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EMPIRICAL PAPER

# Macroeconomic Stability in the Era of Climate Change: A Systematic Review of Environmental Risks and Economic Costs

**Victoria Adekomaya[1], Abdulwaheed Tella[2], Sekinah Adenike Yusuf-Saba[3*], Salami Ibrahim O[4], Zaynab Motunrayo Lukman[5]**

**Affiliations**
[1]School of Entrepreneurship Education, University of Johannesburg, South Africa
[2]Department of Civil Engineering, School of Engineering, Monash University Malaysia, Jalan Lagoon Selatan, 47500, Bandar Sunway, Selangor, Malaysia
[2]Monash Climate-Resilient Infrastructure Research Hub (M-CRInfra), School of Engineering, Monash University Malaysia, Jalan Lagoon Selatan, 47500, Bandar Sunway, Selangor, Malaysia
[3]INCEIF University, Wilayah Persekutuan, 50480, Kuala Lumpur, Malaysia
[4]Department of Geographical and Environmental Education, Lagos State University of Education (LASUED)
[5]School of Business and Economics, Universiti Brunei Darussalam

**Orcid Identifiers**

Victoria Adekomaya
0000-0002-0786-4851

Abdulwaheed Tella
0000-0002-4380-3343

Sekinah Adenike Yusuf-Saba
0009-0001-2262-9518

Salami Ibrahim O
0009-0001-5067-0809

Zaynab Motunrayo Lukman
0009-0003-1227-2206

**DOI**
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## Abstract

**Purpose:** Climate change presents escalating threats to macroeconomic stability, primarily through increasing physical hazards and complex transitional dynamics. This study aims to systematically review and synthesise empirical evidence on how climate-related risks disrupt economic systems and fiscal governance across regions.

**Methodology:** This systematic literature review synthesises findings from 35 peer-reviewed empirical studies published between 2018 and 2025, selected according to PRISMA guidelines and sourced from SCOPUS and Google Scholar.

**Result:** The analysis identifies key climate-related risks that destabilise macroeconomic systems, including rising $CO_2$ emissions, extreme weather events, sector-specific vulnerabilities, and financial system fragility. The agriculture and energy sectors are particularly exposed, with low-income and climate-vulnerable economies experiencing disproportionate impacts. Furthermore, climate policy tools, such as carbon pricing and emission regulations, introduce new sources of volatility and fiscal pressure, particularly for carbon-intensive industries. Although forecasting models are widely used to estimate economic impacts, their accuracy is limited by data constraints and climate uncertainty.

**Novelty and contribution:** This study contributes to the literature by integrating recent empirical findings into a comprehensive review that links climate risk, sectoral vulnerability, and macroeconomic instability. A key contribution lies in highlighting the role of climate uncertainty in undermining policy confidence, delaying regulatory responses, and weakening macroeconomic governance. The review further underscores the limitations of current forecasting tools and calls for improved climate–economic modelling frameworks.

**Practical and social implications:** This study highlights the need for improved institutional capacity in climate-vulnerable regions, where technical skills and tools for interpreting climate-economic data are limited.

*Corresponding author
**E-mail address:** ysekinahgenius@gmail.com

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**Keywords:** Macroeconomic Stability, Climate Change, Environmental Risks, Economic Costs, SDG

## 1 Introduction

Climate change has emerged as a major global challenge, exerting profound and systemic pressure on the stability of the global economy. The World Economic Forum's Global Risks Report (2022) warns that global temperatures are rising at an unprecedented rate and could increase by up to 5°C above pre-industrial levels by the end of the twenty-first century under high-emission scenarios. This climatic trend presents substantial threats to multiple sectors, including agriculture, energy, finance, health, and governance (Auffhammer et al., 2013; Zhang et al., 2024). In recent years, the world has witnessed increasingly severe manifestations of climate change, including the 2022 floods that submerged one-third of Pakistan (Hong et al., 2023), extreme temperatures surpassing 50°C in India (Mandal et al., 2025), and the widespread wildfires across Canada in 2023, which enveloped several U.S. cities in smoke for extended periods (Jain et al., 2024). While no single event can be attributed solely to anthropogenic climate change, the growing frequency and intensity of such extremes closely align with long-term projections from climate models (National Academies of Sciences and Medicine, 2016).

