisms and policy design; Cluster II (green)

Figure 5
Co-citation network in carbon market

includes 12 items related to market efficiency and the financialization of carbon; Cluster III (yellow) contains 9 items emphasizing climate change mitigation and international agreements; Cluster IV (blue) consists of 8 items highlighting corporate strategy and carbon offsetting; Cluster V (purple) encompasses 6 items centered on technological innovation and the low-carbon transition.

Table 6 analyses co-cited references in carbon market research, revealing key intellectual influences and thematic networks. Policy documents such as Bird et al. [64] and Galinato et al. [65] dominate with exceptionally high citation counts (50 and 49, respectively) and link strengths (4950, 4900, respectively), reflecting their foundational role. Theoretical works [66] and policy studies [67] form core clusters, while critical perspectives [68] challenge mainstream market approaches. Recent studies by Wen et al. [52] and Duan et al. [69] show emerging trends, though some niche references by Stern [70] remain isolated. The data highlights both the enduring influence of early policy frameworks and evolving academic discourse, with high link strengths indicating collaborative or interdisciplinary engagement in shaping carbon market research.

Figure 6 presents a keyword co-occurrence network generated using VOSviewer, illustrating the evolution of research themes related to carbon markets over time. Each node in the network represents a keyword extracted from academic publications, with the size of the node indicating the frequency of occurrence of that keyword. The lines connecting the nodes represent co-occurrence links, showing how often two keywords appear together in the same documents. The color gradient, ranging from purple to yellow, indicates the average publication year, where purple/blue shades reflect older studies (around 2012), green represents mid-range years (2016–2018), and yellow shows more recent studies (around 2020).

The most prominent and frequently occurring keywords in this network are "carbon markets," "carbon market," and "climate change," highlighting their central role in the literature (Figure 6). Older research appears to focus on topics such as "carbon trading," "Kyoto Protocol," and "CDM" (Clean Development Mechanism). In contrast, more recent studies are increasingly addressing "carbon pricing," "carbon tax," and regional focuses such as "China" and "EU ETS." Additionally, terms such as "climate policy," "carbon sequestration," and "emissions trading" show strong interconnections, indicating their significance in the discourse surrounding carbon markets. Overall, this network provides a clear visualization of how the focus of carbon market research has evolved over the years and reveals key thematic clusters within the field.

