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# "Evolution of Climate and Weather Risk in Financial Market: A Scopus-Based Bibliometric Perspective"

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***Abstract***
*This bibliometric analysis explores the progression of research on climate and weather-related risks in financial markets, based on 1,376 publications indexed in the Scopus database from 1982 to 2025. Showing a notable annual growth rate of 13.72%, the field reflects growing scholarly attention and increasing relevance. The findings indicate a thematic evolution—from early studies focused on environmental policy and insurance frameworks to more recent emphases on risk assessment, green finance, and carbon trading mechanisms. Collaboration trends reveal a dominant research core led by the USA, UK, and Germany, with additional regional clusters gaining momentum in Asia and the Middle East. The network exhibits a scale-free pattern, where a few central institutions and countries play a disproportionately influential role. Overall, this study offers a thorough overview of the intellectual and collaborative dynamics within the field, providing meaningful insights for academics and stakeholders working at the intersection of climate risk and financial system resilience.*
***Keywords: Climate risk, Weather risk, Financial Market, Bibliometric analysis, Risk Assessment***

## 1. INTRODUCTION

The escalating frequency and severity of climate and weather-related events have significantly altered the dynamics of global financial markets, presenting both emerging challenges and strategic opportunities across a range of sectors including insurance, banking, investment, and real estate (Carney, 2015; Stern, 2007). As both physical risks (such as extreme weather events) and transitional risks (such as regulatory changes and shifts toward low-carbon technologies) become increasingly material, their implications for financial stability, asset pricing, and risk management have drawn heightened attention from scholars and practitioners alike (Battiston et al., 2017; Görgen & Jacob, 2020). This growing awareness has driven a sharp increase in interdisciplinary research at the nexus of climate science and financial economics, positioning climate-related financial risk as a critical field of inquiry for sustainable and resilient financial systems.

Despite the rapid expansion of literature in this domain, a comprehensive, systematic understanding of its intellectual evolution and research structure remains limited. To address this gap, the present study offers a bibliometric analysis titled "Evolution of Climate and Weather Risk in Financial Market: A Scopus-Based Bibliometric Perspective." The aim is to map the development of scholarly output, trace thematic progressions, and examine the collaborative networks that have shaped this emerging field over the past four decades.

Drawing on a curated dataset of 1,376 publications retrieved from the Scopus database, covering the period from 1982 to 2025 and encompassing 656 journals and books, this study employs advanced bibliometric techniques (Aria & Cuccurullo, 2017). The analysis captures key metrics such as an impressive annual growth rate of 13.72%, an average of 22.38 citations per document, and a 35.9% rate of international co-authorship. By examining 4,732 Keywords Plus (ID), 3,730 Author Keywords (DE), and contributions from 3,928 authors, the study provides a data-driven overview of the field's knowledge structure. This research contributes to a deeper understanding of the evolving discourse on climate and weather risks in financial markets, offering valuable insights for academics, policymakers, and financial stakeholders navigating a climate-impacted global economy.

## 2. LITERATURE REVIEW

Over the past few decades, the intersection of climate change and financial markets has emerged as a critical and dynamic area of scholarly inquiry. Initially rooted in broader environmental and policy-oriented discussions, research has increasingly shifted towards quantifying the economic, financial, and investment implications of climate and weather-related risks. Early studies predominantly explored the role of insurance systems, regulatory responses, and environmental governance in addressing climate uncertainties. However, the growing frequency of extreme weather events, such as wildfires, floods, and hurricanes—often linked to anthropogenic climate change (Abatzoglou & Williams, 2016; Barbero et al., 2020)—has triggered a significant evolution in the literature. These phenomena have become focal points for understanding systemic financial risks, prompting the development of climate risk assessment models and market instruments such as catastrophe bonds, carbon pricing mechanisms, and weather derivatives. Recent work has emphasized the urgency of embedding physical and transitional climate risks into financial risk management frameworks (Abram et al., 2021; Bandara & Cai, 2014). Global initiatives, like the Task Force on Climate-related Financial Disclosures (TCFD), have pushed financial institutions to integrate climate exposure metrics into their governance and strategy structures. Simultaneously, empirical research has demonstrated tangible socio-economic impacts—from migration patterns post-disaster (Acosta et al., 2020) to health-related costs of wildfire smoke exposure (Abdo et al., 2019)—highlighting the multidimensional nature of climate-related financial risk. Despite this surge in interest, a systematic evaluation of the intellectual structure and thematic evolution of this field remains limited. Most existing literature either addresses climate risk in isolated sectors or focuses on policy implications without quantitatively mapping the academic landscape.

Given this gap, a bibliometric analysis is both timely and necessary. By synthesizing trends in publication volume, collaborative networks, keyword evolution, and citation impact, this study contributes a comprehensive, data-driven overview of how research in climate and weather-related financial risk has evolved. In line with bibliometric traditions, it also identifies leading authors, institutions, and countries shaping the discourse, providing critical insights into the field's developmental trajectory and emerging thematic clusters.

## 3.METHODOLOGY:

This study adopts a bibliometric approach to systematically explore the intellectual, thematic, and collaborative evolution of research on climate and weather risks in financial markets. Bibliometric analysis is a quantitative method that enables researchers to map scientific outputs, reveal research trends, identify influential contributions, and examine collaboration networks within a specific field (Aria & Cuccurullo, 2017).

### 3.1 Data Source and Retrieval

The data for this study were obtained from the Scopus database, one of the most comprehensive and widely recognized bibliographic repositories for peer-reviewed literature. The search query was designed to capture a broad and relevant scope of literature that intersects climate risk, weather-related events, and financial markets. The query included terms such as "climate risk," "weather risk," "financial market," "weather derivatives," "climate finance," and "green finance" in titles, abstracts, and keywords.

The dataset comprises 1,376 documents published between 1982 and 2025, including journal articles, conference papers, book chapters, and reviews. These documents were extracted from 656 different sources, indicating the multidisciplinary nature of the field.

### 3.2 Analytical Tools and Techniques

The analysis was conducted using bibliometrix, an R-based open-source tool specifically designed for science mapping (Aria & Cuccurullo, 2017). Biblioshiny, the web interface for bibliometrix, was used for data visualization and network analysis. The following bibliometric techniques were applied:

**Performance Analysis**: Quantified publication output, citation metrics, and annual scientific production to assess growth trends.

**Co-authorship Analysis**: Evaluated collaboration patterns among authors, institutions, and countries.

**Keyword Co-occurrence Analysis**: Examined thematic evolution and emerging research topics based on both Author Keywords (DE) and Keywords Plus (ID).

**Thematic Mapping and Evolution**: Used strategic diagrams and Sankey plots to track the development and interconnection of core research themes over time.

**Collaboration Network Analysis**: Mapped global collaboration structures, revealing dominant research hubs and transnational cooperation patterns.

## 4. RESULTS AND DISCUSSIONS:

### 4.1 Descriptives

| Description | Results |
|---|---|
| MAIN INFORMATION ABOUT DATA | |
| Timespan | 1982:2025 |
| Sources (Journals, Books, etc) | 656 |
| Documents | 1376 |
| Annual Growth Rate % | 13.72 |
| Document Average Age | 4.23 |
| Average citations per doc | 22.38 |
| References | 0 |
| DOCUMENT CONTENTS | |
| Keywords Plus (ID) | 4732 |
| Author's Keywords (DE) | 3730 |
| AUTHORS | |
| Authors | 3928 |
| Authors of single-authored docs | 231 |
| AUTHORS COLLABORATION | |
| Single-authored docs | 242 |
| Co-Authors per Doc | 3.37 |
| International co-authorships % | 35.9 |
| DOCUMENT TYPES | |
| article | 1363 |
| article article | 13 |

**Table 1: Overview of Dataset**

#### 4.1.1. Coverage Period and Dataset Scope

The bibliometric dataset spans from 1982 to 2025, offering over four decades of scholarly output related to climate and weather risk in the financial market context. This extended timeframe provides a comprehensive basis for analysing the development and progression of research trends across multiple stages of academic evolution.

#### 4.1.2. Research Output and Growth Dynamics

A total of 1,376 publications were sourced from 656 distinct outlets, including academic journals, books, and conference proceedings. The field has experienced a robust annual publication growth rate of 13.72%, indicating a sharp rise in research interest, particularly in response to growing global concerns surrounding climate change, sustainable finance, and environmental risk management. This consistent upward trend underscores the increasing relevance of the topic in both academic and applied financial domains.

#### 4.1.3. Scholarly Impact and Citations

The dataset reflects an average document age of 4.23 years, highlighting the recent surge in contributions and the field's contemporary significance. On average, each study has been cited 22.38 times, demonstrating considerable scholarly influence and active engagement from the academic community. These metrics affirm that research in this area is not only expanding but also generating meaningful impact across disciplines.

#### 4.1.4. Thematic Breadth and Keyword Usage

An extensive set of 4,732 Keywords Plus and 3,730 Author Keywords is recorded in the dataset, showcasing the thematic depth and diversity of the literature. While Keywords Plus derive from referenced sources and capture broader themes, Author Keywords provide direct insight into the core focus areas as defined by the researchers themselves. This dual keyword dataset enables a well-rounded thematic exploration of the field.

#### 4.1.5. Authorship Patterns and Collaboration Intensity

The dataset includes contributions from 3,928 individual authors, reflecting wide-ranging participation from scholars around the world. Of these, 231 authors produced 242 single-authored papers, indicating some presence of independent research, although the field is largely collaborative. The average of 3.37 authors per publication supports this observation, suggesting that teamwork and joint research efforts are common in this domain.

#### 4.1.6. Global Research Collaboration

International collaboration is a key feature of this field, with 35.9% of the documents involving authors from more than one country. This high level of cross-national co-authorship emphasizes the global scope of climate and weather-related financial research and highlights its importance as a shared academic and policy concern across borders.

#### 4.1.7. Types of Publications

The majority of the documents (1,363) are categorized as peer-reviewed journal articles, underlining the scholarly rigor and formal research standards applied within this field. An additional 13 entries labelled as "article" may reflect duplicate or misclassified records due to metadata inconsistencies and should be reviewed during data cleaning.

