EBU European Business Institute LUXEMBOURG

Mapping Climate Risk: A Comparative Bibliometric Analysis of Transition and Physical Risks in the EU and China Using CiteSpace

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Abstract: This study conducts a comparative analysis of climate risks in the European Union and China using the bibliometric tool *CiteSpace*. It focuses on two primary types of climate risks: transition risks and physical risks. The research uses data from the *Web of Science* core database, analyzing keyword co-occurrence in climate risk literature from 1998 to 2024. The study reveals a general upward trend in climate risk publications, with distinct thematic focuses in the EU and China. The EU's research emphasizes policy frameworks, renewable energy adoption, and urban resilience, reflecting a holistic approach to climate adaptation. Conversely, China's research highlights technological solutions, public health, and energy security, showcasing a pragmatic approach. The study identifies key research hotspots and future directions of climate risk studies, offering insights for investors, policymakers, and stakeholders to develop effective climate strategies tailored to regional contexts.

Keywords: climate change; transition risk; physical risk; climate finance; EU and China; risk management; bibliometric analysis

1. Introduction

Extreme shocks, including climate change, economic sanctions, and geopolitical conflicts, present significant and complex challenges to the global community (Chen et al., 2024; Yin et al., 2024). Among these, climate change is particularly pressing, with far-reaching impacts across all aspects of society, including the economy, finance, and the environment. The global economy is grappling with the multifaceted challenges posed by climate change, which affects numerous industries and introduces new risks to financial institutions (Fan & Gao, 2024).

Central to the discourse on climate change are the concepts of climate risks, broadly categorized into transition risks and physical risks (Gourdel et al., 2024; Zhang, 2022). Transition risks refer to the financial and operational dangers that arise when a company fails to orient its activities towards a low-carbon economy, potentially resulting in the loss of financial value from disinvestment or the obsolescence of activities and assets (Alessi et al., 2024; Guo et al., 2024). Transitioning to a lower-carbon economy may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change (Bloomberg, 2017). Physical risks, on the other hand, are the direct impacts of climate change on natural and human systems, leading to financial losses from increasingly frequent and severe natural disaster events (Mansoux & Soler, 2024). These include acute events such as hurricanes, floods, and heatwaves, as well as chronic changes like prolonged droughts, sea-level rise, and shifting climate zones. Understanding and addressing both transition and physical risks are crucial for developing comprehensive strategies to mitigate the multifaceted impacts of climate change.

The European Union (EU) has led climate action with ambitious carbon reduction targets and renewable energy adoption, supported by comprehensive policy frameworks, substantial green technology investments, and strong public support. Examining the EU's transition risks involves analyzing policy changes, market dynamics, and technological innovations reshaping its economy (Brad & Schneider, 2023; Wang et al., 2024). Conversely, China, with its rapid industrialization, vast population, and significant carbon emissions, plays a critical role in global climate change (Xu et al., 2024). Despite progress in renewable energy and a commitment to peak carbon emissions before 2030, China faces unique challenges due to its economic transformation (Dong et al., 2018; Wang et al., 2024). Analyzing China's climate risk approach focuses on balancing economic growth with environmental sustainability and addressing both transition and physical risks in a rapidly changing context. The 2014 EU–China ETS Project marks significant collaboration in carbon emissions reduction, reflecting broader efforts to implement carbon markets as part of sustainable climate strategies (Yu, Chen, et al., 2024; Yu, Xu, et al., 2024a, 2024b).

This paper maps and compares climate risks in the EU and China using the bibliometric tool *CiteSpace*. *CiteSpace* visualizes and analyzes research trends, collaborations, and emerging themes in scientific literature, providing an overview of the evolving landscape of climate risk research. This study addresses two primary questions: (1) How have focal points regarding climate risk evolved, and what is their current status? (2) What are the differences in current hotspots and future directions on transition and physical risks between the EU and China? These questions are significant due to the distinct geopolitical, economic, and environmental contexts of the EU and China. The comparative analysis highlights varied approaches and challenges each region faces, offering insights into the effectiveness of different strategies and the potential for cross-learning. Additionally, it identifies current research hotspots and future directions, guiding policymakers, researchers, and stakeholders in developing more effective, context-specific climate policies.

2. Data and Method

2.1. Data Collection

The literature data examined in this study is sourced from the *Web of Science* (WoS) core database, a globally recognized academic information repository. The data was retrieved on May 21, 2024. We conducted four separate searches, and the search conditions were: the keywords "EU" and "Climate Transition Risk", the keywords "EU" and "Climate Physical Risk", the keywords "China" and "Climate Transition Risk", and the keywords "China" and "Climate Physical Risk". The document type was specified as "Article", and non-journal articles were filtered out using the *Web of Science* screening tools. A total of 1,930 records were retrieved.

2.2. Research Method

CiteSpace is a versatile software tool for visualizing and analyzing bibliometric networks. Widely used in academia and research, it empowers users to explore scientific landscapes, uncover trends, and map relationships between scholarly articles, authors, and keywords (Lin-Bin et al., 2024; Liu et al., 2024; Zheng et al., 2024). With its intuitive interface and robust analytical capabilities, *CiteSpace* enables researchers to reveal hidden patterns within large datasets, aiding in knowledge discovery across diverse fields. Its robust analytical capabilities include network visualization, clustering, density visualization, and customization options, making it an indispensable tool for bibliometric analysis, facilitating insights into scientific structures, trends, and potential collaborations. In keyword co-occurrence analysis, *CiteSpace* generates networks where nodes represent keywords, and edges indicate co-occurrence relationships, with edge thickness reflecting relationship strength. This visualization helps researchers identify prominent topics, emerging trends, and potential gaps in the literature (Jin & Jian, 2024).

3. Climate Risk Analysis

3.1. Annual Distribution of Publications

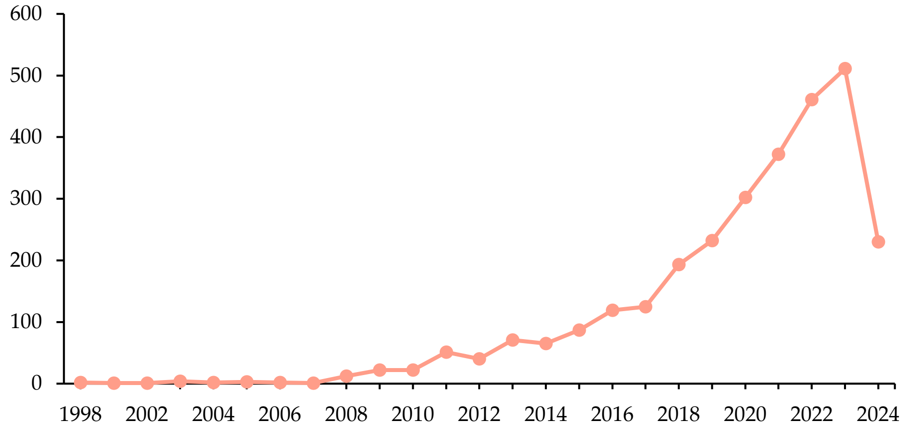

Figure 1. Annual distribution of publications.