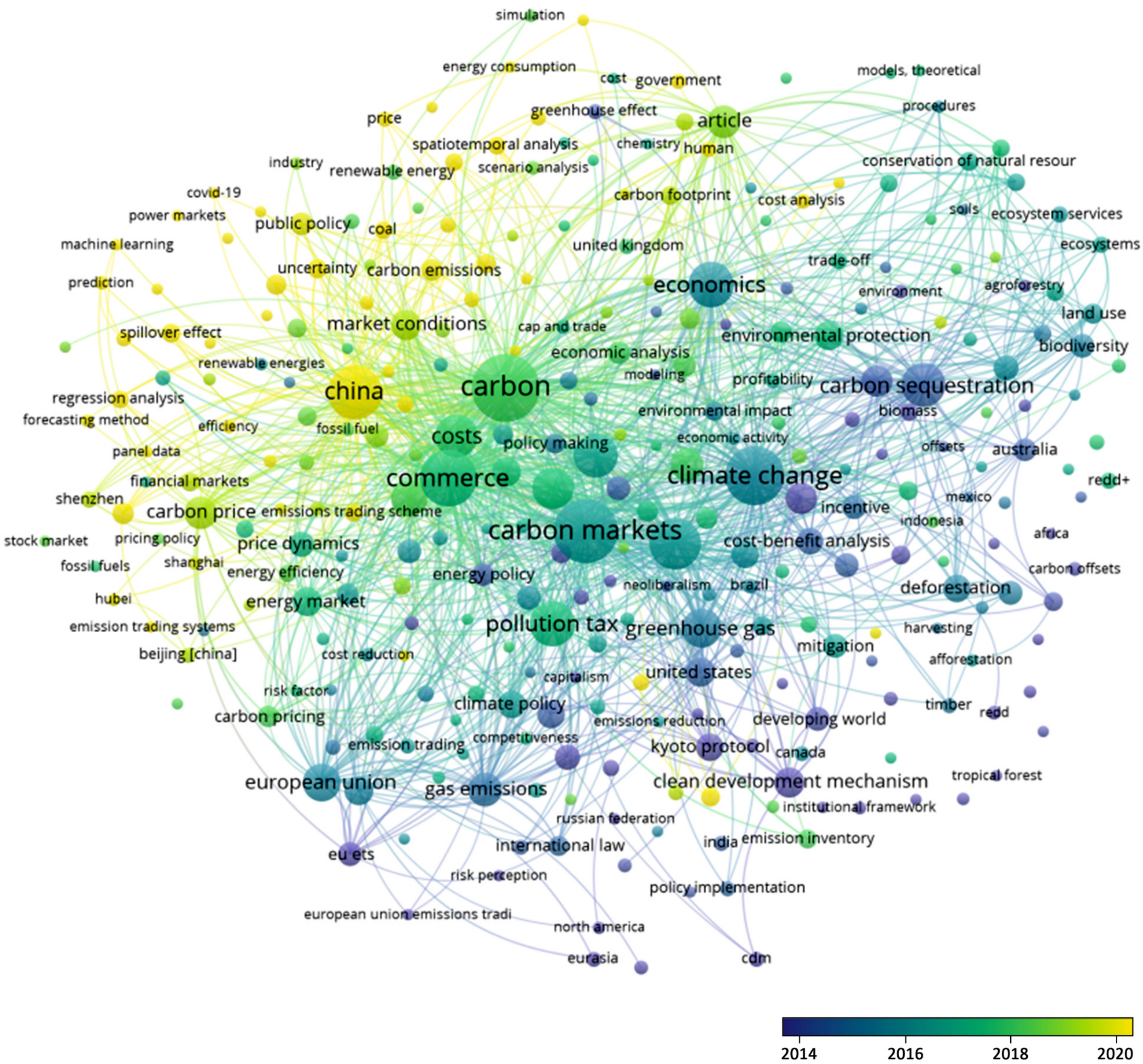
Figure 7 illustrates the evolution of research themes related to carbon markets and climate policy from 2008 to 2023. Each horizontal line represents a specific keyword, while the size of the blue circles along the line indicates the frequency of its appearance in publications during particular years. Larger circles signify greater attention to that topic in the respective year. Early research (pre-2013) primarily focused on foundational mechanisms such as the Kyoto Protocol, CDM, emissions trading, carbon credits, and linking, reflecting global efforts to establish formal carbon market structures. Between 2013 and 2017, attention shifted toward operational and institutional aspects of carbon governance, including terms such as carbon markets, climate change, carbon trading, and ecosystem services, suggesting the maturation and diversification of the field. Following the 2015 Paris Agreement, emerging themes included carbon pricing, cap-and-trade, REDD+, and climate finance, indicating a growing interest in implementation strategies and financial instruments to achieve climate goals. From 2018 onward, research became increasingly focused on practical and region-specific mechanisms, particularly around carbon market instruments such as carbon tax, carbon pricing, and voluntary carbon markets. In recent years (2021–2023), dominant topics include the Paris Agreement, emission trading schemes, and China's role in carbon markets—highlighting current research momentum around global policy frameworks and market-based solutions for emission reductions. Overall, Figure 7 captures a clear trajectory of scholarly focus transitioning from foundational policies to market dynamics and implementation pathways in response to global climate action.

A word cloud was employed to visually represent the primary topics, thematic clusters, and research areas within the field, as depicted in Figure 8. In line with Hassanein and Mostafa [71], the font size and color in the word cloud correspond to the frequency of occurrence

Table 6
Co-citation of cited reference

Cited Reference	Citations	Total Link Strength	Cited Reference	Citations	Total Link Strength
Alberola et al. [72]	8	13	Molitor [75]	6	3
Baumol and Oates [66]	5	3	Lohmann [68]	6	16
Bumpus and Liverman [73]	9	16	Munnings et al. [76]	7	29
Callon [74]	7	21	Newell and Paterson [77]	8	23
Duan et al. [69]	6	16	Spash [78]	6	16
Fan and Todorova [56]	6	18	Stern [70]	7	2
Bird et al. [64]	50	4950	Wen et al. [79]	6	15
Galinato et al. [65]	49	4900			