#### 4.1.8. Overall Observations

In conclusion, the bibliometric profile indicates that the field of climate and weather risk in finance is rapidly evolving, highly collaborative, and internationally significant. With a strong citation record, increasing publication volume, and broad thematic diversity, the literature in this area offers a rich foundation for advanced analyses. Future research can further explore thematic trends, author networks, and knowledge structures to better understand the intellectual development and global impact of this growing field.

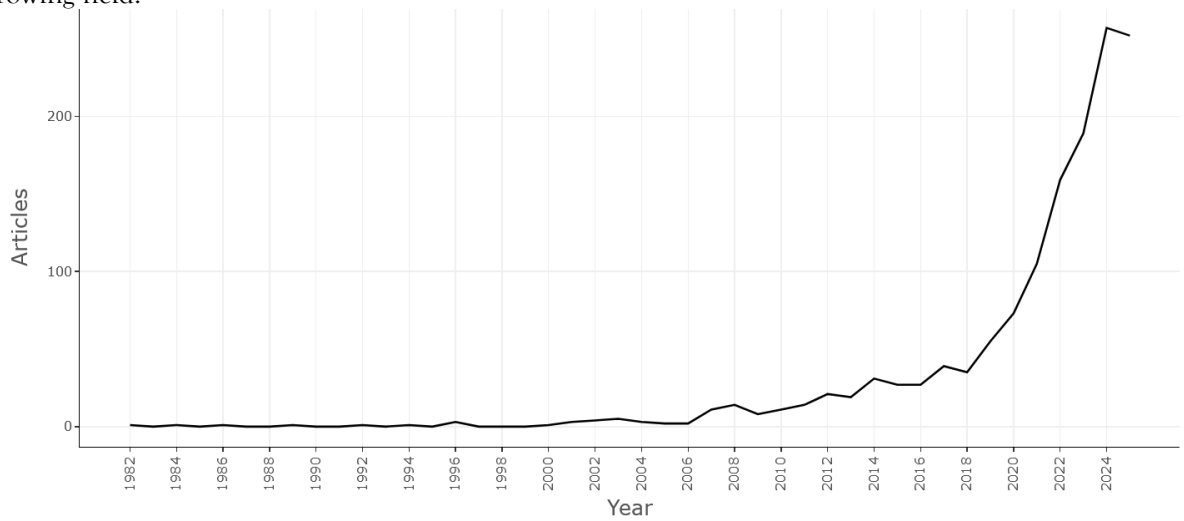


**Fig 1: Annual Research Productivity**

**Figure 1** presents the yearly publication trend in the domain of climate and weather risk in financial markets from 1982 to 2025. The graph indicates minimal research activity during the initial decades, with relatively few publications from 1982 through the early 2000s. A gradual upward trend becomes noticeable around 2008, followed by a more pronounced and steady increase after 2015. The most significant growth is observed between 2020 and 2024, where the number of articles rises sharply, reaching its highest point in 2024 with over 250 publications. This rising trend highlights the increasing academic interest and urgency surrounding climate-related financial issues, driven by global environmental challenges, policy interventions, and the expansion of sustainable finance initiatives.

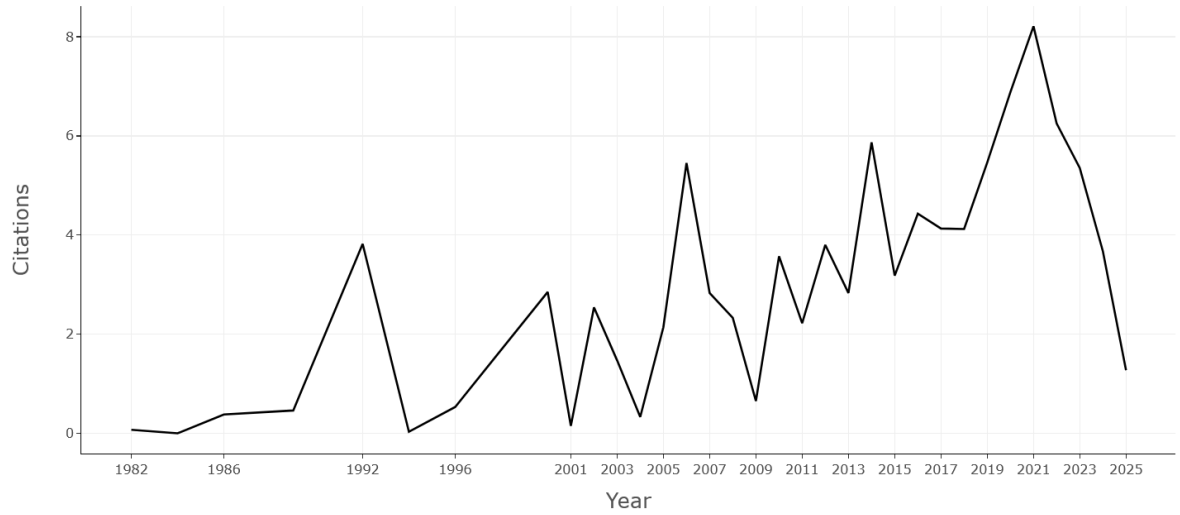


**Fig 2: Yearly Citation Rate**

Figure 2 displays the yearly average of citations received by publications in the field of climate and weather risk in financial markets between 1982 and 2025. The trend reveals irregular citation activity in the earlier decades, with modest levels that begin to rise gradually in the mid-2000s. From around 2010, citation averages become more stable with occasional spikes, peaking notably in 2020—suggesting that research from this period had a strong academic impact. A downward trend is visible in the most recent years (2023–2025), likely due to the shorter time frame available for newer publications to be cited. Overall, the graph indicates increasing scholarly recognition of the field over time, particularly in the last 10 to 15 years.

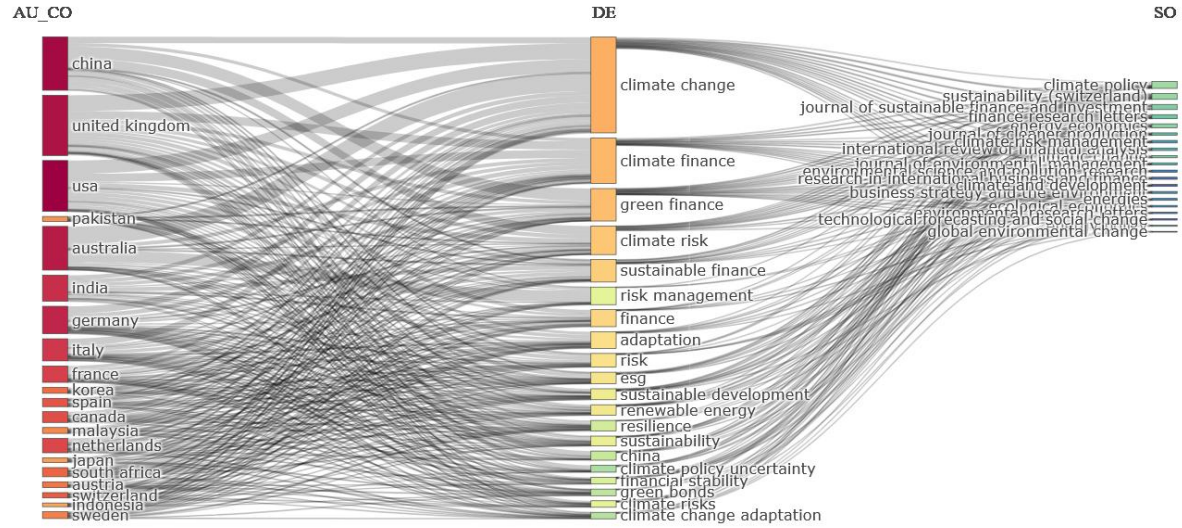


**Fig 3: Tripartite Relationship Map**

This network visualization provides a clear and informative visualization of the relationships between major research themes, contributing countries, and publishing journals in the area of climate and weather risk within financial markets. The width of each connecting line reflects how frequently or strongly these elements are associated. The keyword "climate change" appears most prominently, indicating its central role in the body of research analyzed. Other frequently occurring terms such as "finance," "risk assessment," and "article" point to a strong emphasis on financial dimensions and analytical approaches within climate-related studies. Countries like China and the United Kingdom feature prominently in the diagram, highlighting their significant roles in contributing to this research area, with the United States and Australia also emerging as key players.

Notably, the journal Climate Policy emerges as a leading publication channel for research connecting these themes and countries, indicating its importance as a platform for work focused on climate governance, sustainable finance, and environmental risk. The diagram also shows strong linkages between certain themes and national contributions—for example, research on "climate change" and "finance" is strongly tied to Chinese institutions and commonly published in Climate Policy. Similarly, the United

Kingdom demonstrates a close association with the theme of "sustainable finance" and certain specialized journals, suggesting a concentration of expertise and publication activity in this subfield.

This visualization prompts several insightful considerations and future research questions. China's strong presence points to the potential for deeper analysis into its research priorities, such as technological innovations or policy responses to climate risks. The clustering of specific countries and journals raises questions about national research strategies or editorial preferences. Additionally, the underrepresentation of certain countries or themes—such as climate adaptation research from vulnerable nations—may indicate gaps in global research coverage. However, it's important to acknowledge potential limitations: the use of Scopus may influence coverage due to indexing bias, and affiliations may not always reflect the actual origin of the work. Also, merged keywords may oversimplify nuanced concepts. Despite these factors, the Sankey diagram offers a valuable snapshot of the global research structure, revealing key patterns and guiding further thematic and bibliometric exploration.