These escalating physical risks are reshaping public and corporate attitudes, accelerating the shift toward decarbonisation and climate adaptation. The declining costs of renewable energy technologies, such as solar power, batteries, and electric vehicles, have further incentivised this transformation (Bilal & Stock, 2025). As a result, capital flows are being reallocated on a massive scale, potentially amounting to tens of trillions of dollars, with profound implications for economic structures, policy priorities, and global development trajectories. These transitions, while necessary, may introduce new forms of macroeconomic volatility and structural adjustment, posing complex challenges for maintaining economic stability in a climate-constrained world (Bilal & Stock, 2025).

Unexpected disruptions to economic systems, such as those induced by climate change, can prompt shifts in government policy, thereby reducing the reliability of policy forecasts and increasing economic policy uncertainty (EPU) (Baker et al., 2016). In recent years, global crises, including financial instability, migration pressures, rising unemployment, income inequality, and oil price volatility, have amplified EPU (Al-Thaqeb et al., 2022; Iyke, 2020). Elevated uncertainty regarding policy directions significantly affects macroeconomic outcomes by delaying investment and consumption decisions. Both firms and households tend to adopt more cautious strategies: households increase savings and reduce consumption, while firms reduce investment, mergers and acquisitions, and hiring, opting instead to accumulate cash reserves (Bloom, 2009; Caggiano et al., 2017; Kahle & Stulz, 2013). These behaviours contribute to slower economic growth, heightened unemployment, and reduced capital formation. Moreover, EPU has been shown to heighten volatility in key markets such as housing and commodities, as seen in increased fluctuations in house prices and oil inventories (Jones & Olson, 2013; Krausmann & Cruz, 2013).

By influencing crop yields, human health, operational costs, and retail sales, climate change introduces new sources of macroeconomic volatility (Carleton & Hsiang, 2016). In response, governments frequently revise or introduce new economic policies to buffer the impacts, inadvertently increasing policy uncertainty. This dynamic underscores the complex interplay between climate risks, government policy, and economic behaviour —an interaction critical to understanding macroeconomic stability in the era of climate change.

The economic consequences of climate change are not limited to a specific location or income bracket. Both advanced and developing economies are increasingly vulnerable (Kahn et al., 2021). However, low-income countries are disproportionately affected due to limited financial and technological capacity to mitigate and adapt to climate-related shocks, resulting in considerable economic losses (Dell et al., 2008). The effects are severe even in high-income regions such as Europe, where climate-related disasters have caused an estimated €5 trillion in economic damages over the past four decades (Tollefson, 2020). Moreover, high-latitude developed economies are experiencing warming at a rate higher than the global average, consequently intensifying the economic burden of extreme weather events. As a result, climate change has become an increasingly salient area of inquiry in economic scholarship. Understanding the magnitude and transmission channels through which environmental risks affect key macroeconomic indicators is essential for the design and implementation of effective economic policies (Cashin et al., 2017; Kotz et al., 2021).

While several high-quality reviews have examined economic aspects of climate change, such as the social cost of carbon, mitigation strategies, and spatial impacts (Dell et al., 2014; Dietz et al., 2021; Timilsina, 2022; Moore et al., 2024), these studies typically focus on specific domains in isolation. Consequently, there is a lack of integrative, cross-cutting synthesis that evaluates the full spectrum of environmental risks and economic costs from the perspective of macroeconomic stability. Existing reviews often overlook the collective influence of climate change on core macroeconomic indicators. This systematic review addresses these gaps by synthesising findings across the domains of loss and damage, adaptation, and mitigation, providing a unified framework to understand the macroeconomic implications of climate change.

To achieve this, the study will be based on the following research questions:

i. What are the key environmental risks associated with climate change that impact macroeconomic stability?

ii. How does climate change affect the economic costs and fiscal stability of different sectors and regions?

iii. What forecasting models are used to predict the economic impact of climate change, and how accurate are these models in real-world applications?

iv. How does uncertainty about climate projections impact policy decisions related to macroeconomic stability?