Figure 6
Factor map cluster of high-frequency keywords



of each term in the literature—larger and more prominently colored words indicate higher frequency. The analysis reveals that terms such as "carbon market," "climate change," "carbon price," "development," and "economic" appear most frequently, highlighting their central role in the scholarly discourse. Additional frequently occurring terms include "emissions trading," "energy," "environmental," and "climate policy," reflecting key areas of focus and ongoing research. Overall, this visualization provides a concise overview of dominant themes and emerging trends in the domain.

Figure 9 presents a thematic evolution map that illustrates how high-frequency keywords in the literature on carbon markets and emissions have evolved over time. The timeline is segmented into four distinct periods: 2000–2012, 2013–2017, 2018–2021, and 2022–2024. Each column lists dominant keywords for a specific period, and the flow lines connecting the boxes show how themes transitioned and developed across these timeframes.

In the period 2000–2012, Early research themes focused on foundational concepts such as carbon, deforestation, reforestation, carbon price, emission trading, CDM, and carbon markets. These topics reflect the early policy mechanisms and theoretical frameworks aimed at addressing climate change, particularly through market-based approaches. Between 2013 and 2017, the field began to coalesce around key topics such as carbon market, carbon markets, and deforestation, showing continuity and growth from the previous period. New themes also emerged, such as Australia and cookstoves, indicating geographic expansion and interdisciplinary interest.

Between 2018 and 2021, the research saw a shift toward more applied and outcome-focused research. Key themes during this phase included carbon trading, carbon price, carbon market, carbon sequestration, emission trading scheme, and payments for ecosystem services. This indicates growing interest in evaluating the effectiveness of carbon pricing, ecosystem incentives, and trading systems. In the most recent period, 2022–2024, themes such as carbon market, carbon sequestration, emission trading scheme, climate change, carbon markets, and carbon emission have continued to dominate, suggesting sustained interest in implementation, scaling, and integration of carbon-related mechanisms. The recurrence of "carbon market" across all periods emphasizes its central and enduring role in the scholarly discussion.

