CLIMATE RISK INSURANCE: BIBLIOMETRIC REVIEW ON PRESENT, PAST AND FUTURE

Haris Ur Rehman Horani[1], Muhammad Amin[1], Farhan Ahmed[2] (Corresponding Author)

[1]Department of Mathematics, NED University of Engineering and Technology, Pakistan. ORCID: https://orcid.org/0009-0005-4194-5689; https://orcid.org/0009-0003-3645-4653; Email: harishorani@neduet.edu.pk & amin1992.ah@gmail.com

[2]Derpartment of Economics&Management Sciences, NED University of Engineering and Technology, Pakistan. ORCID: https://orcid.org/0000-0002-1147-8347; Email: fahmed.ned@gmail.com

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ABSTRACT

The paper aims to examine the interrelation between climate risk and insurance, focusing on emerging trends, the evolution of risk assessment methodologies, and the challenges and opportunities in leveraging climate insurance to mitigate climate change risks. The study utilizes bibliometric analysis, network analysis, and content analysis on the bibliometric data comprises 1,726 documents from the Scopus database, narrowed down to 1,688 documents published within the time span of 1975-2023. The research identifies significant trends in the literature, with notable contributions from the United States, China, the United Kingdom, Germany, and France. The evolution of risk assessment methodologies reflects a shift towards addressing systemic complexity, multi hazard risks, and forward-looking scenarios. The study also highlights the role of climate risk insurance in promoting sustainable development, encouraging adaptation strategies, and reducing long-term climate change costs. Policy makers and regulators can support the insurance sector's contribution to climate adaptation by promoting risk reduction measures and fostering public-private partnerships. Enhancing data collection and analysis, developing innovative insurance products, and integrating technological advancements can improve the accuracy of risk prediction models and the effectiveness of climate insurance. This study provides a comprehensive bibliometric review of climate risk insurance literature, offering valuable insights into the field's development and identifying future research directions.

Keywords: Climate risk insurance; climate change; risk assessment; bibliometrics analysis

JEL Classification: Q54, Q56, G22

INTRODUCTION

Climate risk insurance is emerging as a crucial tool in addressing the climate change challenges like natural disasters, food insecurity and sea level rise. By providing financial protection against climate-related losses, such insurance schemes can help vulnerable communities and economies recover more quickly from disasters. Additionally, they increase benefits over investments in building measures, such as early warning systems and infrastructure improvements (Rogers & Tsirkunov, 2010). Furthermore, climate risk insurance can play a pivotal role in promoting sustainable development by encouraging adaptation strategies and reducing the long-term costs associated with climate change impacts. Climate change hinders socioeconomic progress by weakening sustainability and resilience, reinforcing poverty cycles, and causing loss of life and property. In 2022, natural disasters caused about 270 billion USD in damages, with almost 55% of the amount was not under insurance (Munich Re, 2022). Like Germany is expected to face insured losses of 4-5 billion EUR due to the severe floods in July 2021 (GDV, 2021). Climate-related hazards could put around 4% of the global economy at risk in 2022 (Mundey, Amiot, & Sifon-Arevalo, 2022).

Climate risk insurance has emerged as a critical tool for managing the impacts of climate change by providing financial protection against the losses associated with climate-related events. Climate risk insurance can take various forms, including traditional insurance products, such as property and casualty insurance, as well as innovative financial instruments, such as parametric insurance and catastrophe bonds (Boreux, 2013). These financial instruments can provide protection against a wide range of climate-related risks, including extreme weather events, natural disasters, and sea-level rise.

Climate risk insurance is especially important for vulnerable populations, such as low-income communities, smallholder farmers, and small and medium-sized enterprises. These groups are often the most affected by climate-related events. They usually lack access to traditional insurance products and are more vulnerable to the impacts of climate change due to limited financial resources, inadequate infrastructure, and reliance on climate-sensitive livelihoods.

This paper aims to examine the interrelation between climate risk and insurance, addressing three key inquiries. Firstly, it inspects the emerging trends in research pertaining to risk management and climate insurance over the preceding decade (RQ1). Secondly, it assesses the evolution of methodologies employed in risk assessment within the context of climate insurance (RQ2). Lastly, the paper explains the principal challenges and opportunities inherent in utilizing climate insurance as a mechanism for mitigating risks associated with climate change (RQ3).