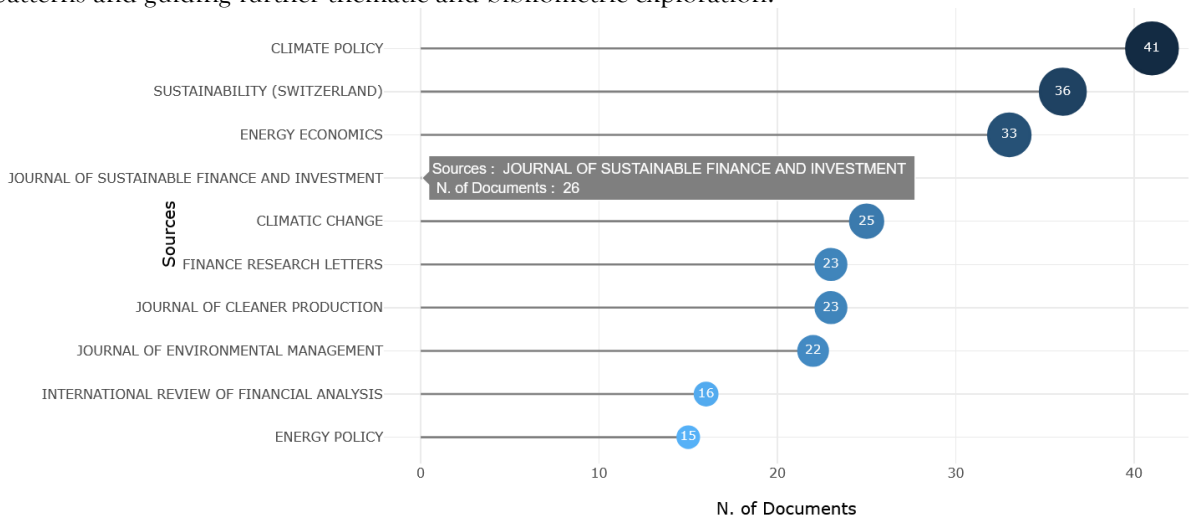


**Fig 4:Top Contributing Journals**

The chart titled "Top Contributing Journal" displays the top ten academic journals that have published the most documents in the field, likely focusing on sustainable finance and climate-related risks. Each source is shown with a horizontal bar and a bubble indicating the number of publications. Climate Policy ranks highest with 41 documents, followed by Sustainability (Switzerland) with 36, and Energy Economics with 33. The Journal of Sustainable Finance and Investment contributes 26 publications. The rest of the journals, including Energy Policy with 15, show a descending trend in output. The bubble size and colour intensity visually represent the publication volume, highlighting the most influential journals in this research domain.

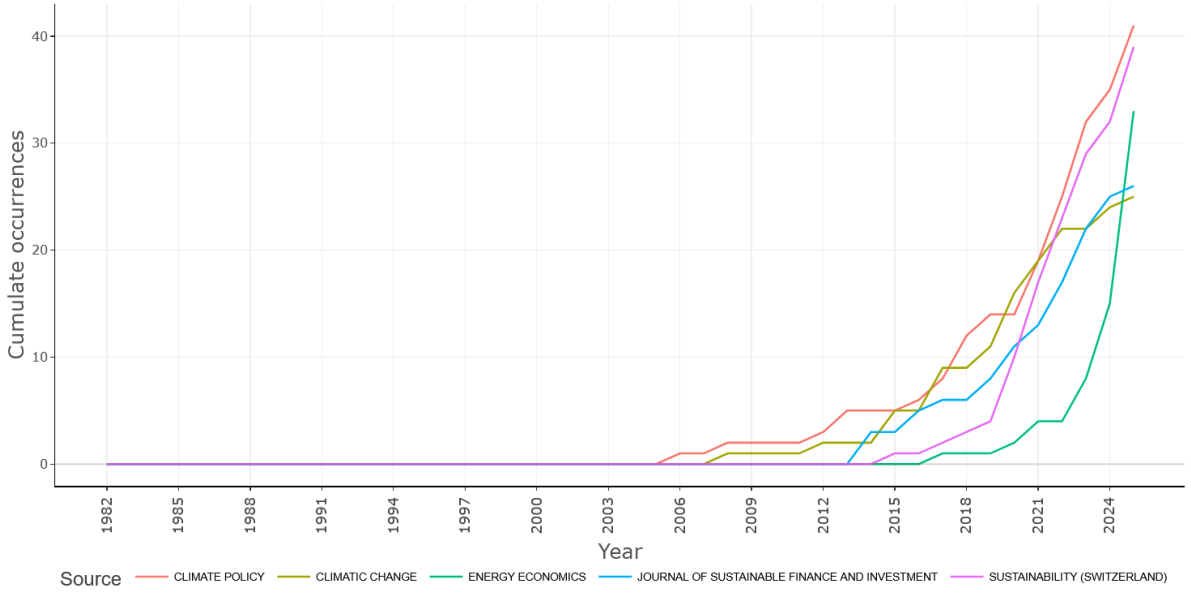


**Fig 5: Chronological Source Output**

The graph shows the cumulative growth in the number of publications from various academic journals focused on climate and sustainability research over time. Beginning in the early 2000s, there is a gradual increase in output, with a notable surge after 2015. One source demonstrates the most significant rise in publications, particularly from 2018 onward, followed closely by another with a similar upward trajectory. Other journals also exhibit steady growth, reflecting a rising academic interest in topics such as environmental policy, sustainable finance, and energy-related issues. This overall trend highlights the growing importance of climate and sustainability in scholarly research.

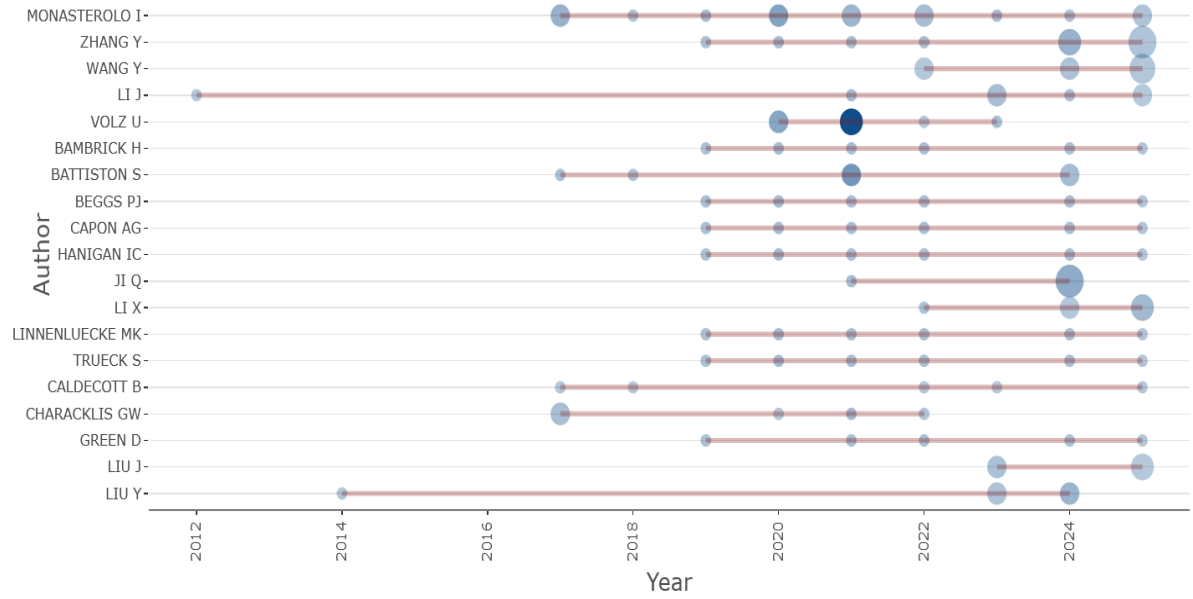


**Fig 5: Yearly Research Output by Authors**

This visual representation showcases the research output of individual authors across different years. Each row corresponds to an author, with circles indicating the years they published. The size of each circle reflects the volume or significance of their publications in that particular year. Spanning from 2012 to 2025, the chart highlights a rise in academic activity after 2018, with several authors maintaining steady contributions. Notably, some researchers, such as Volz U. and Li J., demonstrate higher levels of productivity or impact in recent years, pointing to increasing interest and engagement in the field. The evolving academic contributions of prominent authors over the past decade, focusing on both publication frequency and scholarly impact measured through citations. Red lines denote the active research periods of each author, while bubble size and shading reflect annual publication volume and citation intensity, respectively. This depiction reveals an overall increase in research output starting around 2020, suggesting a growing scholarly focus on climate-related issues. Notably, researchers such as Monasterolo, Volz, and Battiston stand out for their influential work in areas like climate-related financial risk and central bank policy, particularly with highly cited papers published between 2020 and 2022. In parallel, authors like Bambrick, Beggs, Capon, and Hanigan contribute consistently to climate-health discourse, especially through their involvement in the MJA-Lancet Countdown reports, highlighting sustained collaborative engagement in public health research.

From a thematic perspective, the chart illustrates an upward trend in interdisciplinary research linking climate change to finance, policy, and health. Authors like Ji, Li, Wang, and Liu have shown strong recent productivity, particularly in climate economics. The high citation rates of works related to central bank mandates, climate risk disclosure, and health assessments reflect the academic community's growing attention to both economic and human dimensions of climate change. These patterns suggest potential areas for deeper inquiry, such as co-authorship dynamics, keyword clustering, or journal influence. Conducting extended analysis—like keyword frequency tracking, citation flow mapping, or comparing with Web of Science data—can further illuminate how research themes have evolved and help identify emerging thought leaders and influential networks within the broader climate-finance-health intersection.