Figure 7
Trending topics over the years

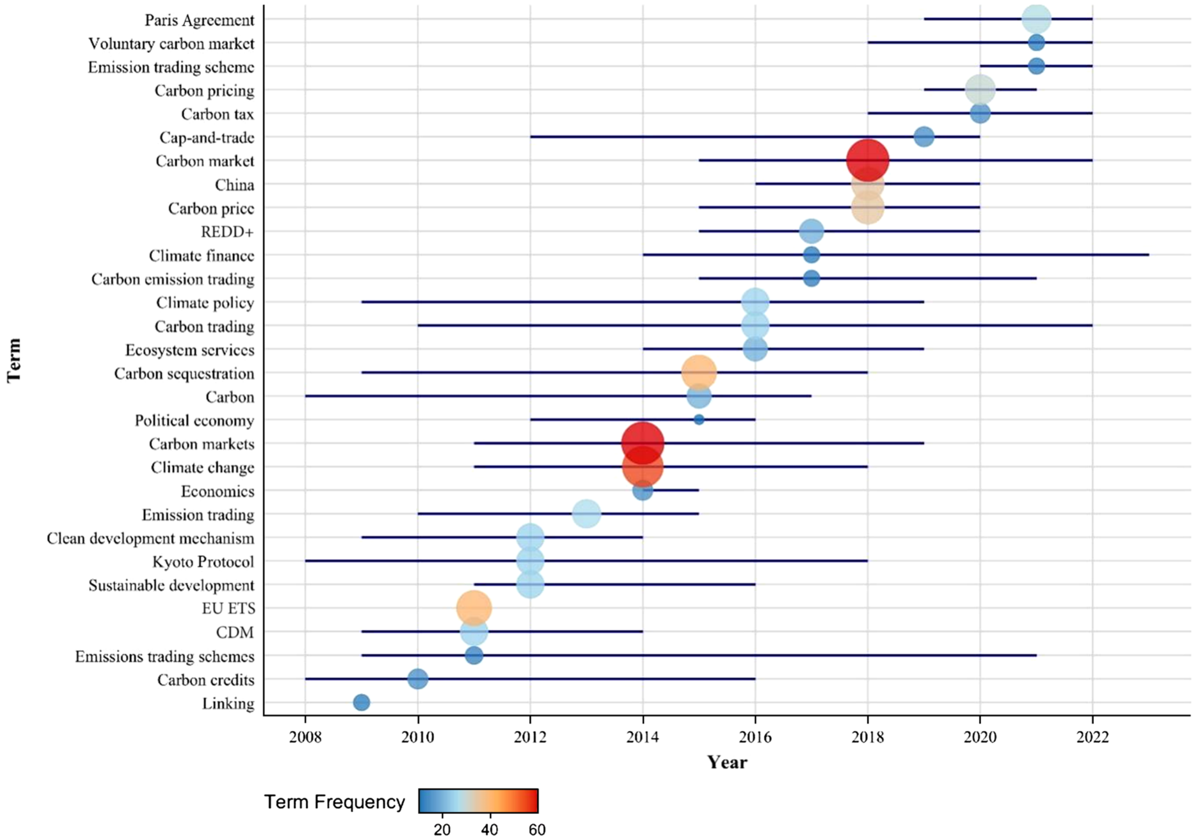


Figure 8
Word cloud of 100 words

Overall, Figure 9 shows a clear progression from theoretical and policy design concepts in earlier years toward more practical, operational, and outcome-oriented research in recent years. The visualized keyword transitions provide insights into the intellectual development and shifting research priorities in the field over time.

Figure 10 presents a thematic map that categorizes the major research themes in the field of GHG emissions and carbon markets based on their relevance (centrality) and development (density). The horizontal axis represents the degree of centrality, indicating how integral a theme is to the broader research field, while the vertical axis reflects the density, showing how internally developed and mature each theme is. The map is divided into four quadrants. In the top-right quadrant, labeled motor themes, we find well-developed and highly relevant topics such as climate change mitigation, carbon finance, environment, ecosystem services, carbon sequestration, and REDD+, indicating that these are driving forces in the literature. The top-left quadrant, labeled niche themes, includes specialized, but less central, topics such as emission reduction, abatement cost, wavelet analysis, and economic policy uncertainty. These themes are advanced within their niche but not widely connected to the broader field. The bottom-right quadrant, representing basic themes, includes carbon market, carbon trading, carbon credits, China, and EU ETS, suggesting these are foundational to the field but still evolving in terms of internal coherence. Finally, the bottom-left quadrant, labeled emerging or declining themes, comprises topics such as carbon pricing, cap-and-trade, carbon tax, Covid-19, and renewable energy. These may represent either nascent areas of inquiry or declining interest. Centrally located terms, such as emissions trading, climate policy, and Paris Agreement, act as thematic bridges, linking multiple areas across the research landscape. The colored bubbles further illustrate clusters of closely related keywords, reflecting the thematic structure and intellectual organization of the field.

4. Discussions

This systematic bibliometric analysis reveals exponential growth in carbon market research, with publication output peaking in 2023, a clear indicator of the rising academic and policy relevance of the field. China emerges as the dominant contributor (352 publications), followed by the USA (218) and Australia (166), reflecting these nations' strong research investments in climate policy and market mechanisms.