LITERATURE REVIEW

Climate risk insurance plays a crucial role in managing the financial impacts of climate-related disasters (Rao, S.; Li, X. (2019); Oh, S.; Sen, I.; Tenekedjieva, A.M. (2022); Jain, D.K.; Chida, A.; Pathak, R.D.; Jha, R.; Russell, S. (2022); Arnold-Dwyer, F. (2024); Sen, I.; Tenekedjieva, A.M. (2021)). It provides households and businesses with financial protection against losses resulting from climate events. However, challenges such as lack of perfect policies, infrastructure, and public awareness hinder its effective implementation. State regulations significantly influence insurance rates, leading to disparities in rate adjustments and risk reflection across different states. In vulnerable regions like the Pacific Small Island Developing States (PSIDS), climate-induced disasters pose significant financial risks, emphasizing the need for efficient climate risk insurance solutions. To ensure the sustainability of insurance markets amidst increasing climate risks, promoting risk reduction through climate adaptation is essential. Policymakers and regulators can play a vital role in supporting the insurance sector's contribution to climate adaptation. The landscape of risk assessment methodologies in climate insurance has evolved significantly. Traditional approaches focused on single hazards, potentially leading to risk underestimations or overestimations (Westra, S.; Zscheischler, J. (2023)). Recent developments emphasize the importance of systemic complexity in risk assessment, highlighting the need to consider compounding and cascading risks, deep uncertainty, and boundary judgments (Meynadier, R.; Rakotoarimanga, H.; Frobert, B.; Weisman, A.; Lobligeois, F.; Deroche, M.S. (2023)). Financial institutions are now developing sophisticated models to estimate climate risk damages and losses, incorporating hazard, exposure, and vulnerability components (Baer, M.; Gasparini, M.; Lancaster, R.; Ranger, N. (2023)). Academics, financial institutions, and regulators are collaborating to assess forward-looking climate transition risks in sovereign bonds portfolios, considering scenarios of disorderly climate policy introductions (Stalhandske, Z.; Steinmann, C.B.; Meiler, S.; Sauer, I.J.; Vogt, T.; Bresch, D.N.; Kropf, C.M. (2024)). This evolution reflects a shift towards more comprehensive, forward-looking, and integrated approaches to climate risk assessment in the insurance sector. Leveraging climate insurance to mitigate risks associated with climate change presents both challenges and opportunities. Challenges include assessing future climate risks, promoting policyholder risk reduction, and supporting resilient reinstatement (Arquint, N.; Berger, A. (2022)). Lack of accessibility, increased risk for insurance providers, and ecological effects (Golnaraghi, M. (2023)). Additionally, the warming and acidification of oceans pose threats to marine ecosystems, such as coral reefs, necessitating innovative insurance products to protect these valuable resources (Basu, A.; Yadav, M.K. (2023)).

On the other hand, opportunities lie in enhancing data collection and analysis to better understand climate risks, enabling businesses to prepare effectively and transfer residual risk through partnerships with insurers (Baer, M.; Gasparini, M.; Lancaster, R.; Ranger, N. (2023)). Insurers can contribute to climate change adaptation by incorporating risk reduction measures in their products, fostering resilience, and directly reducing damages when climate-related events occur, thus aiding in building a more resilient society (Westra, S.; Zscheischler, J. (2023))

METHODOLOGY:

We have incorporated the use of Biblometrix package from RStudio that leads to bibliometric analysis, network analysis and content analysis for Climate Risk and Insurance. For this bibliometric analysis we have used Scopus as a data source for the publications. This review paper summarizes the findings from a comprehensive search on climate risk and insurance. The initial search yielded 1,726 documents covering the period 1935-2024. To gain a more current perspective, the timeframe was narrowed to 1975-2023, resulting in 1,688 documents. The analysis then focused on specific academic disciplines. A significant portion of the research comes from Environmental Science (552 documents), followed by Social Sciences (423), Earth and Planetary Sciences (362), Engineering (330), Economics, Econometrics and Finance (283), Business, Management and Accounting (180), with smaller contributions from Computer Science (48) and Mathematics (26). This distribution highlights the multifaceted nature of climate risk and insurance, encompassing scientific understanding, social impacts, economic implications, and technological solutions. To refine the results further, the search was limited to specific document types: Articles (860), Conference Papers (237), and Reviews (52). This selection emphasizes in-depth research findings, presentations at academic conferences, and critical evaluations of existing knowledge. The final criteria for the search were restricted to English-language documents, resulting in a final set of 1,083 articles.

QUERY:

("climate risk insurance" OR "climate insurance" OR "natural hazard insurance" OR "catastrophe insurance" OR "disaster insurance" OR "flood insurance" OR "drought insurance" OR "hurricane insurance" OR "typhoon insurance" OR "tornado insurance" OR "tsunami insurance" OR "wildfire insurance" OR "landslide insurance" OR "mudslide insurance" OR "hail insurance" OR "sleet insurance" OR "storm insurance" OR "heat wave insurance" OR "cold wave insurance" OR "lightning insurance")

This research is conducted with the help of extensive literature review on climate change and risk management 1975 to 2024. Scopus database was selected from which 1083 articles made it to the final selection. A bibliometric analysis is conducted in the study - which is based on the methodology used by Bajwa, et al., 2022.

In order to conduct a bibliometric review, this paper has worked on the following process mentioned in the figure – moreover this paper has three main steps for working in figure 1.