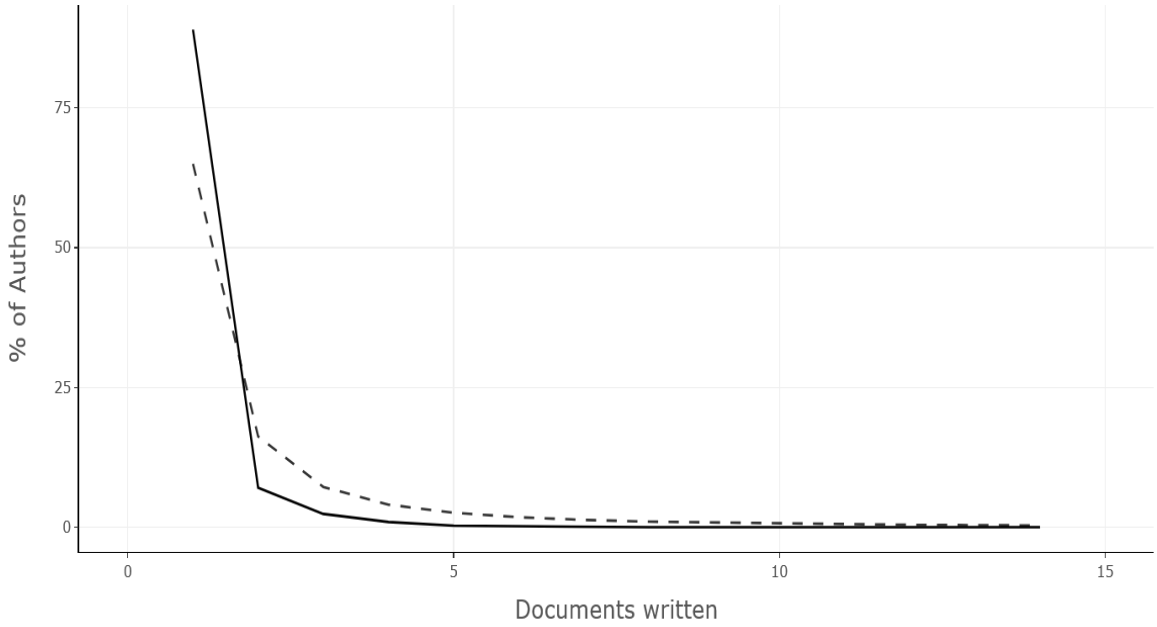


**Fig 6: Analysis of Author Productivity via Lotka's Law**

This graph shows how author productivity aligns with Lotka's Law, which explains how often authors contribute to published works. The horizontal axis indicates how many documents an author has written, while the vertical axis shows the percentage of authors at each level of productivity. The solid line reflects the actual data, and the dashed line shows the theoretical distribution based on Lotka's Law. It highlights that most authors write only one document, and the number of authors decreases rapidly as the number of documents written increases. This supports the idea that a small number of authors are responsible for most of the publications.

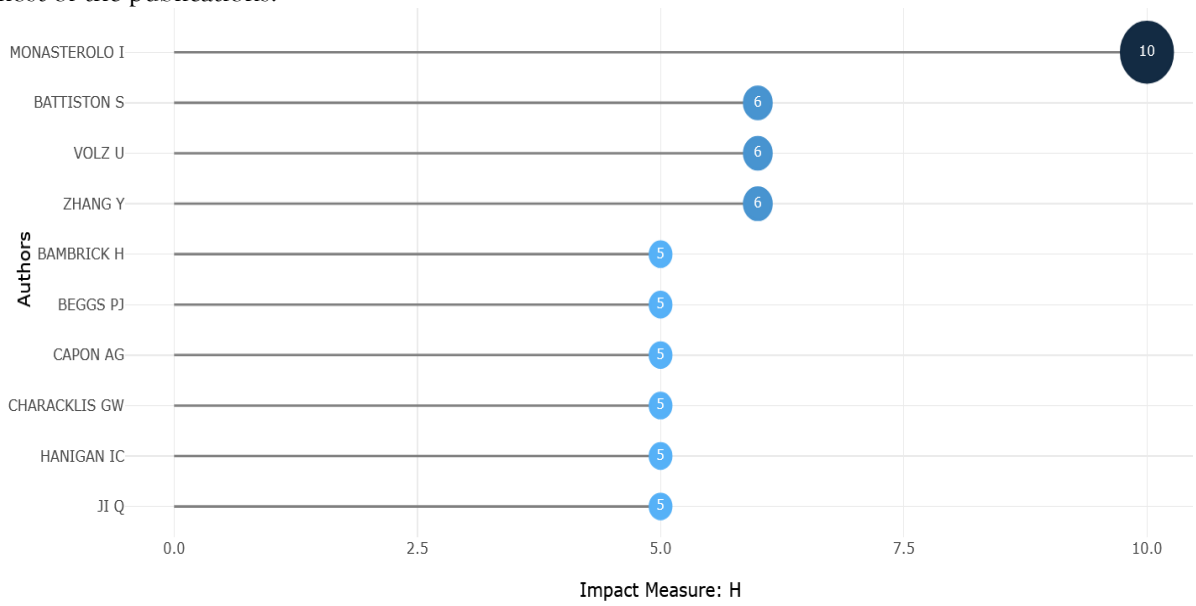


**Fig 7: H-Index-Based Author Impact Overview**

This chart illustrates the local research impact of various authors, using the H-index as a metric to represent both the quantity and influence of their publications. The y-axis lists the authors, while the x-axis shows their corresponding H-index scores. Monasterolo I stand out with the highest score of 10, indicating a significantly greater impact compared to peers. Battiston S, Volz U, and Zhang Y each have an H-index of 6, placing them in the second tier. The remaining authors all have a score of 5, suggesting a relatively equal level of academic influence among them. The graph emphasizes the variation in research impact within the group.

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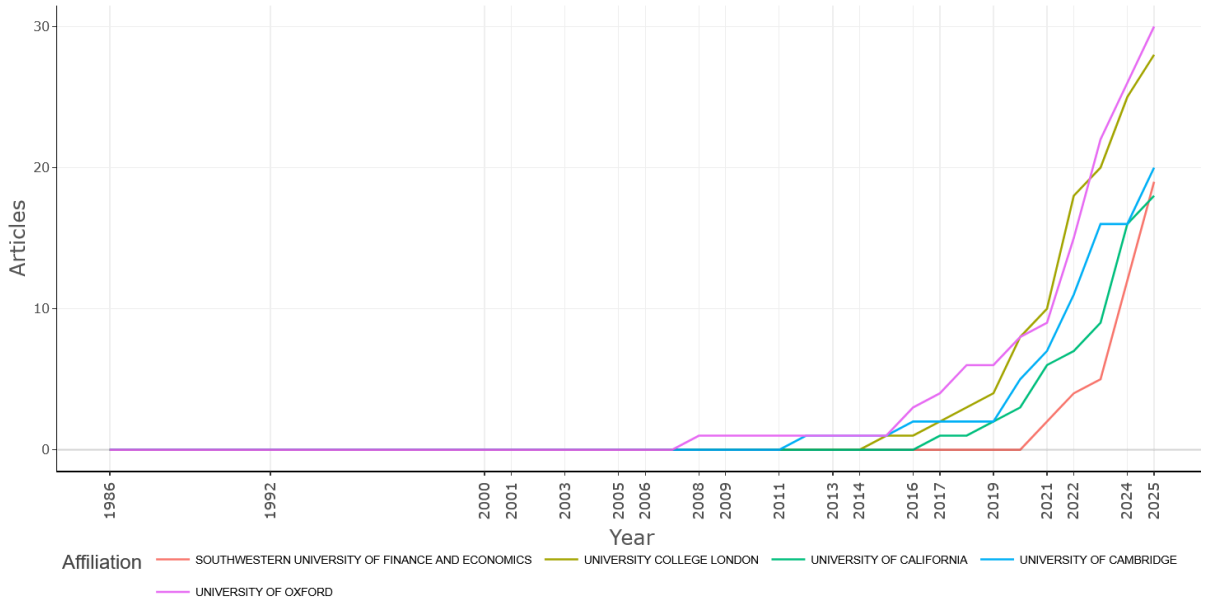


**Fig 8: Evolution of Research Output by Institution**

This graph depicts the progression of academic article output over time for five universities: the University of Oxford, University College London, the University of California, the University of Cambridge, and the Southwestern University of Finance and Economics. The timeline on the x-axis spans from 1986 to 2025, while the y-axis represents the number of published articles. From 1986 until around 2010, publication activity was minimal across all institutions. Starting around 2010, a gradual increase is observed, with a notable acceleration occurring after 2018. The University of Oxford leads in output, surpassing 30 articles by 2025. University College London and the University of California also show significant growth, closely trailing Oxford. Meanwhile, the University of Cambridge and the Southwestern University of Finance and Economics show consistent growth, especially from 2020 onward. The overall trend indicates a marked rise in scholarly productivity among these institutions in recent years, reflecting growing academic engagement in the field

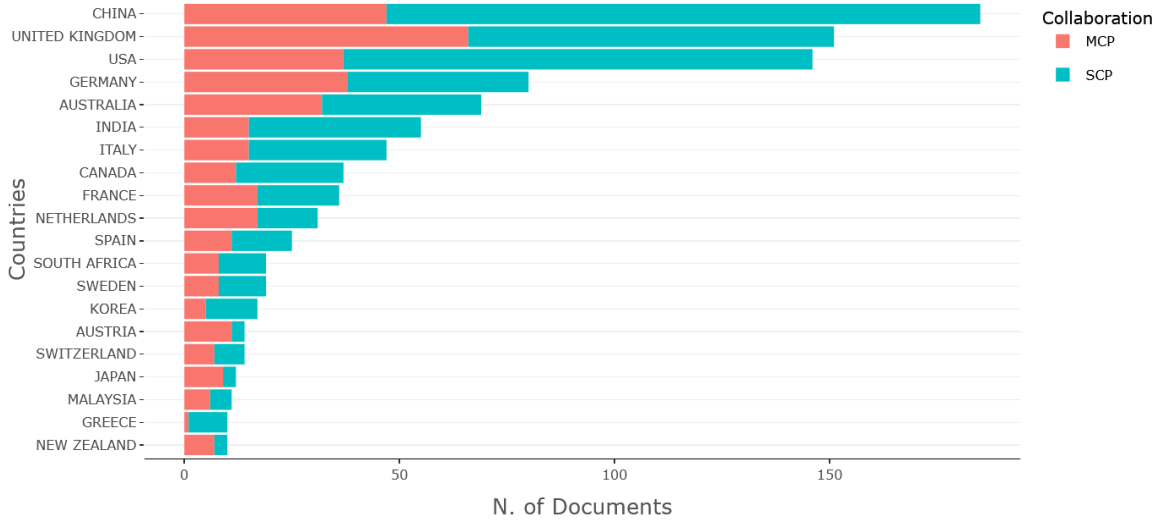


**Fig 9: Geographic Origin of Corresponding Authors**

This chart provides an overview of research productivity by country, specifically highlighting the number of publications where the corresponding author is affiliated with each nation. It distinguishes between Single Country Publications (SCP) and Multiple Country Publications (MCP), showcasing both domestic output and international collaboration. China, the United Kingdom, and the United States are the top contributors in terms of publication volume. However, their collaboration patterns differ: both China and the U.S. have relatively low proportions of internationally co-authored papers (25.4% and 25.3%, respectively), pointing to a stronger emphasis on national research efforts. The UK demonstrates a more collaborative model, with 43.7% of its output involving international partners. Countries such as Germany, Australia, and France also show high levels of global collaboration, each exceeding 45% MCP. Notably, smaller countries like Austria, the Netherlands, and Japan have the highest collaboration rates—

over 50%—indicating a strong reliance on global partnerships, possibly driven by niche research focuses or limited domestic resources.