Figure 9
Thematic evaluation and map cluster of high-frequency keywords

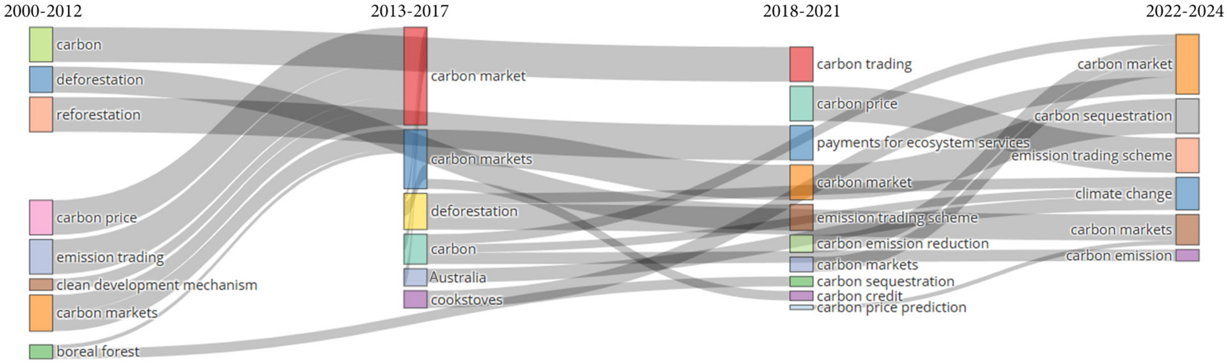
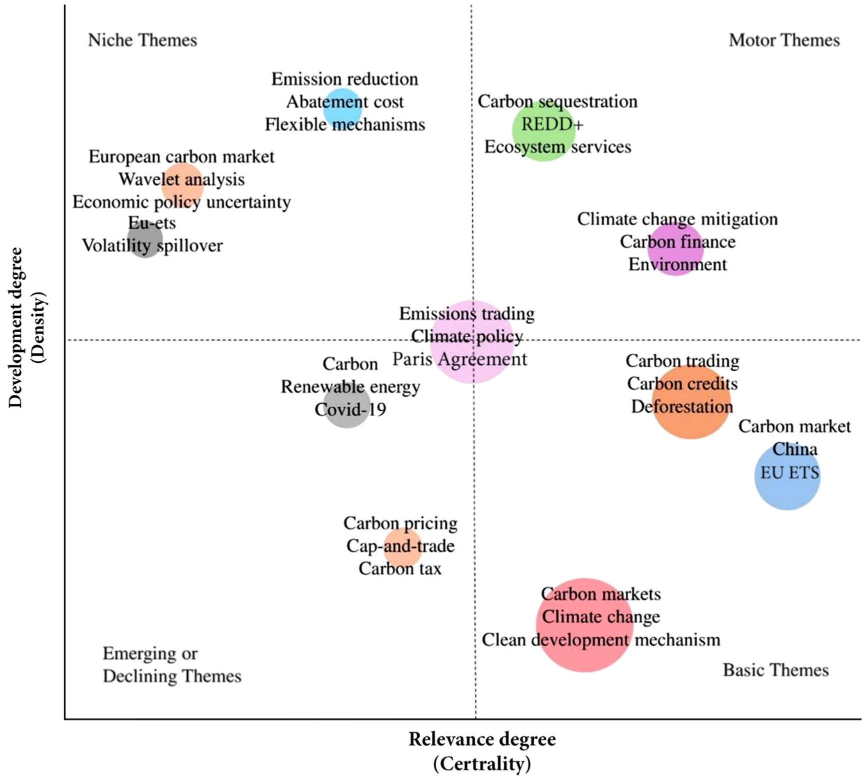


Figure 10
Thematic map



This geographic distribution aligns with the operational scale of major emissions trading systems (e.g., China's ETS, EU ETS) and underscores how national climate strategies drive scholarly attention. The upward trajectory suggests carbon markets will remain a focal point as countries ramp up decarbonization efforts post–Paris Agreement.

The analysis identifies stark contrasts in research impact patterns. Authors such as Li, J. achieve exceptional citation influence (56.1 citations/year) with limited publications, while prolific contributors such as Wang, Y. (11 papers) exhibit broader, but less concentrated, impact. Journals such as Energy Policy (1,858 citations) and Climate Policy (1,215 citations) dominate, reinforcing the policy-applied nature of this field. Seminal works (e.g., Timilsina [41] on renewable energy policy) maintain enduring relevance, whereas recent studies (e.g., Zhang et al. [6]) show accelerated citation rates, signaling shifting priorities toward carbon neutrality and pricing innovations.