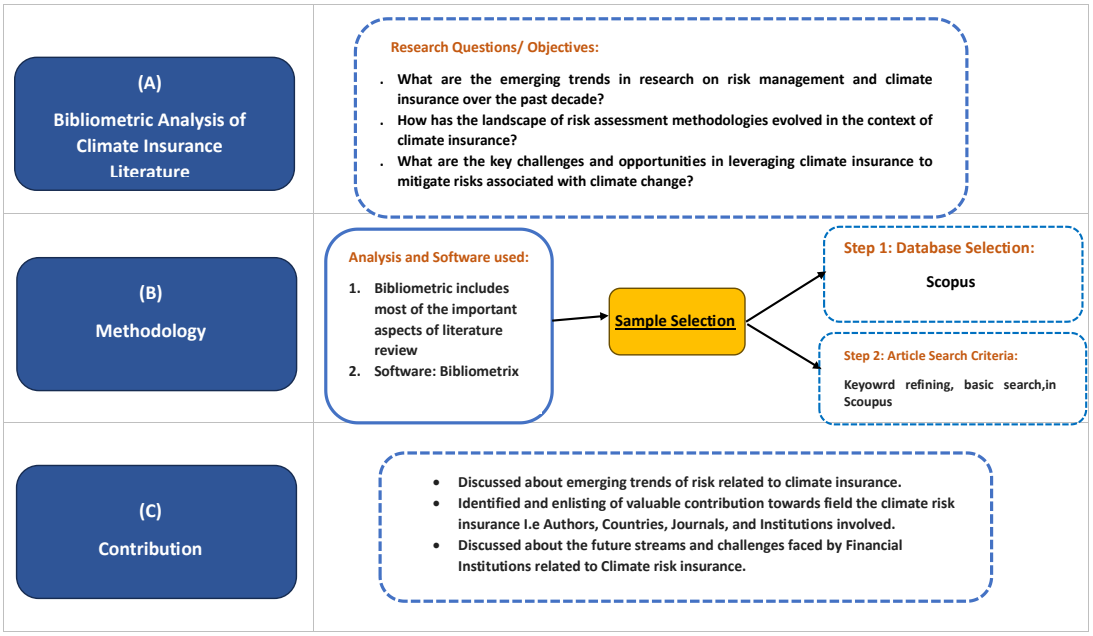

Fig 1. Methodology Flowchart

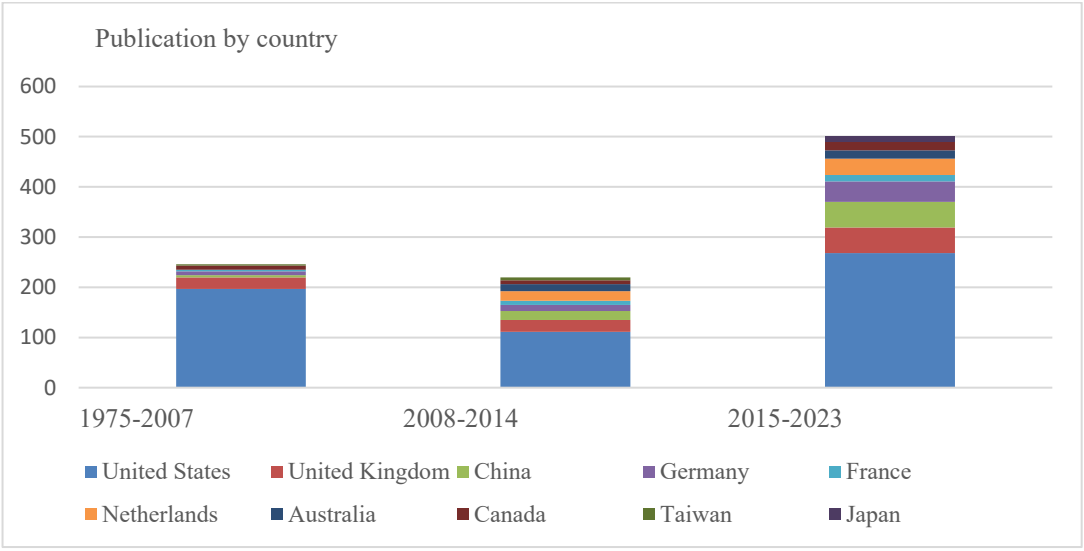

Fig 2. Most Influential Countries

Figure 2 illustrates a noticeable upward trend in the number of publications spanning nearly five decades. Throughout all three time periods, the United States stands out with the highest publication count. However, its dominance has shown a slight decline over time. From 1975 to 2007, the US boasted nearly double the publications of the second-ranked country. In contrast, from 2015 to 2023, it only maintains about a 50% lead over the second-ranked nation. China, on the other hand, has experienced a remarkable surge in publications in recent years. Initially lagging behind most other countries in the period from 1975 to 2007, China has now ascended to become the second-ranked country in terms of publication output by 2015 to 2023. Additionally, countries like the United Kingdom, Germany, and France have displayed notable increases in publication output over the three time periods, reflecting a steady growth trend. In contrast, some countries, such as Australia and Canada, have exhibited relatively stable publication outputs. However, the Netherlands has experienced a decline in publication output in recent years. Despite holding the third position from 1975 to 2007, it has since slipped to sixth place in the ranking.