Figure 1 shows a general upward trend in the number of publications on climate risk research globally from 1998 to 2024. This trend can be categorized into four distinct phases. The initial period (1998–2010) is characterized by a relatively low number of documents published each year, generally below 50, indicating limited research activity or interest in this specific area. The gradual increase period (2010–2015) began around 2010, with a noticeable increase in the quantity of documents, reaching around 100 publications per year by 2015. The rapid growth period (2015–2023) shows a steep increase in the number of documents published annually, rising from about 100 in 2015 to a peak of 511 in 2023. This phase reflects heightened interest and increased research output on climate risk, driven by the urgent need to address climate issues and the global shift towards sustainability. Key international agreements and frameworks, such as the Paris Agreement in 2015, have galvanized global efforts and funding towards addressing climate change (Wen et al., 2023). Additionally, advancements in renewable energy technologies and substantial policy support in regions like the EU and China have spurred increased academic and practical interest in mitigating climate risks (McKinsey & Company, 2023). This surge in research also corresponds with a broader recognition of the interconnectedness of climate risks with socio-economic development and disaster risk reduction. Consequently, interdisciplinary and integrated research efforts have become more prevalent, further driving the increase in publications.

3.2. Keyword Co-occurrence Networks

Figure 2 presents a keyword co-occurrence network of 629 nodes and 2095 links generated from the core database. Significant keywords include "risk", "impact", "temperature", "precipitation", "emissions", "variability", "management", and "air pollution". These keywords are also central and have larger node sizes, indicating their importance and frequent co-occurrence with other terms. This prominence of keywords reflects the focus areas and major themes in climate risk research. The emphasis on terms like "risk" (frequency=322) and "impact" (frequency=270) highlights the increasing concern over the potential consequences of climate change, while "temperature" (frequency=249) and "precipitation" (frequency=162) underscore the critical climatic variables under scrutiny. Furthermore, the high frequency of "emissions" (frequency=105) and "management" (frequency=128) points to the efforts in understanding and controlling greenhouse gas outputs and implementing effective climate policies.

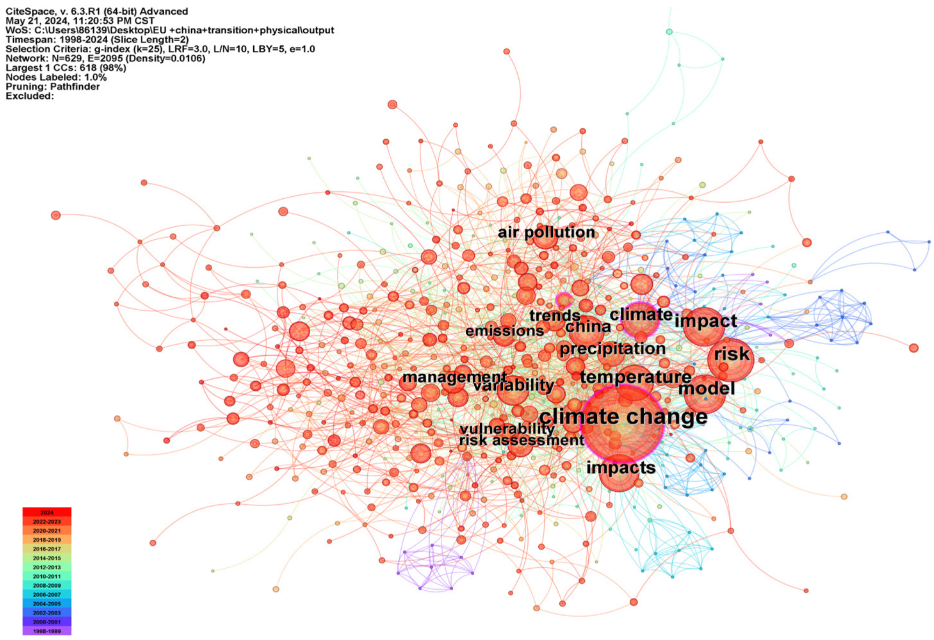

Figure 2. Keyword co-occurrence networks of climate risk.

The color gradient from red to green to blue indicates the temporal progression of keyword usage, with red representing the most recent terms (2022–2024) and blue indicating older terms (1998–1999). "Climate change" and related terms remain relevant throughout the timeline, but newer terms like "trends", "China", and "impact" appear more frequently in recent years, suggesting evolving research focuses. The network has a high density (0.0106), indicating a well-connected structure with many co-occurrences between keywords (Ji et al., 2019). This reflects an integrated and interrelated body of research on climate risk. The presence of larger nodes and thicker edges in the central area of the network signifies strong co-occurrence relationships, highlighting the interconnected nature of key themes within the field (Chen, 2004, 2006; Chen & Leydesdorff, 2014).

3.3. Keyword Co-occurrence Clusters

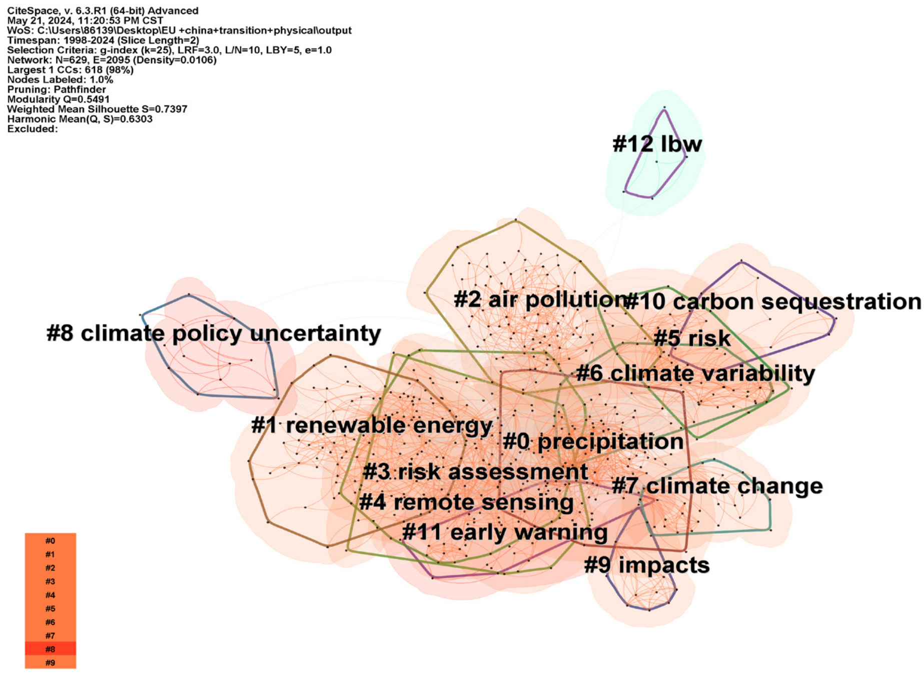

Figure 3. Keyword co-occurrence clusters of climate risk.

Figure 3 displays the clustering map presented by *CiteSpace*. The clusters are labeled and numbered based on their significance and relevance in the research domain. Each cluster is colored distinctly, with larger clusters indicating more prominent or heavily researched areas. The clusters are numbered from #0 to #12, with each number representing a specific thematic focus. The modularity Q index of 0.5491 demonstrated good strength of division into clusters and the mean silhouette index of 0.7397 which was greater than 0.70 conveyed good homogeneity of clusters.