The evolution of carbon market research reveals a clear trajectory from theoretical policy frameworks to practical implementation challenges. In the early 2000s, studies predominantly focused on establishing foundational mechanisms, particularly the Kyoto Protocol's CDM and emissions trading systems. This period emphasized market design principles, international cooperation, and the role of carbon credits in global climate governance. However, following the Paris Agreement in 2015, research priorities shifted toward operationalizing carbon pricing instruments, with increasing attention to cap-and-trade systems, carbon taxes, and sector-specific applications. Recent years have seen a surge in studies examining real-world market performance, including price volatility, regulatory enforcement, and the interplay between compliance and voluntary markets.

A notable trend is the growing regionalization of research, particularly around China's national ETS, the EU's carbon border adjustments, and emerging voluntary markets in the Global South. Keywords such as "carbon neutrality," "just transition," and "nature-based solutions" reflect an expanding scope beyond pure economics to encompass social and ecological dimensions. Yet, while early literature treated carbon markets as largely technical instruments, contemporary studies increasingly grapple with their political economy, including lobbying influences, policy stability, and public acceptance. This thematic progression underscores the maturation of the field from conceptual debates to applied research, though significant gaps remain in translating theoretical models into equitable and scalable solutions.

Despite advancements, the bibliometric analysis exposes critical gaps in carbon market research. One glaring omission is the limited engagement with dissenting perspectives, such as critiques of commodification, carbon offsetting integrity, and distributive justice. While influential works such as Lohmann [68] and Spash [78] question market-based climate governance, their co-citation networks remain peripheral compared to dominant policy-focused literature. This imbalance suggests a need for more pluralistic research that evaluates carbon markets not just for efficiency but also for their socio-ecological consequences, including land rights conflicts and perverse incentives under offset regimes.

Future research should prioritize three key areas. First, interdisciplinary studies must bridge economics with political ecology, ethics, and energy justice to assess trade-offs between market efficiency and equity. Second, granular regional analyses—particularly of non–Organisation for Economic Co-operation and Development (OECD) carbon markets—are essential to understand design variations and their effectiveness in diverse institutional contexts. Finally, empirical work on emerging mechanisms (e.g., Article 6 of the Paris Agreement, which focuses on partnerships, biodiversity credits) could prevent replication of past pitfalls. By addressing these gaps, scholars can help steer carbon markets toward robust, inclusive climate governance rather than treating them as panaceas. The urgency of climate action demands research that not only refines market tools but also interrogates their role in a just transition.

5. Conclusion, Policy Implications, and Future Research Directions

This systematic bibliometric study has mapped the intellectual landscape of carbon market economics research over the past two decades, revealing several critical insights with significant policy relevance. Our analysis of 491 publications demonstrates the remarkable growth of the field, particularly following the Paris Agreement, reflecting on the increasing centrality of carbon pricing in global climate governance strategies. The dominance of research from China, the USA, and EU nations mirrors the geographical distribution of operational carbon markets, while highlighting the need for greater scholarly attention to developing economy contexts.

Three key findings emerge from our analysis. First, the thematic evolution from theoretical market design to implementation challenges underscores that carbon markets have matured from conceptual frameworks to operational policy tools. Second, the persistent focus on technical efficiency metrics in the literature has come at the expense of critical examinations of equity and justice implications. Third, the emergence of new research clusters around carbon neutrality and low-carbon technologies signals the responsiveness of the field to evolving climate policy priorities.

The findings yield four key policy insights for carbon market design: 1) dynamic mechanisms balancing environmental and economic objectives through science-based caps, price stabilization, and flexible allocations; 2) equity-focused governance via progressive revenue recycling, community benefit-sharing, and vulnerable group protections; 3) global harmonization through standardized accounting, capacity-building in emerging economies, and border carbon adjustments; and 4) enhanced integrity via centralized registries, additionality standards, and independent verification.

Critical research gaps include: 1) comparative political economy studies of market performance across institutional contexts, especially in developing countries; 2) longitudinal innovation impact assessments; 3) integrated analyses of carbon markets with complementary climate policies; and 4) critical examinations of power dynamics using political ecology and energy justice frameworks. Addressing these gaps will generate the nuanced evidence needed to refine next-generation carbon pricing instruments.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Author Contribution Statement

Ghanashyam Khanal: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Niranjan Devkota:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Ramkrishna Chapagain:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Chandra Kanta Khanal:** Data curation, Writing – review & editing, Visualization.

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