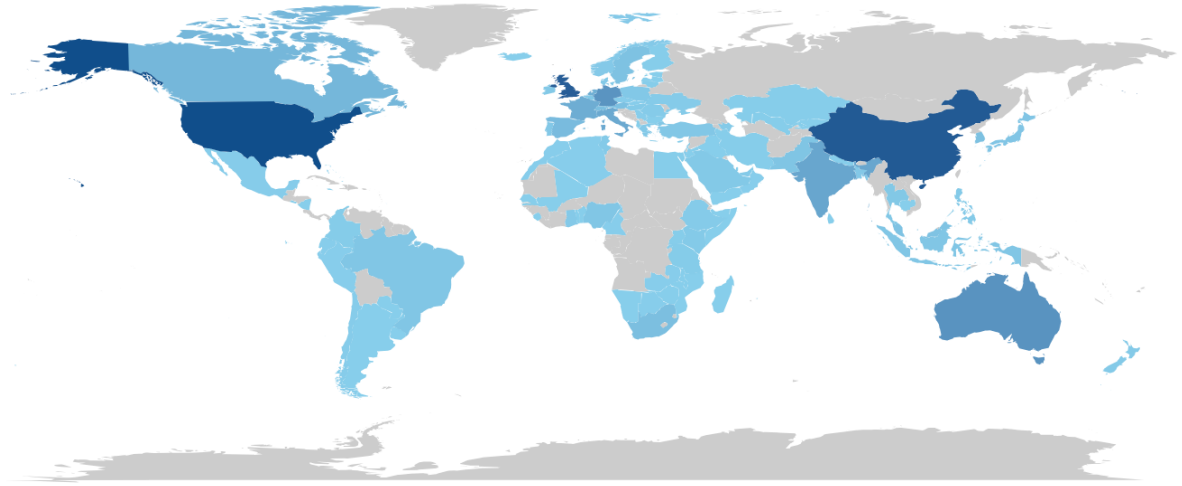

**Fig 10: Global Scientific Output by Country**

This world map visualizes the global distribution of scientific production by country, using a colour gradient to indicate output levels—darker shades of blue represent higher levels of research publication activity, while lighter shades indicate lower levels. The United States, China, and the United Kingdom stand out as the most prolific producers of scientific literature, shown in the darkest blue. Other countries with high output include Germany, India, Australia, Canada, and several European nations, all shaded in moderately dark blues. Much of Africa, parts of Central Asia, and several smaller or developing nations in Latin America and the Middle East are shown in grey or very light blue, reflecting minimal or no recorded research output in this dataset. The map highlights global disparities in scientific productivity, emphasizing the dominance of economically advanced nations in scholarly publication. It also suggests potential gaps in global research collaboration and underscores the need for more inclusive participation in scientific discourse.

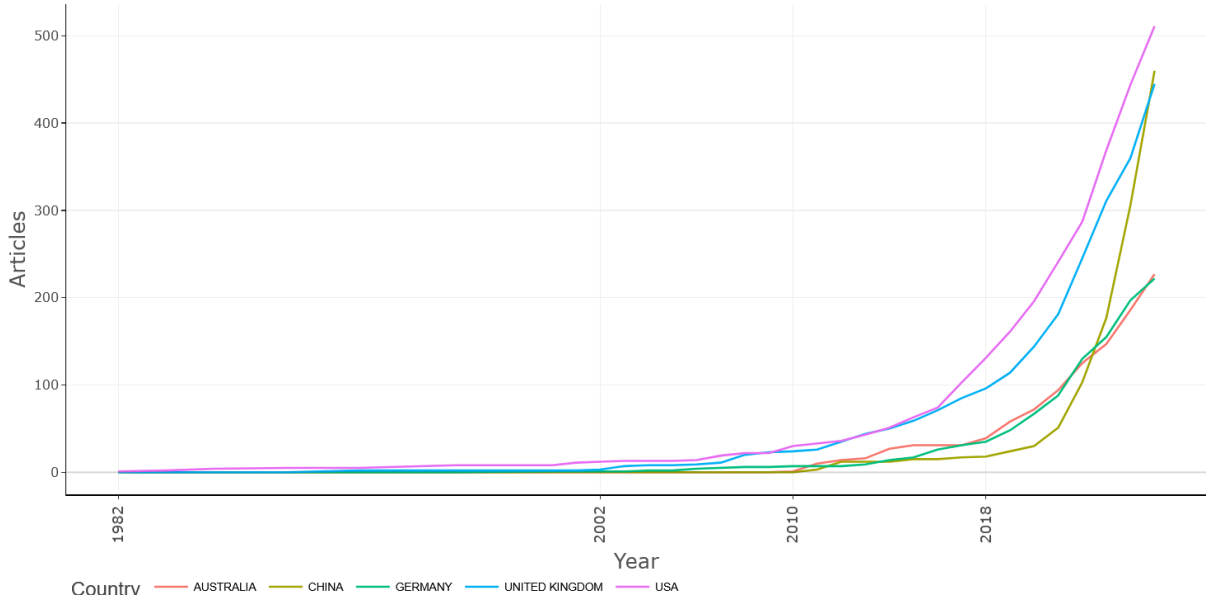


**Fig 11: Country-Wise Research Output Over Time**

This line graph illustrates the progression of scientific article output from six key countries—Australia, China, Germany, the United Kingdom, and the United States—between 1992 and 2025. The y-axis tracks the number of articles published, while the x-axis represents the timeline. During the 1990s and early 2000s, publication numbers remained relatively low and steady across all countries. Around 2010, a gradual increase began, which accelerated significantly after 2015. The United States leads with the highest publication count, exceeding 500 articles by 2025, followed closely by the United Kingdom and China, both showing sharp growth in recent years. Germany and Australia also exhibit upward trends, though their total output remains lower compared to the top three. China's rapid rise in scientific

production is especially notable in the latter part of the timeline. Overall, the graph highlights a strong global surge in research activity, with both established and emerging nations contributing significantly to scientific literature.

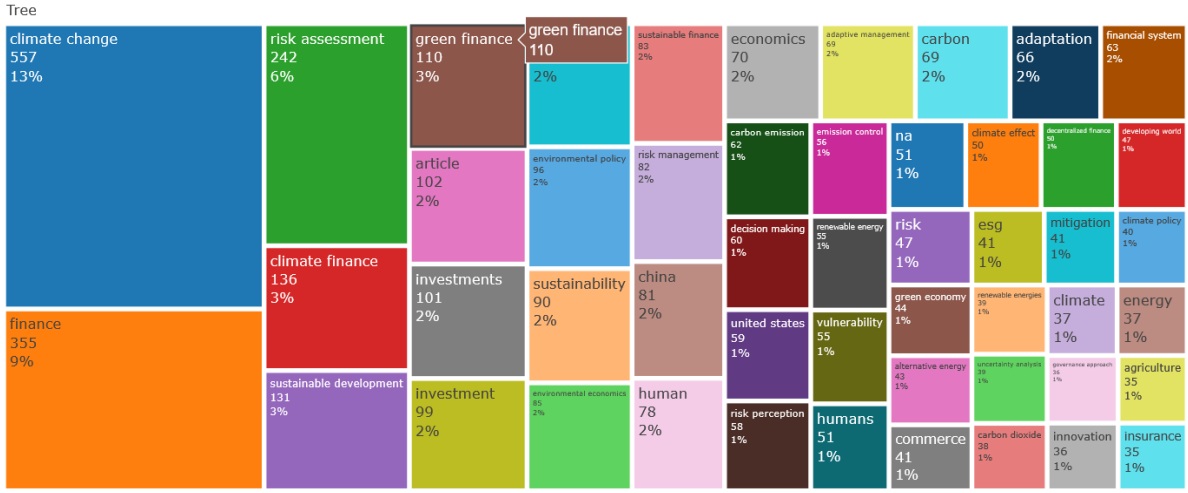


**Fig 12: Conceptual Distribution Map**

This Conceptual Distribution Map provides a visual representation of the most frequently occurring topics within a research dataset, with each rectangle indicating a keyword or subject area. The size of each block reflects the frequency of that term, while different colours help group related themes. “Climate change” is the most prominent topic, appearing 557 times (13%), followed by “finance” with 355 occurrences (9%), and “risk assessment” with 242 (6%). Other significant areas include “climate finance,” “green finance,” “sustainable development,” and “investments,” highlighting a strong focus on the intersection of environmental issues and financial systems. Additional topics like “carbon,” “adaptation,” “mitigation,” “vulnerability,” and “policy” point to a multidisciplinary approach, blending climate science, economics, and governance. Smaller segments such as “insurance,” “agriculture,” “innovation,” and “commerce” show the broader scope of research themes. Overall, the Conceptual Distribution Map underscores a growing academic interest in sustainability and risk within the context of climate and financial systems.