The biggest category is "precipitation". The research on precipitation within the context of climate physical and transition risks focuses on its variability and impact, particularly in northern China, where hydrothermal conditions influence land-atmosphere interactions (Yang et al., 2022). These findings aid in predicting changes in precipitation patterns and their effects on agriculture and water resources. The second largest cluster is "renewable energy". Research in this area highlights the importance of renewable energy in mitigating climate transition risks. Policies like carbon taxes and emissions trading promote renewable energy adoption. Efforts in China and the EU are focused on reducing fossil fuel dependency and meeting climate targets, which also helps mitigate climate change-related physical risks (Lord et al., 2019). The third largest cluster is "air pollution". This research highlights the significant impact of air pollution on public health and climate change. Primary pollutants from combustion processes contribute to global warming and exacerbate respiratory and cardiovascular diseases, especially during extreme weather events (Sario et al., 2013). Studies in Europe and China show that stringent air quality standards and policies, such as the EU-funded projects and China's Air Pollution Prevention and Control Action Plan, have been critical in addressing these issues and mitigating associated health risks (Jin et al., 2016; He et al., 2024).

4. Transition Risk Analysis

4.1. Current Hotspots of Transition Risk

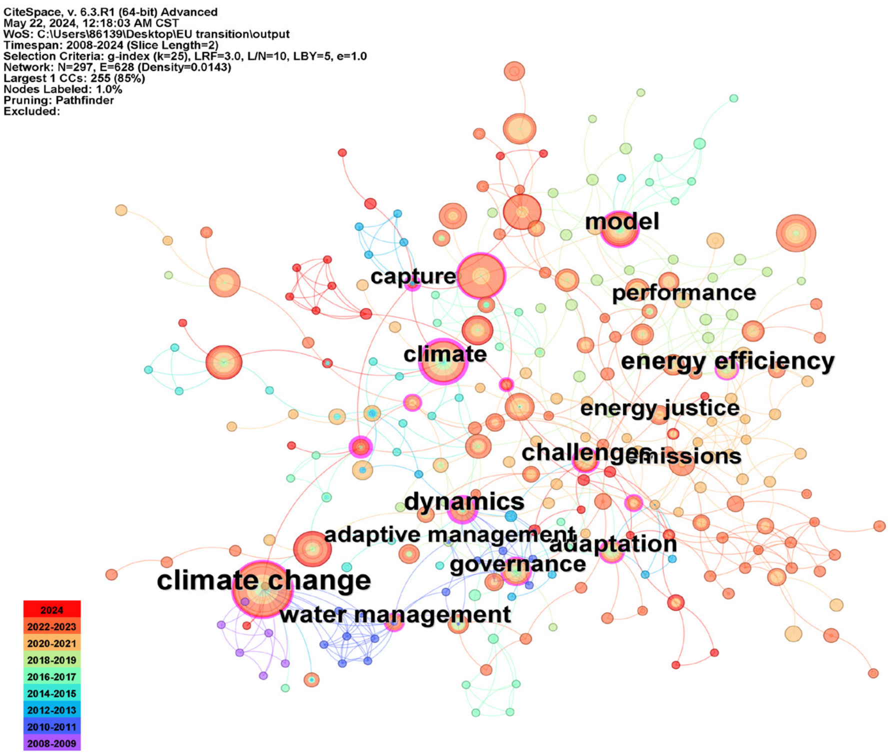

Figure 4. Keyword co-occurrence networks of climate transition risk in the EU.

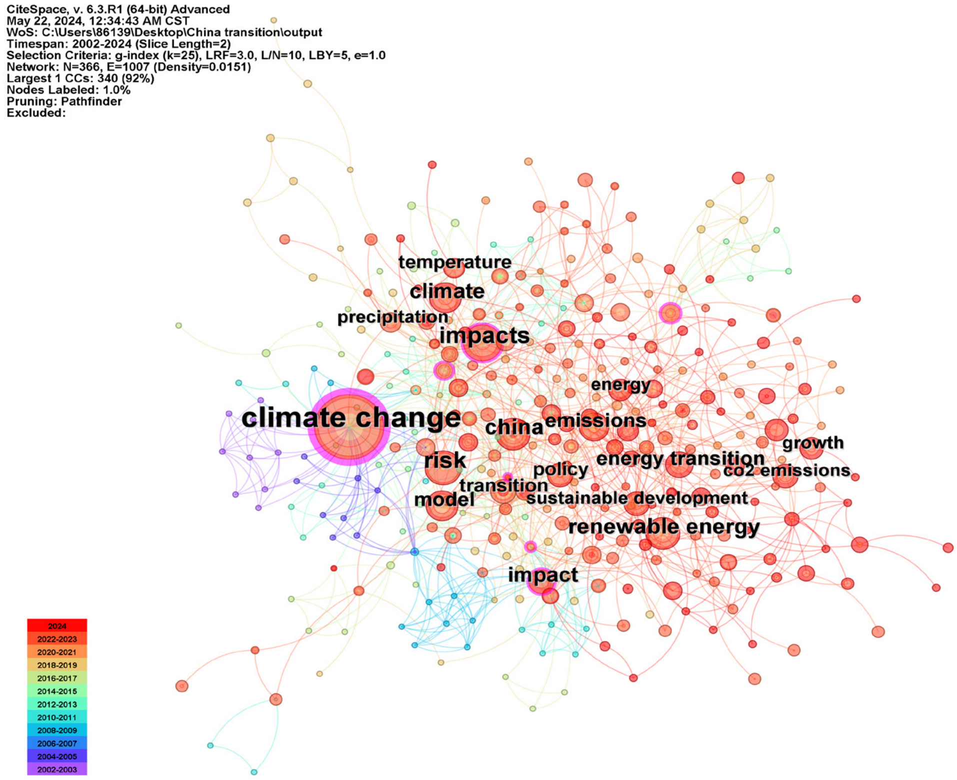

Figure 5. Keyword co-occurrence networks of climate transition risk in China.

Figures 4 and 5 illustrate the keyword co-occurrence network of climate transition risk in the EU and China, respectively. In Figure 4, there are 297 nodes and 628 links, with a centrality of 0.0143, and the top five keywords with the highest frequency are "climate change" (frequency=66), "policy" (frequency=37), "risk" (frequency=31), "renewable energy" (frequency=31), and "climate" (frequency=31). In Figure 5, there are 366 nodes and 1007 links, with a centrality of 0.0151, and the top five keywords with the highest frequency are "climate change" (frequency=167), "risk" (frequency=54), "impacts" (frequency=50), "China" (frequency=49) and "renewable energy" (frequency=41). Both networks prominently feature "climate change" as the central theme, underscoring its global relevance and foundational impact on transition risk research. Additionally, both networks highlight "risk" and "renewable energy", reflecting the widespread concern over climate-related risks and the push for renewable energy solutions as critical components of climate transition strategies.