## 2 Methodology

### 2.1 Database

To ensure a comprehensive and rigorous review of the literature on macroeconomic stability under climate change, this study employed a systematic literature review (SLR) following established protocols. The Scopus database was selected as the primary source for peer-reviewed publications due to its broad disciplinary coverage and credibility. Scopus indexes over 70 million records and more than 21,600 journals from over 4,000 international publishers, making it a robust foundation for evidence synthesis in interdisciplinary fields such as climate economics (Bamiro et al., 2023; Salisu et al., 2024). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021) guided the search and selection process. PRISMA's 27-item checklist and four-phase flow diagram were employed to ensure transparency, reproducibility, and methodological rigour throughout the stages of identification, screening, eligibility, and inclusion. To enhance the breadth of coverage and reduce the risk of omitting relevant literature, Google Scholar was also consulted as a supplementary source during the identification phase.

### 2.2 Search Strategy and Eligibility Criteria

To address the research questions and ensure methodological rigour, a clearly defined and replicable search strategy was employed. The search was conducted using the Scopus database, selected for its comprehensive indexing of peer-reviewed, multidisciplinary scholarly output. Initially, the search yielded 684 records. To align with the study's temporal scope, a publication date filter was applied to restrict results to the period 2018–2025, reducing the dataset to 256 records. This approach ensured the retrieval of relevant and up-to-date scholarly articles. These records were exported in CSV format and screened manually in Microsoft Excel.

The search strategy was guided by a structured string of keywords developed to capture literature specifically addressing the intersection of climate change, environmental risks, and macroeconomic stability. The final search terms included variations and combinations of keywords such as "climate change", "macroeconomic stability", "economic cost", "climate risk", "transition risk", "physical risk", "fiscal stability", and "economic forecasting." This approach was designed to retrieve studies that explored the direct and indirect macroeconomic consequences of climate-related risks, while also capturing various theoretical and empirical lenses.

The screening and selection process followed the PRISMA guidelines (Page et al., 2021), ensuring transparency, replicability, and a high standard of academic rigour. The initial screening phase involved the exclusion of irrelevant titles and duplicates. Subsequently, each study underwent a detailed abstract and full-text review based on a pre-established set of inclusion and exclusion criteria.

The inclusion criteria required that articles:

a) be published between 2018 and 2025,

b) be written in English, and

c) appear in peer-reviewed academic journals

These criteria were established to ensure the inclusion of contemporary, high-quality studies that reflect recent developments in climate economics and macroeconomic policy. The decision to limit the study to English-language publications was made to maintain consistency in interpretation and to avoid potential issues arising from translation inaccuracies or conceptual ambiguities. This is also consistent with the predominance of English in global academic publishing.

Studies were excluded if they:

a) were non-empirical, editorials, theoretical essays, commentaries, conference papers, or books/book chapters.

b) did not directly examine the economic costs or macroeconomic implications of climate change, or

c) lacked a clear focus on environmental risk or fiscal/economic stability.

After applying these filters, 35 articles were retained for final inclusion in the systematic review; the process is shown in the PRISMA diagram below (Figure 1). These studies form the foundation for the evidence synthesis and thematic analysis presented in the findings, providing critical insights into how climate change influences macroeconomic stability across sectors and regions.