Table 1. Most influential countries

Country	TC	Average Article Citations
USA	7729	26.2
UNITED KINGDOM	1656	43.6
NETHERLANDS	1310	48.5
GERMANY	907	26.7
AUSTRALIA	615	28
CHINA	575	9.7
FRANCE	388	27.7
AUSTRIA	317	35.2
CANADA	180	12.9
SWEDEN	106	26.5

Table one represents most influential countries with respect to total citations (TC), as growth for climate risk insurance shows a positive trend. According to the citations published by the country, United States of America has the highest citations, followed by United Kingdom, Netherland and Germany.

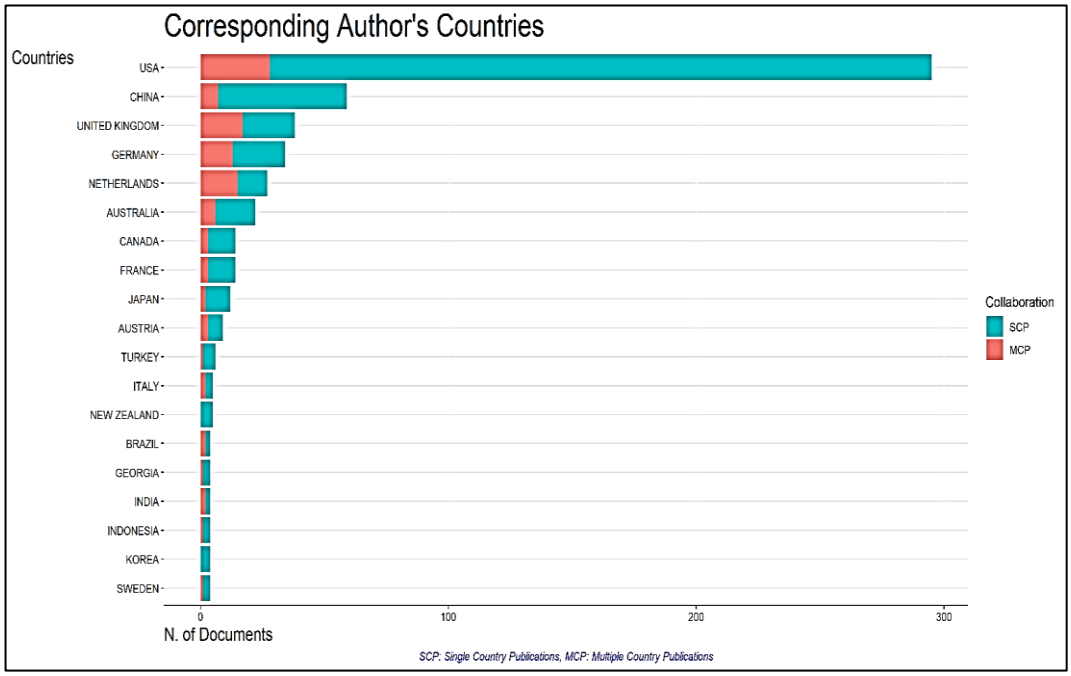

Fig 3a. Corresponding Author's Countries

The top seven countries with the most corresponding authors are: United States, China, United Kingdom, Germany, Netherland, Australia, Canada. There is a large gap between the United States and other countries. The United States has nearly twice as many corresponding authors as China, the second-highest country. The number of authors from each country generally decreases as you move down the list. However, a few exceptions exist, such as Turkey and Italy, which have more authors than New Zealand and Brazil. The graph also includes a breakdown of the publications by Single Country Publications (SCP) and Multiple Country Publications (MCP). SCPs are papers where all of the authors are from the same country, while MCPs are papers where the authors are from multiple countries.