However, there are notable differences between the two networks. The number of nodes and links suggests that China's network is relatively larger and denser, while the centrality values imply that keywords in the China network may be more interconnected and central to the discussion. The EU's emerging topics like "dynamics" and "performance" indicate a focus on the practical and performance-based aspects of climate mitigation, while China's emerging topics such as "growth" and "CO_2 emissions" highlight the balance between economic development and environmental sustainability. Furthermore, the EU's network emphasizes issues such as water management, adaptive strategies, and carbon capture technologies, indicating a focus on managing resources and adapting to climate impacts (Green et al., 2013; Kapetaki et al., 2016). In contrast, China's network places greater emphasis on energy transition and sustainable development, reflecting a blend of technological adaptation and resource management strategies aimed at achieving long-term climate goals (Šekarić Stojanović & Zakić, 2024; Gatto et al., 2023). These differences can be attributed to varying priorities and developmental stages, reflecting the varying regional priorities and approaches to addressing climate transition risks.

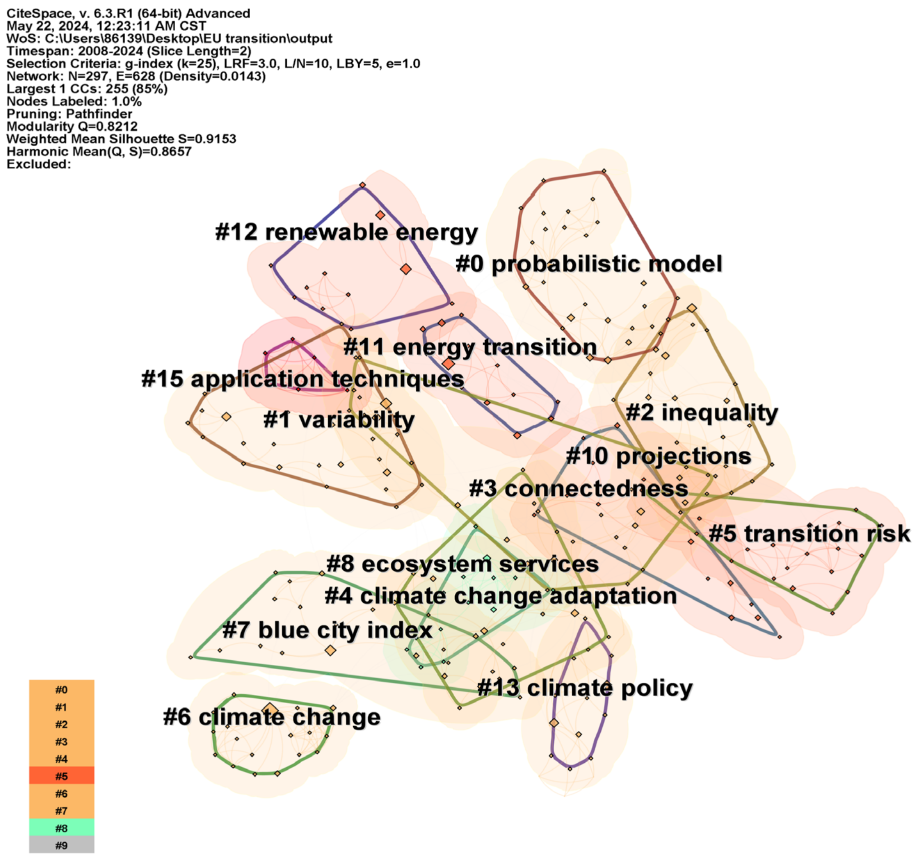

Figure 6. Keyword co-occurrence clusters of climate transition risk in the EU.

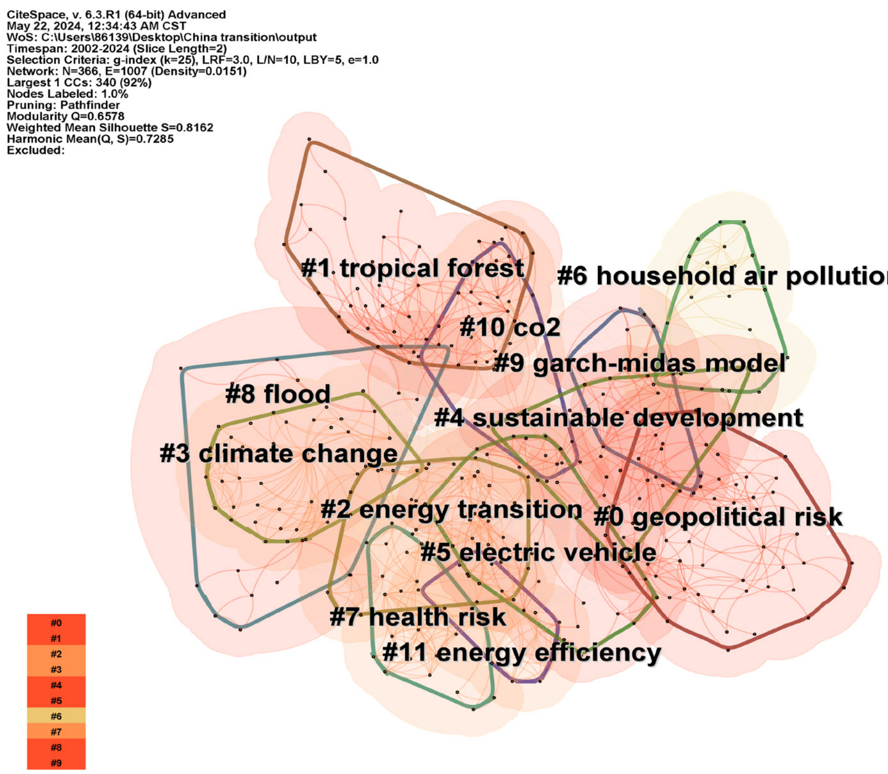

Figure 7. Keyword co-occurrence clusters of climate transition risk in China.

The European Union (EU) and China are at the forefront of global efforts to combat climate change, each implementing distinct and comprehensive strategies suited to their unique socio-economic contexts and policy frameworks. This analysis explores the differences in their approaches, examining the technological, strategic, social, and health dimensions that define their respective climate resilience strategies.

The EU's transition risk clusters underscore a comprehensive strategy that places a high priority on technological advancements and urban resilience. One of the primary areas of focus is the development and integration of renewable energy technologies. Wind, solar, and hydroelectric power are at the forefront of the EU's efforts to reduce carbon emissions and transition to a sustainable energy future. These technological innovations are crucial for achieving the EU's ambitious climate goals which aim for a scenario called "GHGneutral EU2050" as one way to realize a European Union with net-zero greenhouse gas emissions under further sustainability criteria (Örtl, 2019).

In addition to renewable energy, the EU invests heavily in smart grid technologies that enhance energy efficiency and reliability. These technologies facilitate the integration of renewable energy sources into the grid, optimizing energy distribution and consumption (IqtiyaniIlham Net al., 2017). Another significant initiative is the Blue City Index, which exemplifies the EU's commitment to urban resilience. This initiative promotes green infrastructure, sustainable urban planning, and nature-based solutions to create cities capable of withstanding climate impacts. The EU also emphasizes detailed statistical modeling to predict climate impacts and assess risks. These models integrate economic, environmental, and social data to provide a comprehensive understanding of climate risks and inform evidence-based policymaking. For example, the Joint Research Centre (JRC) of the European Commission conducts extensive research and modeling to support climate policies and risk assessments.