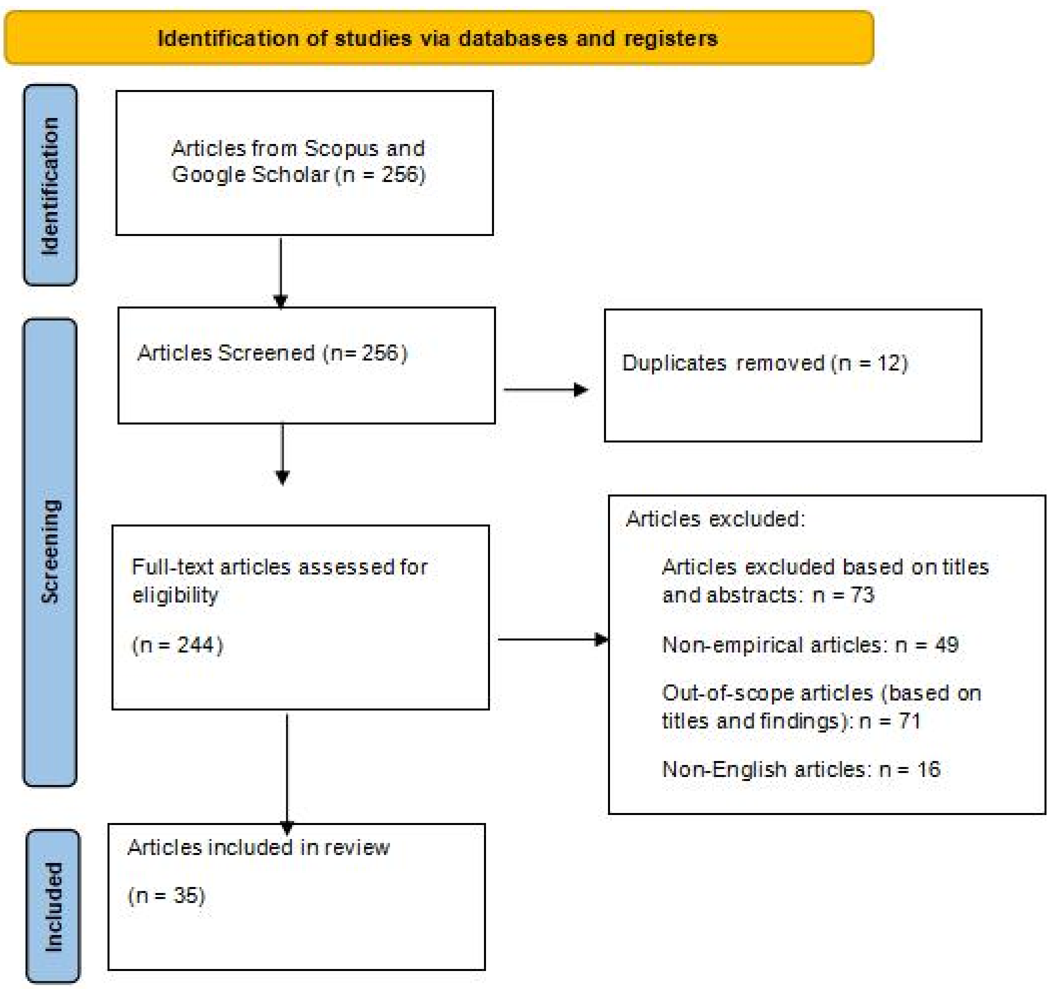


**Figure 1** PRISMA flow diagram

## 3 Data Extraction Table

To ensure consistency, transparency, and analytical rigour, in Table 1, data extraction was conducted for the 35 peer-reviewed studies that fully met the study's inclusion criteria. Each article was thoroughly reviewed, and relevant details were systematically retrieved to support comparative analysis across sectors and regions. The extracted information included the names of the authors, year of publication, the country or region where the research was conducted, and the methodological design adopted in the study. Attention was also paid to identifying the academic journal in which each article appeared, the primary sector examined (e.g., agriculture, energy, or finance), and the specific type of climate risk addressed, whether physical, transitional, or both. This structured approach to data extraction served as the foundation for the evidence synthesis and thematic analysis, enabling a comprehensive understanding of how climate change influences macroeconomic stability across different contexts.

**Table 1** Data Extraction table

| S/N | Authors' name and year | Methodology | Research Country | Journal | Sector | Climate Risk Type |
|---|---|---|---|---|---|---|
| 1 | Liza et al. (2024) | Quantitative | China | Journal of Environmental Management | Agriculture, energy, and infrastructure | Mitigation |
| 2 | He et al. (2024), | Quantitative | China | Energy Economics | Financial sector | Transition risk |
| 3 | Lu et al. (2024) | Quantitative | China | Energy Economics | Financial Market | Transition risk |
| 4 | Negri et al. (2024) | Quantitative | Italy | Field Crops Research | Agriculture Sector | Physical risk, Adaptation |
| 5 | Fan et al. (2024) | Quantitative | China | International Review of Economics & Finance | Banking Sector | Physical risk |
| 6 | Yang et al. (2024) | Quantitative | China | Journal of Environmental Management | Energy Sector | Transition risk |
| 7 | Naseer et al. (2024) | Quantitative | UK | International Review of Financial Analysis | Stock Market | Physical Transition |
| 8 | Hamza et al. (2024) | Mixed-Method | China, Bangladesh | Water | Agriculture Sector | Drought (climate change-induced) |
| 9 | Praveen and Kunnampa lli (2024) | Mixed-method | India | International Journal of Disaster Resilience in the Built Environment | Agriculture Sector | Sea level rise, precipitation, heat stress |
| 10 | Liu et al. (2024) | Quantitative | China, Romania | Resources Policy | Oil Sector | Climate policy uncertainty |
| 11 | Hassna et al. (2024) | Quantitative | Qatar | Sustainability | Agriculture Sector | Temperature rise, water stress |
| 12 | Hungerlan d and Altmeppe n (2024) | Qualitative | Germany | Intereconomics | Economics | Economic risks |
| 13 | Wu and Lin (2024) | Quantitative | China | Environmental Impact Assessment Review | Finance | Extreme climate change and meteorological disasters |
| 14 | Shahbaz | Quantitative | Russia | Journal of | Energy, | Climate policy |