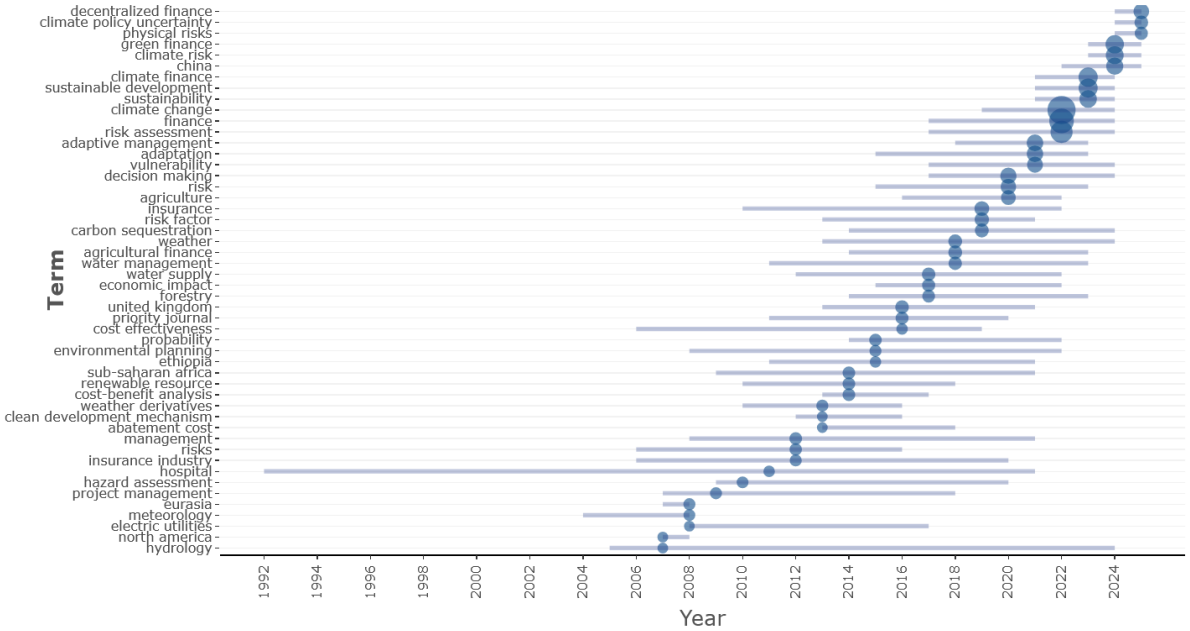


**Fig 13: Emerging Research Themes**

The trend topic chart presents the progression of research themes over time based on keyword frequency from the SCOPUS database, highlighting how academic focus has shifted. In recent years, particularly after 2018, climate-related topics such as "climate change," "climate finance," "green finance," and "sustainable development" have become increasingly prominent. The larger bubble sizes for these terms reflect a rise in publication output, likely driven by growing global concern around climate action and sustainability. Similarly, an upward trend is evident in risk-focused terms like "risk assessment," "adaptive

management," and "vulnerability," pointing to an evolving emphasis on managing the risks of climate change. Earlier research trends, seen lower on the graph, focused more on environmental and resource management issues like “water management” and “forestry,” which have since seen more stable or declining attention.

Additionally, the graph reveals several consistently studied but lower-frequency topics such as “project management,” “hydrology,” and the “insurance industry.” Regional terms like “Sub-Saharan Africa,” “United Kingdom,” and “Eurasia” suggest that some research has been geographically concentrated. The diverse range of keywords across finance, agriculture, policy, and the environment indicate a multidisciplinary research landscape. However, the trends may be influenced by the scope and focus of SCOPUS indexing. To deepen the insights, further investigations—such as analyzing keyword relationships, author networks, and cross-database comparisons—could be undertaken. This would offer a more complete picture of how research themes are evolving and help identify emerging but underrepresented topics.

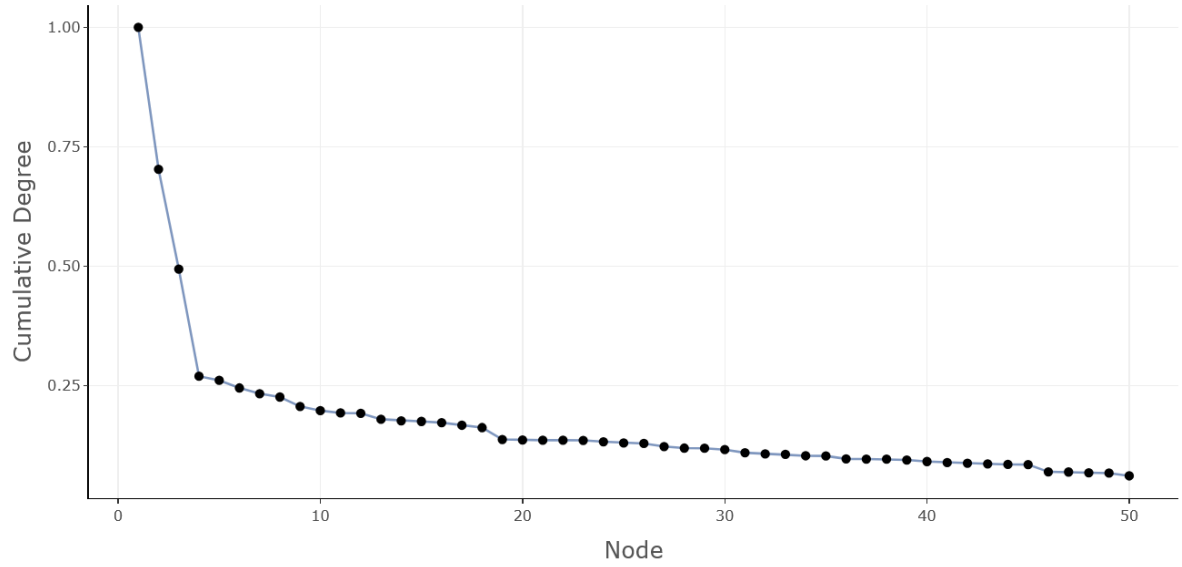


**Fig 14: Connectivity Analysis of Keywords in Co-Occurrence Network**

The chart illustrates the cumulative degree distribution within a keyword co-occurrence network, where each node signifies a unique keyword. The vertical axis reflects the cumulative degree, representing how often each keyword is linked to others, while the horizontal axis lists the nodes based on their connectivity from highest to lowest. The steep drop at the beginning of the curve reveals that a small number of keywords are highly interconnected, indicating their central importance in the research landscape. These keywords likely act as thematic hubs that bridge various research areas. Conversely, most keywords exhibit low connectivity, suggesting they play more specialized or supporting roles. This uneven distribution is characteristic of scale-free networks, where a few nodes dominate in terms of connections. Overall, the graph reveals a concentrated structure of knowledge, shaped by a core set of frequently occurring topics surrounded by numerous less commonly used but still relevant terms.

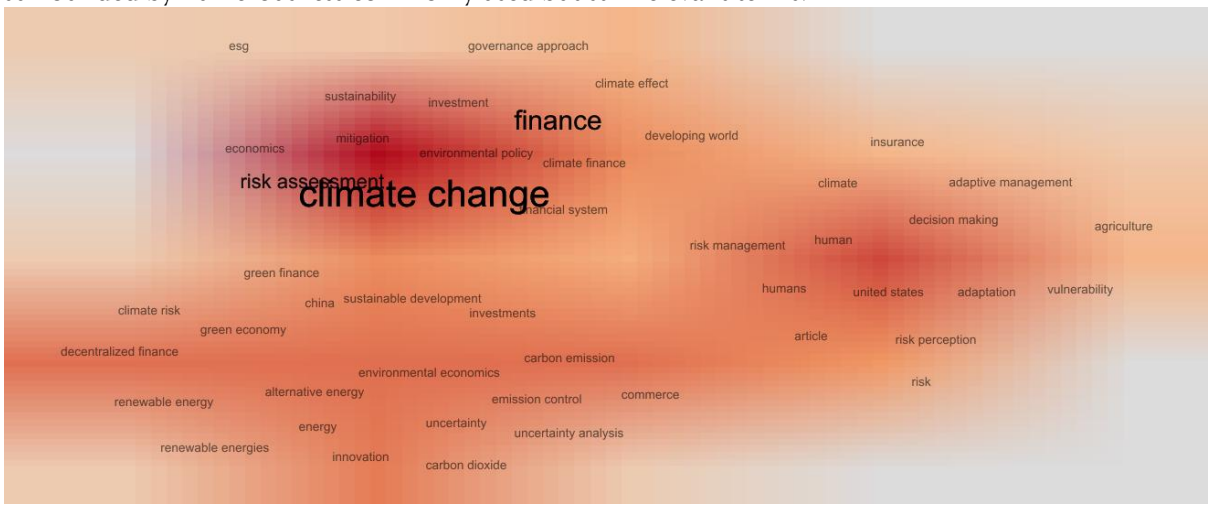


**Fig 15: Conceptual Relationship Network**

The Conceptual Relationship Network presents a well-defined and interconnected view of the research landscape surrounding climate change. At the core of the network, represented by the darkest and most densely connected nodes, are the keywords "climate change," "risk assessment," and "finance," indicating these are the dominant and most frequently explored themes. This central cluster is strongly linked to terms like "mitigation," "sustainability," "investment," and "environmental policy," reflecting a concentrated research effort on financial strategies and policy responses aimed at managing climate-related risks and promoting sustainable development.

Beyond the core, the network features several secondary clusters. To the left and bottom, terms such as "renewable energy," "green finance," and "decentralized finance" highlight research focused on economic transformation toward sustainability. On the right, keywords like "adaptation," "vulnerability," and "risk management" point to studies on the social and human impacts of climate change, particularly in areas like "agriculture." This distribution suggests a strong emphasis on financial and policy mechanisms, while also recognizing the importance of social and technological responses.