The EU's approach to climate resilience is deeply rooted in addressing social inequality and enhancing ecosystem services, reflecting a holistic and inclusive strategy. One of the critical areas of focus is the recognition and mitigation of social inequalities exacerbated by climate change. Climate impacts often disproportionately affect vulnerable populations, including low-income communities, the elderly, and marginalized groups. The EU emphasizes the importance of creating policies that protect these vulnerable populations, ensuring that climate resilience efforts do not leave anyone behind. Furthermore, the EU integrates ecosystem-based approaches into urban planning and development, promoting green infrastructure solutions like green roofs, urban parks, and sustainable drainage systems. These nature-based solutions help cities adapt to climate impacts by reducing urban heat, managing stormwater, and improving air quality, thereby enhancing overall urban resilience.

In contrast, China's transition risk clusters reveal a pragmatic approach focused on scalable technological solutions and broader geopolitical considerations. A significant area of focus is the development and deployment of electric vehicles (EVs). China is the world's largest market for EVs, driven by substantial investments in research, development, and infrastructure. The National Development and Reform Commission, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and other relevant authorities have taken action to introduce various policies (Wang et al., 2019). Those policy documents have formed a policy system, that greatly motivates the enthusiasm of enterprises in R&D, production, market promotion, and application, and have strongly supported the development of the electric vehicle industry (Wu et al., 2021). The Chinese government supports this transition through subsidies, incentives, and stringent emissions regulations, aiming to reduce reliance on fossil fuels and lower air pollution levels. This focus on practical technological solutions is evident in the rapid growth of the EV industry and the expansion of charging infrastructure across the country.

Beyond technological solutions, China's transition risk analysis includes considerations of geopolitical implications. Energy security is a critical concern, with climate policies designed to reduce dependence on imported fossil fuels and enhance domestic energy production capabilities. China's Belt and Road Initiative (BRI) also plays a role in its climate strategy, as it involves investments in green infrastructure and renewable energy projects in participating countries. It not only directly reduces carbon emissions by increasing carbon reduction resources, but also indirectly reduces carbon emissions by promoting renewable energy and optimizing the energy structure (Zeng et al., 2022). These efforts aim to bolster China's global leadership in green technology and mitigate the international trade impacts of carbon policies.

Moreover, China's climate resilience strategy includes a strong focus on public health, particularly in addressing household air pollution and broader health risks associated with climate change. Household air pollution remains a significant public health challenge in China, primarily due to the widespread use of biomass and coal for cooking and heating in rural areas. In response, the Chinese government has launched various initiatives to promote cleaner energy alternatives, such as electricity and natural gas, to reduce indoor air pollution and its health impacts. Programs aimed at improving rural energy infrastructure and providing subsidies for cleaner fuels are critical components of these efforts. In addition to household air pollution, China is acutely aware of the broader health risks posed by climate change. China's climate policies increasingly incorporate health considerations, recognizing the need for integrated approaches that address both environmental and public health.

4.2. Future Directions of Transition Risk

Table 1 outlines the top ten hotspots in EU climate transition risk research, detailing their year of first appearance, burst intensity, and duration. Notably, early bursts like "deforestation" and "biodiversity" in 2012 underscore the initial recognition of forest conservation and biodiversity in mitigating climate impacts. The enduring interest in "climate" since 2014 highlights its sustained relevance. Additionally, "sustainable development" leads with a burst strength of 2.24, followed by "uncertainty" (2.03) and "deforestation" (1.94), emphasizing their pivotal roles in balancing environmental, economic, and social goals. The latest burst, "sustainable development", which began in 2022, focuses on integrating sustainable goals into climate strategies. Consequently, future research should prioritize sustainable development integration, refine climate projection models, innovate climate technologies, and manage risks in transitioning to a low-carbon economy equitably, aiming for holistic progress and resilience against climate challenges.

Similarly, Table 2 shows the top ten hotspots in China's climate transition risk research, detailing their year of first appearance, burst intensity, and duration. The keyword "climate change" experienced an early burst from 2014 to 2017, reflecting the initial recognition of its significance in China. Meanwhile, "dynamics" exhibited prolonged interest from 2012 to 2017, indicating ongoing research in understanding climate systems. Additionally, "trends" and "risk assessment" are the strongest keywords with burst strengths of 3.8 and 3.17, respectively, suggesting a strong focus on identifying climate trends and assessing risks as critical areas of research. The recent burst of the keyword "market" starting in 2022 points to a shift towards understanding market mechanisms in the context of climate change. Consequently, future research should focus on identifying and analyzing emerging climate trends, enhancing risk assessment methodologies to better understand and mitigate climate-related risks, and integrating these assessments into national and regional planning. Emphasis should also be placed on developing robust climate policies, leveraging market mechanisms, and improving predictive models.

Both the EU and China prioritize addressing climate change and associated risks through policy-making, technological innovation, and sustainable practices. The EU focuses on sustainable development, energy efficiency, and managing uncertainties, emphasizing a structured approach to climate transition risks. In contrast, China emphasizes risk assessment, market-based solutions, and integrating climate policy with broader economic and social strategies, reflecting a more pragmatic and immediate application of climate solutions.

Table 1. Top 10 keywords with the strongest citation bursts (transition risk in the EU).

Keywords	Year	Strength	Begin	End	2008–2024
sustainable development	2022	2.24	2022	2024	
uncertainty	2020	2.03	2020	2021	
deforestation	2012	1.94	2012	2013	
model	2015	1.84	2015	2017	
climate	2014	1.84	2014	2021	
energy efficiency	2019	1.83	2019	2021	
innovation	2020	1.8	2020	2023	
biodiversity	2012	1.8	2012	2015	
adaptation	2012	1.76	2016	2019	
climate transition risk	2021	1.68	2021	2023	

Table 2. Top 10 keywords with the strongest citation bursts (transition risk in China).

Keywords	Year	Strength	Begin	End	2002–2024
trends	2018	3.8	2018	2019	
risk assessment	2021	3.17	2021	2023	
transition	2015	2.87	2018	2021	
china	2011	2.81	2018	2021	
market	2022	2.62	2022	2024	
prediction	2017	2.53	2017	2019	
climate policy	2020	2.4	2020	2021	
global burden	2018	2.39	2018	2019	
climate change	2003	2.12	2014	2017	
dynamics	2012	2.02	2012	2017	