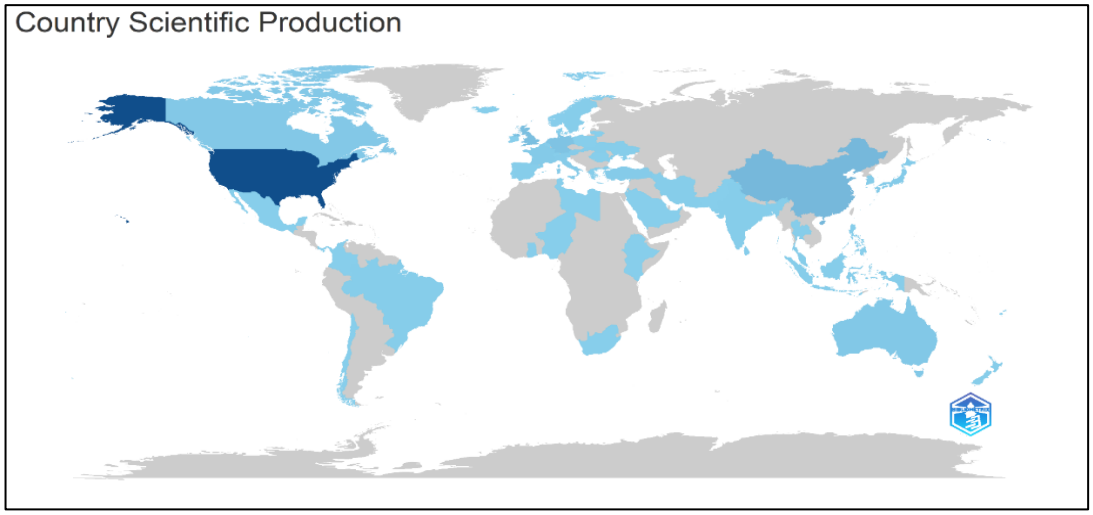

Fig 3b. Country Scientific Production

Figure 4 illustrates a consistent increase in articles from all institutions over time. Louisiana State University has the highest number of articles, followed by the University of California, the University of Pennsylvania, VU University Amsterdam, and an undisclosed institution. The data spans from 1996 to 2021, with a significant surge in articles from Louisiana State University observed in 2005. The University of California has steadily increased in articles over time, while articles from the University of Pennsylvania have fluctuated. VU University Amsterdam has seen a consistent rise in articles, while the undisclosed institution's article count has varied over time.

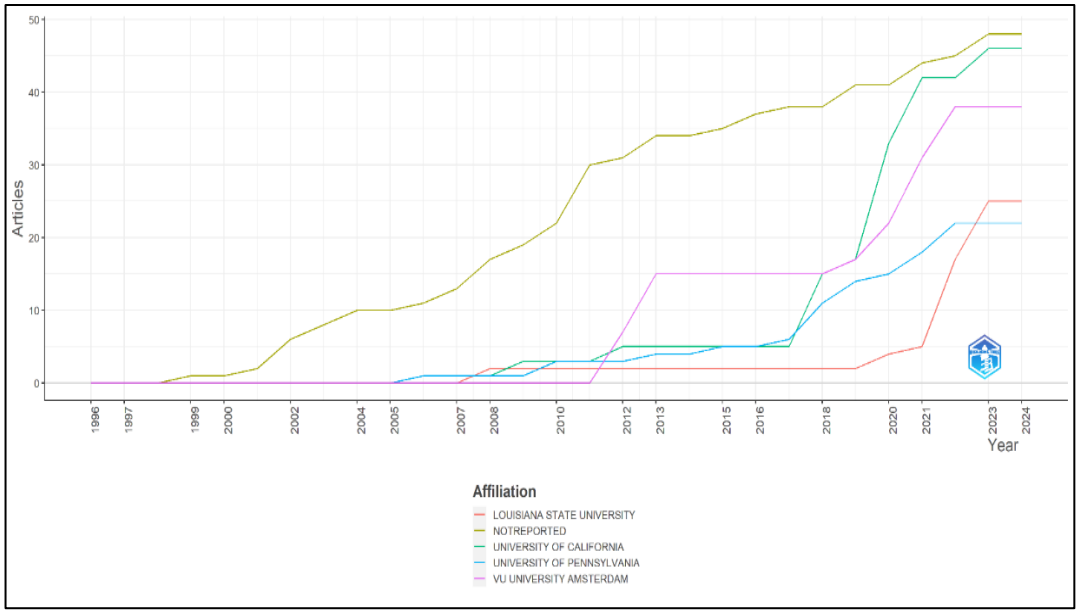

Fig.4. Most Influential Institutions in Climate Insurance Research

MOST RELEVANT AFFILIATIONS

In the field of climate risk analysis, affiliations that consistently produce a high volume of research articles play a pivotal role in driving the field forward. University of California is noteworthy for its high-volume output, with researchers affiliated with this institution publishing a substantial number of articles annually, particularly in areas of climate risk and sustainability. Similarly, University of Amsterdam distinguishes itself by maintaining a high-volume research agenda, contributing significantly to the body of knowledge in this critical field. These affiliations, marked by their prolific research endeavors, are at the forefront of advancing our understanding of climate risk.