| | | | | | | |
|---|---|---|---|---|---|---|
| | et al. (2024) | | | Environmental Management | manufacturing, and transportation sectors | uncertainty, energy price uncertainty |
| 15 | Jackson and Bailey (2024) | Qualitative | UK | The British Journal of Politics and International Relations | Banking sector | Climate risk, net zero transition mandate |
| 16 | Safi et al. (2024) | Qualitative | Afghanistan | GeoJournal | Agriculture | Temperature rise, drought, floods, heatwaves |
| 17 | Sahu and Mahalik (2024) | Quantitative | India | Environment, Development and Sustainability | Economics | Carbon inequality, income inequality |
| 18 | Khurshid et al. (2024) | Quantitative | Pakistan | Environment, Development and Sustainability | Multiple sectors | CO2 emissions |
| 19 | Di Febo et al. (2023) | Quantitative | Italy | Risks | Energy sector | Transition risk |
| 20 | Sahu et al. (2023) | Quantitative | India | Environmental Science and Pollution Research | Multiple sectors | Environmental degradation |
| 21 | Baranyai and Banai (2022) | Quantitative | Hungary | Climatic Change | Banking | Physical risk |
| 22 | Lamperti and Roventini (2022) | Quantitative | Italy | European Journal of Economics and Economic Policies | Energy | Transition risk |
| 23 | Liang et al. (2022) | Quantitative | China | Technological Forecasting and Social Change | Energy | Transition risk |
| 24 | Hu et al. (2025) | Quantitative | China | Environmental Research | Construction | Transition risk (industrial emissions) |
| 25 | Khodayar et al. (2025) | Qualitative | Portugal | Reviews of Geophysics | Multi-sector (Health, Energy, Transport, Agriculture, Cultural Heritage) | Physical risk (extreme weather events – Medcyclones) |
| 26 | Fasolino et al. (2025) | Qualitative | Italy | Journal of Environmental Management | Water, Agriculture, Energy | Physical risk (drought) |
| 27 | Shoaei et al. (2025) | Quantitative | Iran | Environmental Monitoring and Assessment | Forestry, Tourism, Health, Energy | Physical and transition risks (forest loss, ozone depletion, global warming, acidification) |
| 28 | Hatamkhani et al. (2025) | Quantitative | Iran | Energy | Energy | Physical risk (streamflow reduction due to |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | climate change) |
| 29 | Kyrimis et al. (2025) | Quantitative | Greece | Energies | Energy | Transition risk (green hydrogen integration) |
| 30 | Di Noia et al. (2025) | Quantitative | Italy | Journal of Economic Behaviour & Organisation | Manufacturing, Services | Physical risk (river flood) |
| 31 | Mastroeni et al. (2025) | Quantitative | Italy | Energy Economics | Agriculture | Transition & Physical (climate sentiment, climate events) |
| 32 | He et al. (2025) | Quantitative | China | Marine Pollution Bulletin | Shipping, Urban Economy | Transition risk (emissions impact) |
| 33 | Rezaee et al. (2024) | Quantitative | Iran | Environmental Processes | Healthcare, Waste Management | Transition risk (emissions, pollution) |
| 34 | Anwar et al. (2024) | Quantitative | Pakistan | Heliyon | Energy, Infrastructure, Trade | Transition and physical risk (pollution, biodiversity loss) |
| 35 | Belford et al. (2023) | Quantitative | Gambia | International Journal of Climate Change Strategies and Management | Agriculture | Physical risks: crop yield loss, livestock decline, sea-level rise |