5. Physical Risk Analysis

5.1. Current Hotspots of Physical Risk

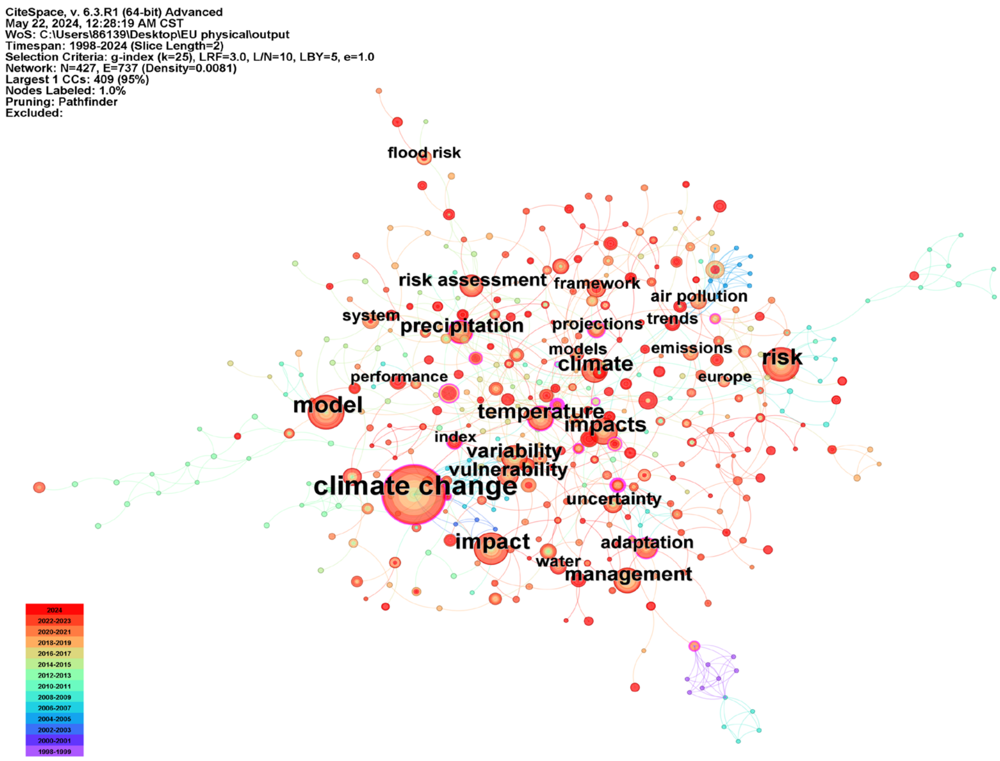

Figure 8. Keyword co-occurrence networks of climate physical risk in the EU.

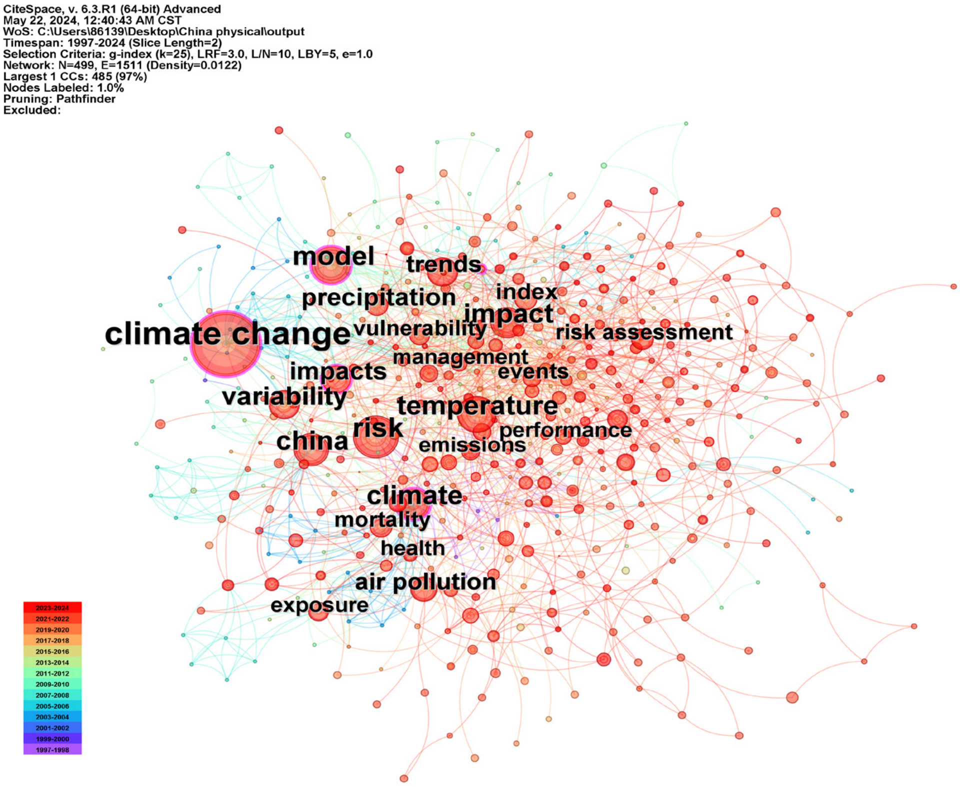

Figure 9. Keyword co-occurrence networks of climate physical risk in China.

Figure 8 and Figure 9 illustrate the keyword co-occurrence network of climate physical risk in the EU and China, respectively. In Figure 8, there are 427 nodes and 737 links, with a centrality of 0.0081, and the top five keywords with the highest frequency are "climate change" (frequency=258), "model" (frequency=95), "risk" (frequency=87), "impact" (frequency=82), and "temperature" (frequency=66). In Figure 9, there are 499 nodes and 1511 links, with a centrality of 0.0122, and the top five keywords with the highest frequency are "climate change" (frequency=461), "risk" (frequency=167), "temperature" (frequency=162), "model" (frequency=152) and "impact" (frequency=146).

The comparative analysis of climate physical risks in the EU and China reveals both commonalities and distinct regional focuses. Both regions prioritize "climate change", "risk", "impact", and "temperature" as central themes, indicating a shared understanding of the critical nature of these issues. Modeling and risk assessments are also prominent in both networks, underscoring the reliance on scientific and predictive tools to guide policy and adaptation strategies. This shared emphasis on scientific modeling and risk evaluation reflects a global recognition of the need for informed decision-making in addressing climate change impacts. Additionally, both the EU and China highlight the importance of understanding the broad impacts of temperature variations, signaling a unified approach to tackling the direct and indirect consequences of climate change.

However, significant differences in their research focus and thematic connections highlight the unique challenges and priorities of each region. The EU's network, characterized by a lower density and centrality, suggests a more focused approach, with a significant emphasis on ecosystem services and social dimensions. This includes addressing social inequality and promoting urban resilience through specific technological solutions and green infrastructure. On the other hand, China's denser network reflects a broader and more interconnected research framework, with a notable focus on public health issues such as air pollution and its health impacts. Keywords like "health", "air pollution", and "mortality" feature prominently, indicating China's acute awareness of the health risks associated with climate change and its strong emphasis on practical technological solutions. These differences underline the importance of tailored, region-specific strategies in climate policy.

The EU's focus on social equity and ecosystem health can complement China's public health initiatives, suggesting that increased cooperation and shared learning could enhance global climate resilience efforts.