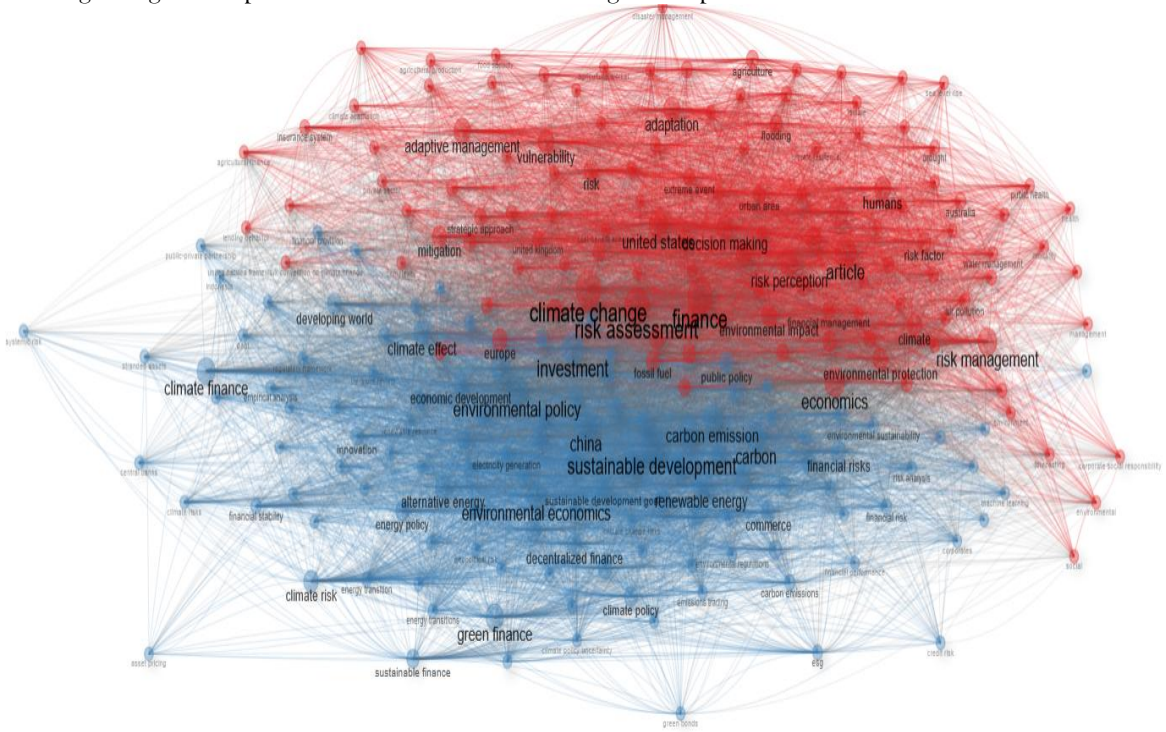


**Fig 16: Thematic Clustering of Research Topics**

Theis map offers a clear visual representation of the research landscape related to climate change, organized by centrality (how relevant a theme is to the broader field) and density (how well-developed the theme is internally). Two prominent clusters emerge. The first, positioned in the Niche Themes quadrant, includes terms like "climate change," "finance," and "risk assessment." These topics are well-established within their own research community but have limited influence on the wider academic landscape. Influential papers in this cluster, particularly from Journal of Environmental Management and Medical Journal of Australia, suggest a focus on the intersection of environmental management, health, and financial risk in the context of climate change.

The second cluster, found in the Basic Themes quadrant, features "climate finance," "green finance," and "sustainable development." These areas are considered central to the field but are still developing in depth and complexity. Their presence indicates growing interest in leveraging financial tools to support sustainable initiatives. The lack of highly developed and influential themes (i.e., no entries in the "Motor Themes" quadrant) may reflect the fragmented or emerging nature of this research area. It may also result from limitations in the dataset (SCOPUS) or analytical parameters. To gain deeper insight, further steps like adjusting keyword filters, applying different clustering methods, or exploring changes over time are recommended.

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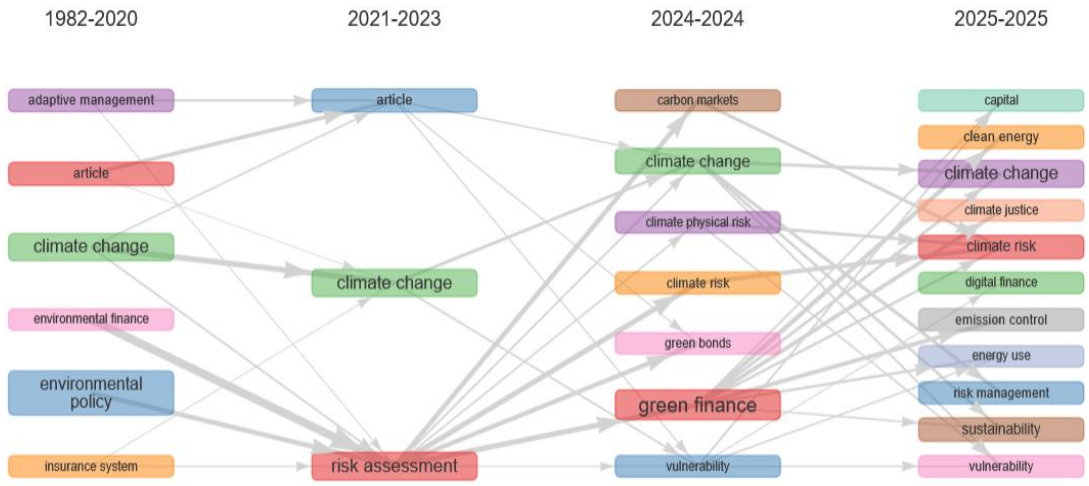


**Fig 17: Evolution of Research Themes**

A review of the strategic maps over time shows that climate change has remained a consistently central theme, often linked with topics such as climate risk, climate finance, and risk assessment. These interconnected themes indicate that research has increasingly focused on financial and risk-oriented approaches to addressing climate-related challenges. In more recent years, there is a noticeable rise in attention to financial instruments like green bonds, digital finance, and environmental finance, reflecting a growing interest in using economic tools to support sustainability. From 2024 onward, the emergence of topics such as clean energy, emission control, and energy use suggests a shift toward practical implementation and policy-oriented solutions to climate issues.

Analyzing the specific periods highlights changes in research focus. In the early phase (1982–2020), foundational concepts such as environmental policy and insurance systems shaped the field. Between 2021–2023, themes like COVID-19 and sustainable development emerged, reflecting real-world influences. By 2024, newer subjects including climate physical risk and nature-based solutions began to appear, pointing to diversification in research interests. In 2025, themes like sustainability and climate justice gained prominence, showing an increasing emphasis on social equity and resilience. Meanwhile, the appearance of niche areas like air navigation suggests exploration into sector-specific applications. Overall, the evolution of these themes highlights a research landscape that is broadening and deepening, with stronger connections between environmental, financial, and societal dimensions—offering valuable insights for future studies and policymaking.

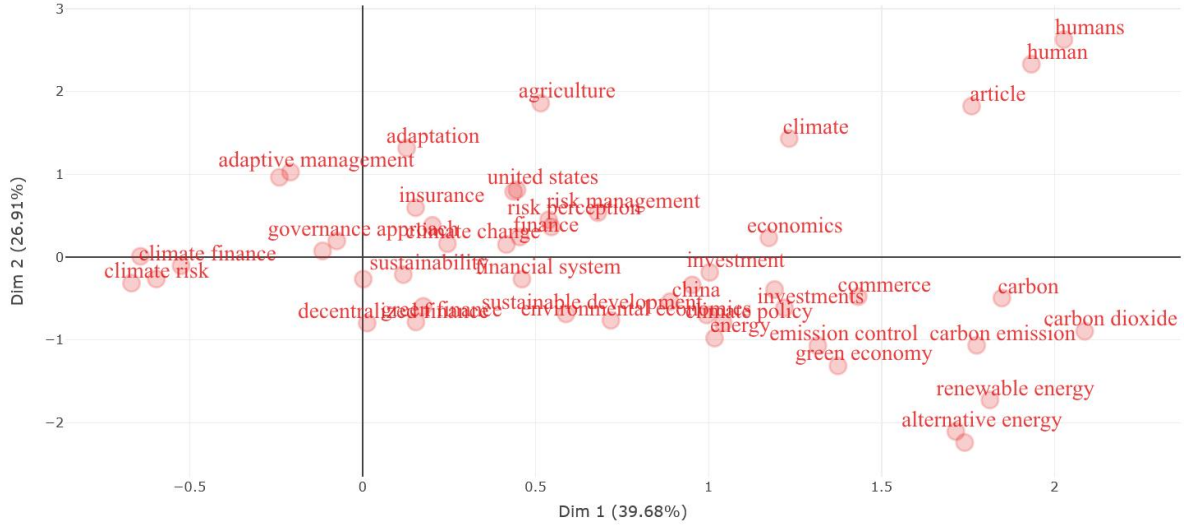


**Fig 18: Conceptual Structure Analysis**

The factorial analysis of terms related to climate change research reveals a well-defined structure shaped by two dominant dimensions. The first dimension, which captures 39.68% of the variance, differentiates studies cantered on core financial and governance-related aspects of climate risk from those addressing practical mitigation efforts and energy transition strategies. The second dimension, accounting for

26.91% of the variance, separates human-cantered or conceptual research from more application-driven, technology-based investigations.

This analytical framework highlights several distinct research clusters. In the top-left quadrant, themes revolve around "adaptation and governance," while the bottom-left is dominated by "climate risk and finance." The bottom-right quadrant emphasizes research areas like "sustainable development" and "energy transition," encompassing topics such as "renewable energy" and "carbon emissions." Meanwhile, the top-right quadrant reflects studies focused on human and societal dimensions of climate change. Collectively, the map offers a comprehensive view of the intellectual structure, revealing a divide between financial-policy frameworks and socio-technological responses.

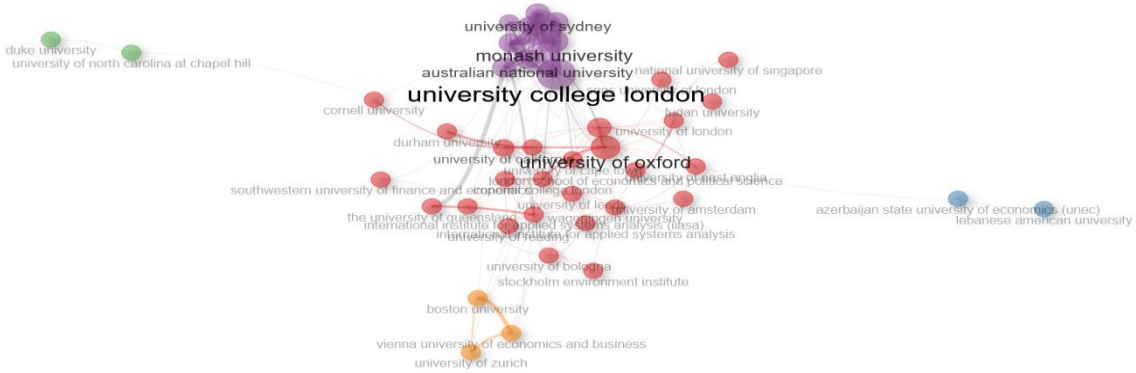


**Fig 19: Inter-Institutional Research Network**

The collaboration network highlights a landscape largely anchored by UK universities, with University College London and the University of Oxford emerging as key players. Their prominent size and central positioning in the network suggest they play a leading role in fostering research partnerships. Rather than forming a single unified network, the map shows a web of interconnected yet distinct communities, indicating that collaboration tends to occur within specific institutional groups. For example, the dominant red cluster represents a broad alliance of European and North American institutions, while smaller, more localized clusters—such as the purple group in Australia or the blue cluster in the Middle East—point to regionally concentrated collaborations. The thickness of the connecting lines reflects the strength or frequency of collaboration, with bolder lines representing more intensive partnerships.