# 4 Descriptive Statistics

## 4.1 Research Paper by Method

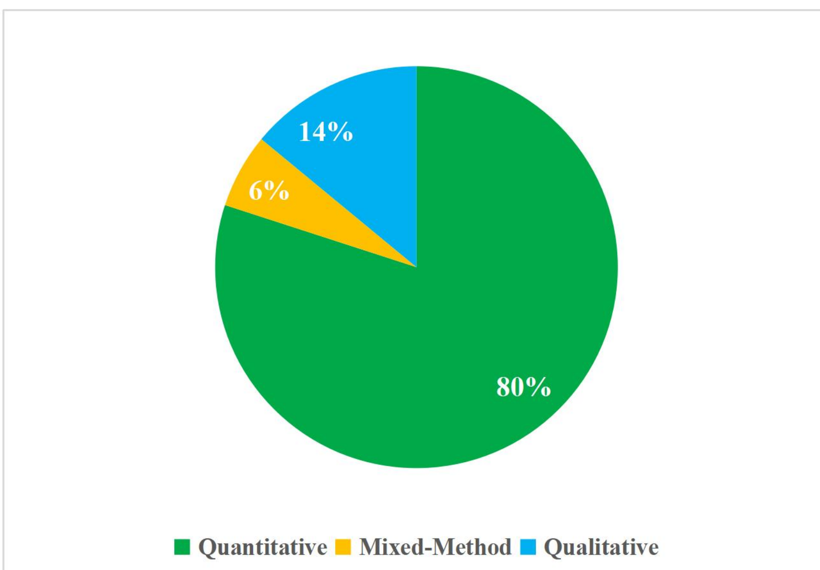


**Figure 2** Methodology Analysis

The methodological analysis in Figure 2 reveals a significant dependence on quantitative research methods, as 28 of the 35 analysed publications employed statistical models, econometric techniques, or extensive data analysis. This reflects a strong emphasis on empirical measurability and the use of structured, data-driven frameworks to examine the relationship between environmental risks and macroeconomic stability. In contrast, only five studies adopted qualitative designs, and just two employed mixed-method approaches, indicating a significant underrepresentation of interpretive and integrative methodologies. This methodological imbalance suggests that while quantitative studies provide valuable macro-level insights, they may overlook localised, context-dependent dynamics and the lived experiences of affected communities. To advance a more holistic understanding of the economic costs of climate change, future research should consider incorporating qualitative and mixed-method designs. Such approaches could offer richer, more nuanced perspectives, particularly in regions where quantitative data is limited or where institutional and behavioural dimensions play a critical role.

## 4.2 Publication Year

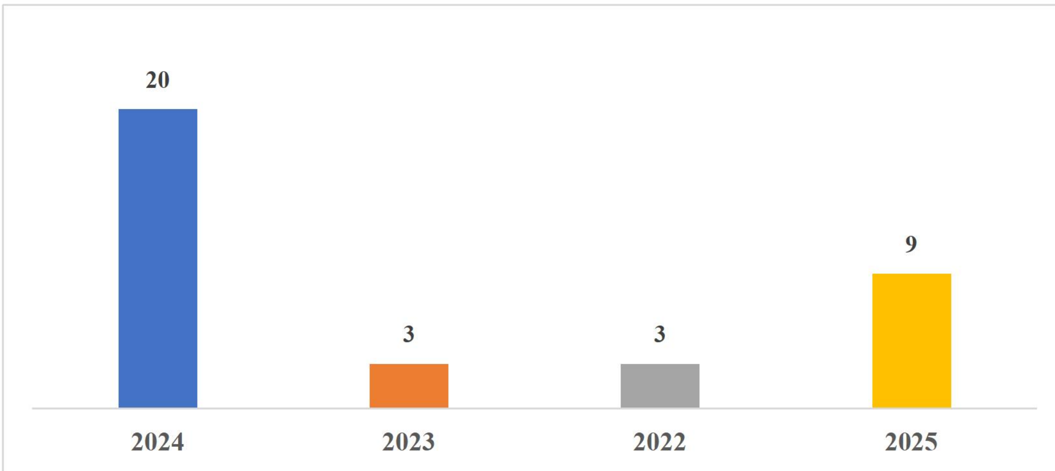


**Figure 3** Article Publication Year

The distribution of studies from 2018 to 2025 reveals a marked increase in scholarly interest in the intersection of climate change and macroeconomic stability in recent years. As shown in Figure 3, the majority of included articles were published in 2024 (20 studies), followed by 2025 (9 studies), suggesting a sharp surge in academic output on this topic over the last two years. This reflects the growing urgency of climate-related economic risks in global policy discourse, as well as increased availability of climate-financial datasets and heightened support for climate-oriented research agendas.