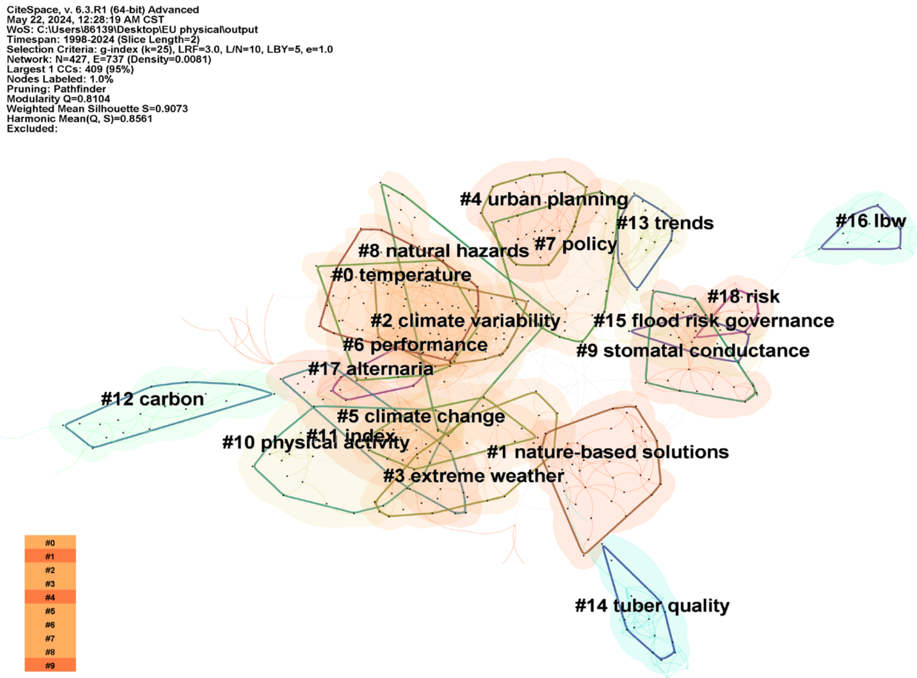

Figure 10. Keyword co-occurrence clusters of climate physical risk in the EU.

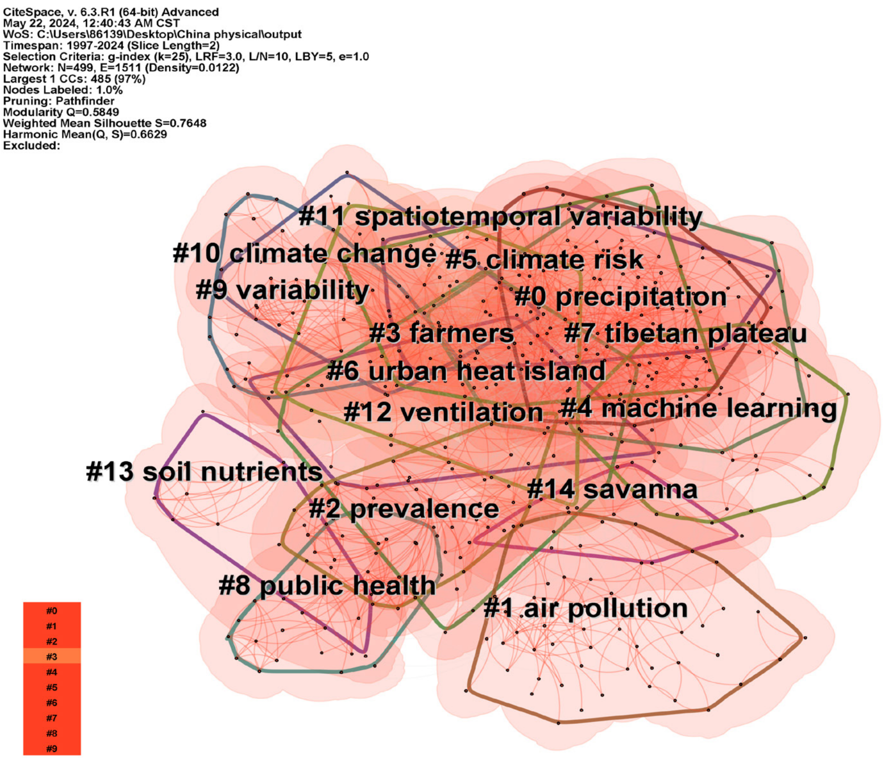

Figure 11. Keyword co-occurrence clusters of climate physical risk in China.

The EU's approach to addressing climate physical risks integrates environmental sustainability, urban resilience, and policy development, reflecting its comprehensive strategy for climate adaptation. One primary focus is on temperature variability and its impacts on climate risk. The research underscores the influence of temperature fluctuations on extreme weather events, urban heat islands, and overall climate variability, which is essential for developing robust adaptation strategies (Ebi et al., 2017). Another significant emphasis is on nature-based solutions. The EU prioritizes integrating green infrastructure and ecosystem restoration into urban planning and climate resilience strategies. Nature-based solutions, such as green roofs, urban forests, and wetlands, are effective in reducing urban heat, managing stormwater, and enhancing biodiversity (Kabisch et al., 2017). Policy development is also a critical area for the EU. Effective climate policies are essential for coordinating national and regional efforts in climate adaptation and mitigation. The EU's policy framework includes directives and regulations mandating reductions in greenhouse gas emissions, promoting renewable energy, and enhancing energy efficiency (European Commission, 2020).

China's approach to climate physical risks highlights different priorities, shaped by its unique socioeconomic and environmental context. A primary focus is on air pollution and its intersection with climate change. Air quality issues are a significant concern in China, and extensive research explores how air pollution exacerbates climate-related health risks, such as respiratory and cardiovascular diseases (Zhang et al., 2022). Additionally, China places significant importance on agricultural impacts. Research highlights the need for adaptive strategies to ensure stable agricultural output and food security in the face of climate variability. The Chinese government is exploring measures such as improved crop varieties, efficient irrigation systems, and sustainable farming practices to mitigate these impacts (Chandio et al., 2020). Technological advancements also play a crucial role in China's climate strategy. The use of machine learning and other advanced analytics helps model climate impacts, predict extreme weather events, and develop targeted adaptation measures. This technological focus enables China to leverage data-driven insights for more effective climate risk management.

While both the EU and China address fundamental climate physical risks, their approaches and areas of emphasis reflect their specific socio-economic contexts and policy priorities. The EU adopts a holistic and integrated strategy, focusing on environmental sustainability, urban resilience, and comprehensive policy frameworks. In contrast, China emphasizes health impacts, air quality, and agricultural resilience, leveraging technological advancements to address these challenges.

These differences underscore the importance of tailored climate strategies that address the unique needs and priorities of different regions. Both the EU and China demonstrate the necessity of integrating scientific research, technological innovation, and policy development in addressing climate physical risks, but their distinct focuses highlight the varied approaches required to achieve climate resilience.

5.2. Future Directions of Physical Risk

Table 3 outlines the top ten hotspots in EU climate physical risk research. Key findings include: (1) Early bursts like "rainfall" (2009) and "interannual variability" (2009) reflect the initial focus on understanding precipitation patterns and the year-to-year changes in climate, which are critical for predicting and managing the impacts of climate change. (2) "Rainfall" (strength=4.72) and "sensitivity" (strength=4.7) highlight significant research on the variability and sensitivity of climate systems to various factors, emphasizing the importance of these elements in assessing and mitigating climate risks. (3) Long-term keywords like "sensitivity" (2010–2017) and "21st century" (2010–2017) emphasize the ongoing importance of studying the responsiveness of climate systems and projecting future climate scenarios to inform policy and adaptation strategies. (4) Future research should prioritize refining predictive models, enhancing flood risk assessments, understanding sea-level impacts, and integrating findings into comprehensive climate policies.