This network structure demonstrates that global research cooperation exists but is unevenly distributed. A strong UK-cantered hub coexists with several smaller, geographically or thematically oriented clusters. The central role of UK institutions may reflect their leadership in the field under study. To better understand the nuances of this structure, further investigation is needed to determine the specific research focuses of each cluster and to identify institutions that may act as bridges between them. Overall, the map presents a global research network that is both centralized and segmented, reflecting both dominant players and regionally defined communities.

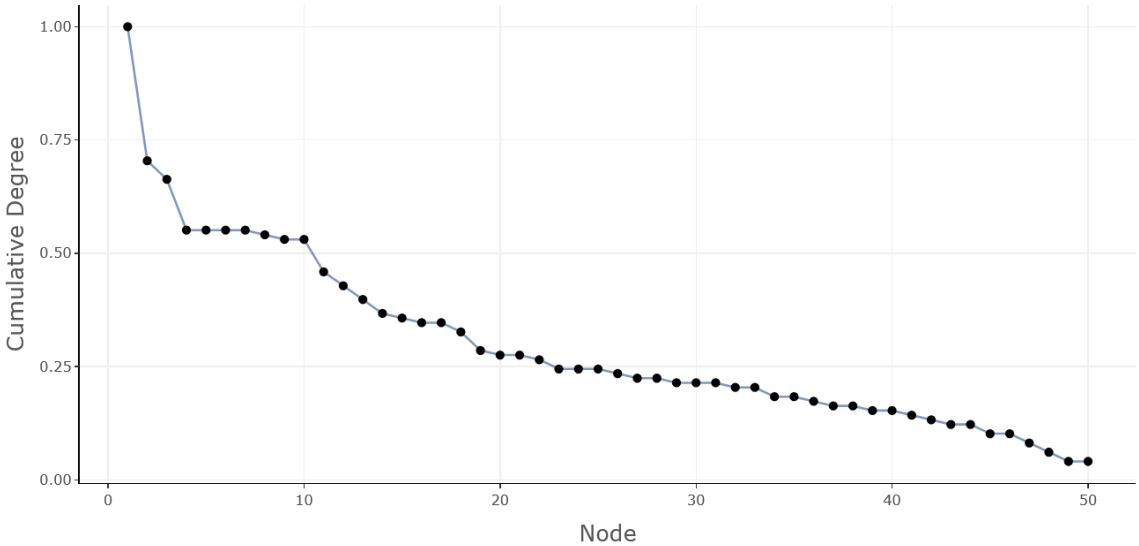


**Fig 20: Cumulative Degree Distribution of a Network**

The graph illustrates the cumulative degree distribution of a network, showing the fraction of nodes with a degree equal to or exceeding a given value. On the y-axis, the cumulative degree is normalized to a maximum value of 1, while the x-axis ranks nodes based on their degree. The sharp decline at the start of the curve reveals that a small number of nodes—referred to as "hubs"—have a significantly higher number of connections compared to the rest. These initial nodes contribute heavily to the overall connectivity of the network. This distribution is typical of a scale-free network, characterized by a few dominant nodes and a large number of nodes with minimal links. The extended, flat portion of the curve reflects the presence of many low-degree nodes, reinforcing the "rich-get-richer" dynamic common in various systems such as social, technological, and biological networks. This structure suggests that the network is robust against random disruptions but vulnerable to targeted removal of hub nodes.

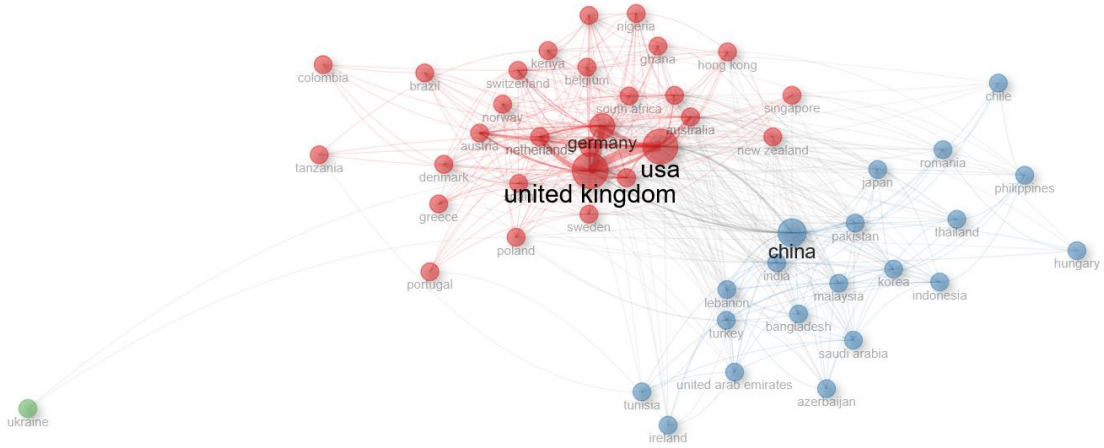


**Fig 21: Country-Level Collaboration Network**

The network graph illustrates international research collaboration among countries, revealing two dominant clusters and several smaller, less connected nodes. The largest cluster, shown in red, centres around a tightly linked group of countries, with the United States, United Kingdom, and Germany emerging as key hubs. This suggests a strong collaboration network largely involving North America, Europe, and allied nations such as Australia and New Zealand.

The second major cluster, depicted in blue, is led by China and includes countries like India, Japan, and South Korea. This indicates a separate yet cohesive collaboration network primarily within Asia and parts of the Middle East. Some countries, such as Ukraine (shown in green), appear as isolated nodes with minimal or no links to the major clusters. While there are a few connections bridging the red and blue clusters, they are relatively sparse, suggesting limited collaboration between the two groups. Overall, the graph portrays a multi-centred global research landscape with two primary regional hubs.

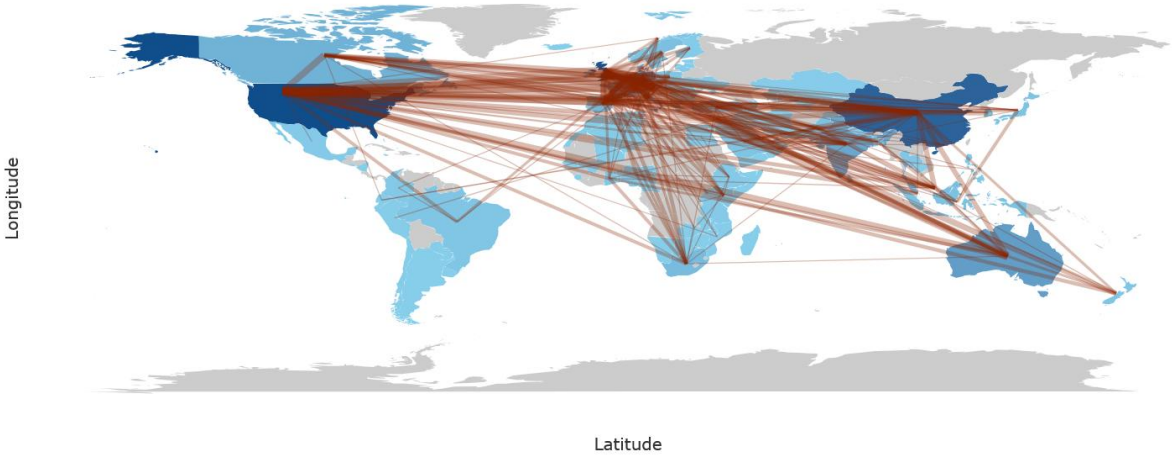


**Fig 22: International Research Collaboration Landscape**

The global research collaboration map illustrates a notably uneven distribution of scientific activity, heavily concentrated around a few dominant hubs. Countries such as the United States, the United Kingdom, and Germany emerge as key contributors, evidenced by their darker shades and dense interconnections. China and Australia also stand out as influential research nodes. The map reveals

strong and well-established partnerships—particularly transatlantic ties between the U.S. and Europe—as well as robust collaborations with China, collectively forming a central cluster of highly active and interconnected nations.

Outside of this core, the map reflects a core-periphery pattern, where the majority of collaborative efforts stem from central, high-output countries and extend outward to less-connected regions. Although there are visible connections to developing countries, they are notably sparser compared to those within the core. Additionally, the map highlights significant regional collaborations, especially within Europe and Asia. This analysis is based on SCOPUS co-authorship data, which, while comprehensive, may carry inherent biases and may not fully capture the scope of global research activities.

## CONCLUSION:

This bibliometric analysis offers a comprehensive examination of the evolving academic landscape surrounding climate and weather-related risks in financial markets. Based on 1,376 documents retrieved from the Scopus database between 1982 and 2025, the study highlights a robust annual growth rate of 13.72%, indicating a rapidly expanding research field. Thematic developments have shifted from early discussions on environmental policy and insurance mechanisms to more specialized areas such as green finance, weather derivatives, carbon markets, and climate-related risk assessment. These evolving research interests reflect the growing relevance of climate issues within the broader context of financial stability and economic resilience.

Collaboration patterns show a scale-free network structure dominated by a few key countries, including the USA, UK, and Germany, which serve as central nodes in global scholarly networks. Emerging clusters in Asia and the Middle East suggest increasing international engagement, although a core-periphery structure remains evident, indicating the underrepresentation of developing nations. This study not only maps the intellectual and collaborative dynamics of the field but also provides actionable insights for researchers, financial institutions, and policymakers. As climate risks become increasingly embedded in financial systems, further interdisciplinary, regionally inclusive, and policy-driven research will be critical in shaping resilient and sustainable financial strategies in the years ahead.

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