In contrast, earlier years within the inclusion window saw considerably lower publication volumes, with only three studies each in 2022 and 2023. Notably, no studies from 2018 to 2021 met the inclusion criteria, indicating a limited alignment with the set standards (e.g., methodological rigour, relevance to macroeconomic stability, or empirical climate-economic focus).

The concentration of studies in the most recent two years may also be attributed to heightened institutional awareness following global climate summits and economic disruptions triggered by climate-related disasters and policy shifts. This upward trend signals a promising trajectory for future inquiry.

### 4.3 Authors' Country Affiliations

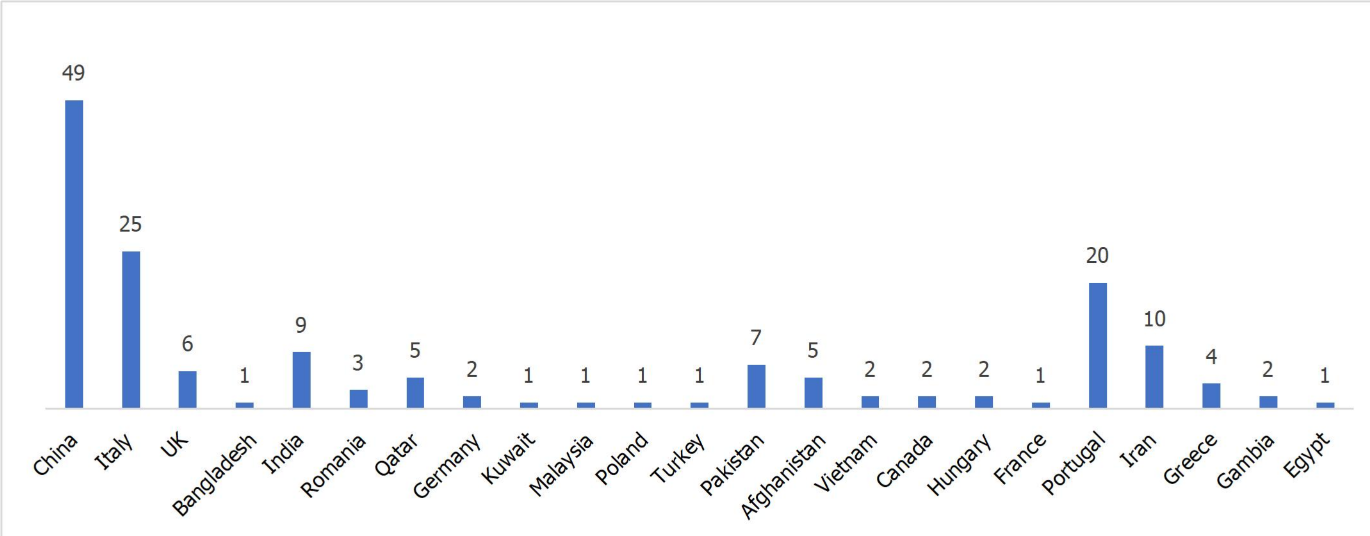


**Figure 4** Authors' Country Affiliation

The analysis of author affiliations in Figure 4 reveals a significant geographical concentration of scholarly contributions, with China (49 affiliations) and Italy (25 affiliations) leading by a substantial margin. These two countries alone account for more than half of the total author affiliations, indicating their strong institutional commitment and research capacity in climate-related macroeconomic studies.

Other countries with substantial representation include Portugal (20), Iran (10), India (9), Pakistan (7), the UK (6), Qatar (5), Afghanistan (5), and Greece (4). While some of these are major economies, others, such as Afghanistan, Pakistan, and Qatar, highlight emerging or regionally focused academic interest in environmental macroeconomics, possibly driven by direct exposure to climate-related disruptions or international research collaborations.