Table 4 presents the top ten hotspots in China's climate physical risk research, highlighting key findings. Firstly, high-intensity bursts for "Simulation" (strength=6.16) and "United States" (strength=5.23) underscore significant research using advanced modeling techniques and international comparisons to deepen understanding of global climate dynamics and their implications for China. Secondly, the emergence of the keyword "heavy metals" (2021) indicates a recent focus on pollution within the climate context. Thirdly, the sustained importance of "simulation" (2005–2016) highlights ongoing efforts to utilize simulation models for predicting and analyzing climate patterns over extended periods. Looking ahead, future research should prioritize enhancing methodologies for assessing food security impacts, developing adaptive strategies to mitigate climate change, and integrating findings into broader economic and social planning frameworks.

Both the EU and China prioritize addressing climate physical risks through comprehensive research, but their approaches and focuses differ. The EU emphasizes understanding precipitation, sensitivity, and extreme weather patterns, with a balanced distribution of research across multiple aspects of climate risks. In contrast, China focuses heavily on simulation models, food security, and the impacts of climate change on water resources, reflecting a robust model-based and practical application approach.

Table 3. Top 10 keywords with the strongest citation bursts (physical risk in the EU).

Keywords	Year	Strength	Begin	End	1998–2024
rainfall	2009	4.72	2009	2015	
sensitivity	2010	4.7	2010	2017	
variability	2006	4.23	2010	2015	
weather	2020	4.15	2020	2024	
flood risk	2014	3.95	2014	2017	
sea level rise	2016	3.91	2018	2021	
transmission	2013	3.87	2013	2017	
21st century	2010	3.61	2010	2017	
dynamics	2014	3.47	2014	2017	
interannual variability	2009	3.3	2009	2015	

Table 4. Top 10 keywords with the strongest citation bursts (physical risk in China).

Keywords	Year	Strength	Begin	End	1997–2024
simulation	2005	6.16	2005	2016	
united states	1998	5.23	2013	2018	
variability	2003	5.03	2009	2016	
food security	2017	4.92	2017	2020	
runoff	2017	4.23	2017	2020	
dynamics	2013	4.21	2013	2018	
frequency analysis	2017	3.84	2017	2020	
sea level rise	2014	3.69	2014	2016	
heavy metals	2021	3.59	2021	2024	
climate change adaptation	2019	3.37	2019	2020	

6. Discussions

6.1. Impacts and Adaptation to Climate Change

Climate change impacts are diverse and pervasive, affecting ecosystems, economies, and communities globally. The increasing frequency and severity of extreme weather events, such as hurricanes, floods, and droughts, pose significant challenges. These impacts are global but vary across regions, each facing unique yet interconnected threats.

Adaptation strategies are essential to mitigate these impacts. Countries worldwide are adopting various approaches to enhance their resilience. Bangladesh consistently grapples with its vulnerability status, confronting ongoing adverse effects of climate change and the consequent escalation of environmental risk (Rumpa et al., 2023). To effectively identify environmental risk zones and address climate change impacts, it's crucial to employ micro-level analyses and trend assessments. These analyses provide valuable insights into the specific vulnerabilities and challenges faced by different regions, allowing for more targeted and effective interventions (Haque et al, 2024). For instance, Chaudhary et al. (2019) assessed eco-environmental fragility by applying an analytic hierarchy process based methodology for Nepal's Dordi river basin, which has a growing potential for farmland abandonment (Chaudhary et al., 2019).

Urban green spaces are also emerging as a key strategy for promoting climate change resilience (Reynolds et al., 2020), where resilience refers to a socio-ecological system's ability to persist, transition, or transform so as to maintain functioning and well-being in response to disturbance (Biggs et al., 2015; Walker and Salt, 2012). Parks, for example, are considered effective in lowering the effects of urban heat islands. To better manage urban green spaces in response to climate change, scholars and policymakers are advocating for more integrated coordination among various local government departments to take leadership in climate change adaptation and mitigation (Cheng et al., 2021).

6.2. Risk Management and Climate Change

Risk management is critical in addressing both the immediate and long-term threats posed by climate change. Different countries and regions adopt various strategies tailored to their specific vulnerabilities and capacities.

The EU's integration of policy frameworks and renewable energy adoption into its risk management approach highlights a structured and policy-driven strategy. Meanwhile, China's use of advanced analytics and machine learning for climate risk modeling demonstrates a more technology-centric approach.

In sub-Saharan Africa, agriculture's central role as a leading GDP earner, employer, and food provider is increasingly threatened by climate variability and change (Kotir., 2011; Calzadilla et al., 2013). In these countries, one such initiative is the promotion of the use of climate information services among smallholder communities, which encompass the provision of tailored weather and climate information together with advisories in support of decision-making (Mwangi et al., 2021). Climate information services are tools that can be used to reduce the effects of climate risk and uncertainty on crop production and increase resilience as well as the adaptive capacity of smallholder farmers in the long term.

6.3. Mitigating Climate Change

In order to mitigate climate change, global climate action began with the 1979 World Climate Conference in Geneva, which highlighted the impacts of climate change. The 2015 Paris Agreement set more ambitious goals and marked a significant step in global climate policy, including limiting global temperature rise to 2°C by 2100 and pursuing efforts for 1.5°C. It emphasizes national commitments, transparency, and support for developing countries (Fawzy et al., 2020).

The EU's comprehensive policy frameworks and significant investments in green technology illustrate a strong commitment to sustainable development and renewable energy. China's pragmatic approach combines technological solutions and public health improvements, with a significant focus on optimizing the energy structure and promoting renewable energy projects.

Addressing climate change requires a multifaceted approach that includes both adaptation and mitigation strategies. By leveraging technology, implementing effective policies, and fostering international cooperation, the global community can enhance resilience and reduce the risks associated with climate change.

7. Conclusions

This study provides a comprehensive comparative analysis of climate risks in the EU and China using

CiteSpace to map and visualize trends in the scientific literature from 1998 to 2024. By examining both transition and physical risks, the study highlights distinct approaches and challenges faced by these two regions in addressing climate change. The EU's research emphasizes policy frameworks, renewable energy adoption, and urban resilience, reflecting a holistic approach to climate adaptation. In contrast, China's research highlights technological solutions, public health, and energy security, showcasing a pragmatic approach tailored to its rapid industrialization and significant carbon emissions.

The key research hotspots identified in this study offer valuable insights into future directions for climate risk research in both regions. For the EU, future research should prioritize integrating sustainable development goals, refining climate projection models, innovating climate technologies, and managing the risks associated with transitioning to a low-carbon economy. This approach underscores the importance of a balanced strategy that includes technological advancements and social equality in urban planning. For China, the focus should be on enhancing risk assessment methodologies, developing adaptive strategies, integrating climate assessments into national and regional planning, leveraging market mechanisms, and improving predictive models. This pragmatic approach is essential for addressing immediate climate challenges while ensuring long-term sustainability.

The comparative analysis reveals both commonalities and unique regional focuses in addressing climate risks. Both the EU and China demonstrate the necessity of integrating scientific research, technological innovation, and policy development in their climate resilience strategies. The EU's emphasis on environmental sustainability and comprehensive policy frameworks complements China's focus on practical technological solutions and public health. These differences highlight the importance of tailored climate strategies that address the unique needs and priorities of different regions. Policymakers, researchers, and stakeholders can use these findings to develop more effective, context-specific climate policies that enhance global climate resilience and contribute to mitigating climate change.

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