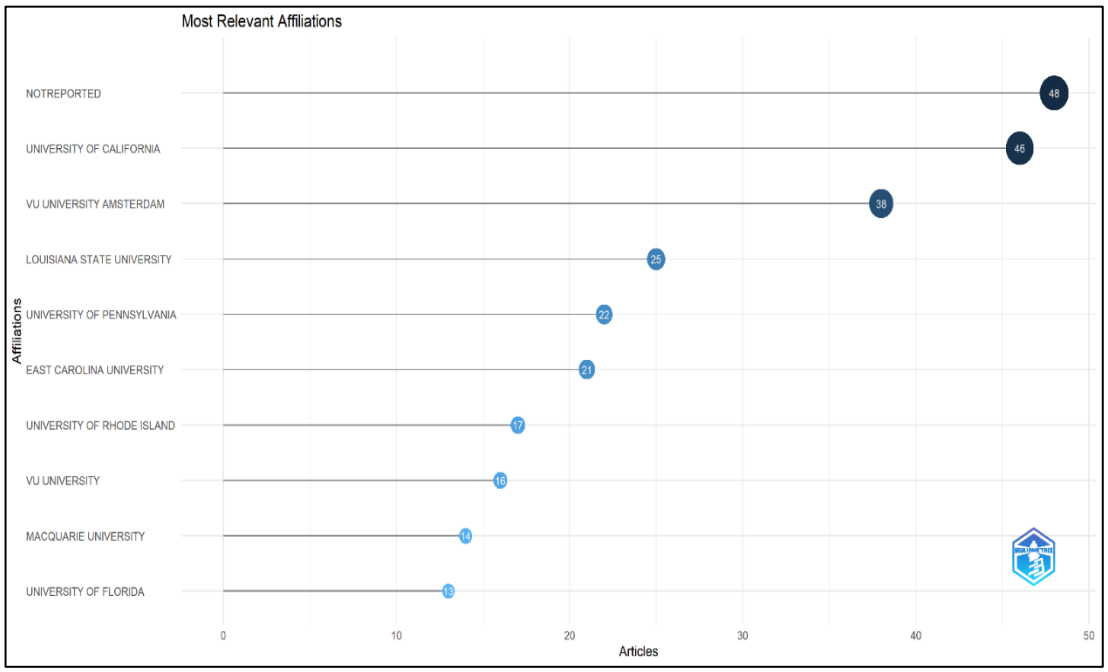

Fig. 5. Affiliation's production over time

Influential Authors in Climate Insurance Research

In the figure 6. the landscape of climate risk analysis, several prominent authors have significantly contributed to the scholarly discourse. Notable among them is Botzen, whose groundbreaking work in climate risk and management has garnered widespread recognition. Another key figure in the field is Kunreuther, whose innovative methodologies and insightful perspectives have left a lasting impact on the way researchers approach climate risk assessment. These authors, along with several others, form the vanguard of climate risk analysis research, shaping the intellectual terrain and pushing the boundaries of knowledge in this critical field.

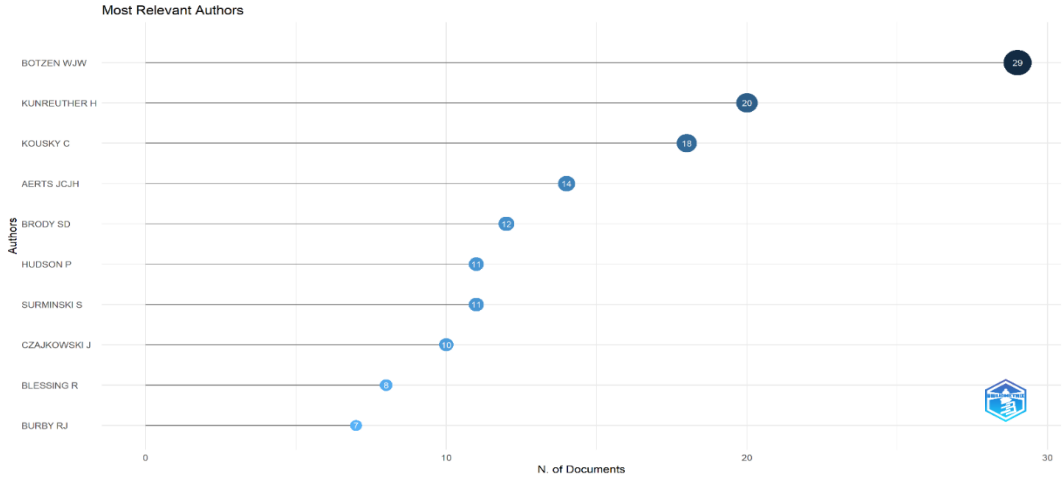

Fig. 6. Most relevant authors

INFLUENTIAL ARTICLES

The figure 7 below depicts the results of the keyword analysis through co-occurrence network. The software R studio package bibliometrix was used to obtain the keyword analysis also known as cartography analysis. The minimum selected scale of co-occurrence of selected keywords is 5. Out of the 900 keywords used by the authors, 42 met the threshold. This analysis is a significant step in identifying the key research streams in the selected fintech literature. The clusters represent the closely related research streams for example the light blue clusters show all the keywords that are related to the flood and natural disasters streams. The size and distance between the spheres show the link strength and the number of occurrences. The bigger bubbles imply that the keyword has greater occurrences. The longer the distance between bubbles the weaker the links among keywords.

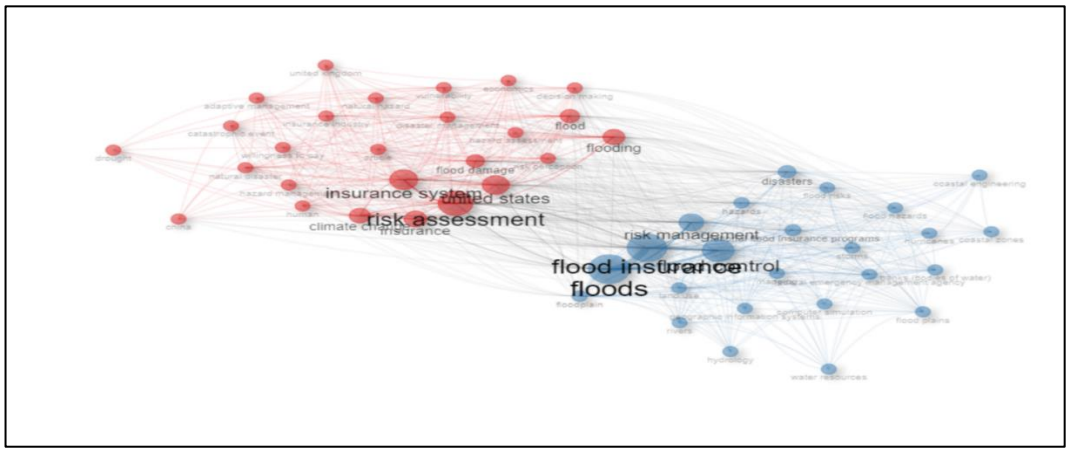

Fig 7. Co-occurrence Network

KEYWORD ANALYSIS

REVIEW OF RESEARCH STREAMS

After the identification of the influential aspects of Climate Risk Insurance literature, a three-factor analysis was performed to identify the top 10 keywords and their connection with various authors and countries. The result of the three-factor analysis is presented in Fig 10. The analysis is done through biblioshiny, which enables the use of bibliometric tools incorporated from the R package - bibliometrix. The analysis concludes that the top 10 keywords were Flood insurance, insurance, flood risk, climate change, flooding, flood risk management, natural hazards, disaster insurance, national flood insurance program, and adaptation. These keywords connected with authors who were mainly linked with countries such as USA, Netherland, the UK, Australia, Germany, Sweden, France, Italy, and Austria.

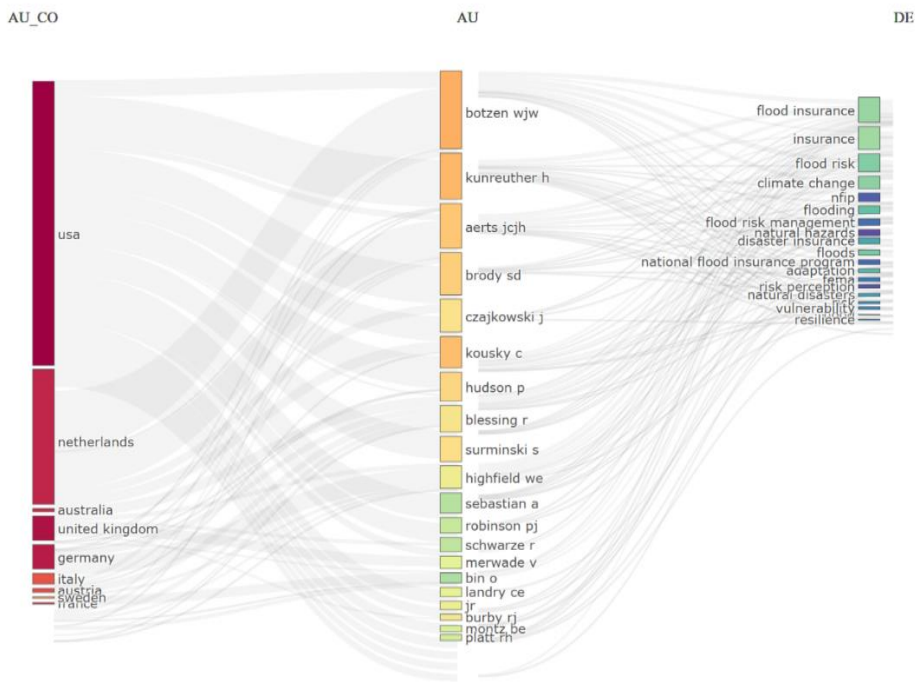

Fig 8. Three Factor Analysis

The cartography results from the keyword co-occurrence analysis along with the three-factor analysis helped in pointing out the prominent research streams in risk insurance literature. However, risk in itself and climate insurance were the broadest research streams identified from the sample. RQ2) How has the landscape of risk assessment methodologies evolved in the context of climate insurance?

The landscape of risk assessment methodologies in the context of climate insurance has evolved significantly. Traditional risk assessments have transitioned towards addressing systemic complexity, deep uncertainty, and multi-hazard risks (Meynadier, R.; Rakotoarimanga, H.; Frobert, B.; Weisman, A.; Lobligeois, F.; Deroche, M.S. (2023); Zscheischler, J.; Westra, S.(2023)). This evolution involves considering the physical hazard, exposure, and vulnerability components of climate risk, along with the development of Natural Hazard models for estimating damages and losses. New approaches include global proportional models for large-scale risk assessment and more sophisticated local-scale assessments integrating forward-looking scenarios. The incorporation of diverse lines of evidence, stakeholder engagement, participatory processes, and the integration of quantitative and qualitative information have become crucial in enhancing the resilience of climate-sensitive systems. These advancements aim to provide a more comprehensive and accurate approach to climate risk management and insurance pricing. Furthermore, there is a growing awareness of the limitations, uncertainties, and trade-offs inherent in data, models, and methods for financial risk assessments related to climate change, urging for a more comprehensive scenario taxonomy to navigate financial risks under uncertainty. This evolution highlights the necessity of integrating diverse lines of evidence and expertise, enhancing inter-disciplinarily, and encouraging inclusiveness in climate risk assessment practices. Moreover, some suggested methodologies related to RQ1 are recommended below:

1. How do advancements in artificial intelligence and big data enhance the accuracy of risk prediction model for climate change?
2. How can policy makers and regulatory make frameworks to decrease the barriers in climate risk insurance markets?
3. Identifying the behavior change and adaptation of individuals and organizations towards climate change and insurance uptake?

RQ3) What are the key challenges and opportunities in leveraging climate insurance to mitigate risks associated with climate change?

Climate change poses significant challenges to communities worldwide, increase in the frequency and austerity of weather and other climate-related risks. The concept of climate risk insurance has emerged as a tool for mitigating the financial impacts of risky climate related events. The key challenges and opportunities associated with leveraging climate insurance to address climate change risks, by *examining data uncertainty*, *affordability concerns*, *moral hazard*, *coverage gaps*, and *policy complexities*, alongside opportunities for innovation, *public-private partnerships*, r*isk reduction incentives*, *technological advancements*, and *policy integration*.

CONCLUSION AND FUTURE RESEARCH

Integration of Big Data and Artificial Intelligence (AI) by exploring how advancements in big data analytics and artificial intelligence can enhance predictive models for climate risks and insurance claims thus helping in decision making models for the insurance companies and interrelated organizations. There is a trend towards the development of innovative microfinance models for insurance specifically tailored for the needs related to risks. These may include parametric insurance, index-based insurance, and microinsurance models designed to provide financial aid to communities and sectors.

Research is examining the role of policy and regulatory frameworks in facilitating the expansion of climate risk insurance markets. This includes exploring ways to overcome barriers to market development, promote transparency and accountability, and ensure the equitable distribution of insurance coverage. Moreover, there is a growing apprehension on the importance of behavior analysis for the understanding in how individuals or organizations responds towards climate risk. Research in developing insurance products and communications strategies can provide a significant interest towards climate risk insurance which could lead towards a better understanding – thus reducing risk behaviors.

Research Stream	Potential Research Objectives	Possible Outcome
Integration of Big data and AI in Climate Risk Insurance	1. How can big data analytics provide accuracy for climate risks?	Advancements in Predictive Models
	2. What are the recent techniques in Artificial Intelligence used in developing predictive models for climate risk insurance?	Advancements in Predictive Models
	3. Comparative analysis of traditional and AI enhanced models for risk assessments on climate change?	Advancements in Predictive Models
	4. Case studies on Implementation of AI in Climate Risk Management - in context of risk management.	Enhancing Decision Making Models
Development of Microfinance Models for Climate Risk Insurance	5. Identify challenges and bottlenecks in design and implementation of insurance products.	Enhancing Parametric insurance models
Policy and Regulatory Frameworks	6. Identification of barriers in the development of climate risk insurance?	Enhancement of public private partnership - improving awareness related climate risk insurance
	7. Significance related to accountability and transparency of insurance leading to promotion of insurance products.	Enhancement of public private partnership - improving awareness related climate risk insurance
Behavioral/ Sentiment Analysis in Climate Risk Insurance	8. Patterns of individuals and organization pre and post effect of climate disaster.	Development of Insurance products related to sentiments

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