Countries like Romania (3), Germany (2), Vietnam (2), Hungary (2), and Canada (2) reflect moderate levels of engagement, while Bangladesh, Malaysia, Poland, Turkey, Kuwait, France, Egypt, and Gambia each had one or two affiliated authors, suggesting limited but growing interest or capacity.

This distribution underscores a globalising research landscape, yet with clear dominance by a few countries, primarily China and European states. The strong showing from China particularly reflects the country's large and rapidly expanding academic infrastructure focused on environmental policy, economic modelling, and climate science. Similarly, the high Portuguese count, though disproportionate to its overall country study output, likely reflects extensive participation in multi-authored international collaborations.

Despite the diversity, there remains a notable underrepresentation of authors from low-income, high-risk regions, particularly in Sub-Saharan Africa, Southeast Asia (excluding Vietnam and Malaysia), and Latin America. This poses risks to the comprehensiveness and contextual sensitivity of the global evidence base.

Future efforts should encourage more inclusive collaboration models, funding mechanisms, and open-access initiatives to enable researchers from underrepresented regions to contribute more meaningfully to the discourse on climate-related macroeconomic stability.

## 4.4 Research Study Location

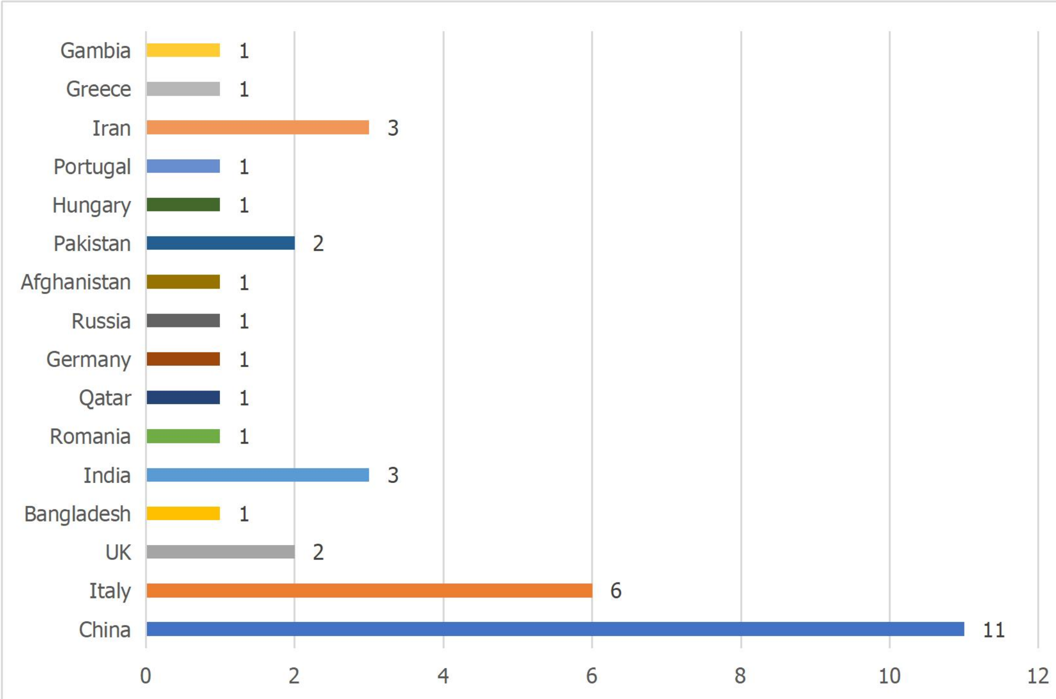


**Figure 5** Research Country Analysis

The geographical distribution of the reviewed studies reflects a diverse but uneven landscape of research on macroeconomic stability and climate change. As shown in Figure 5, China leads with a significant margin, contributing 11 studies, followed by Italy with 6 studies, and India and Iran each contributing 3. The United Kingdom and Pakistan each accounted for 2 studies, while the remaining countries, Bangladesh, Romania, Qatar, Germany, Russia, Afghanistan, Hungary, Portugal, Greece, and Gambia, were represented by a single study each.

China's leading position is not surprising given its central role in both global emissions and macroeconomic policy debates. Its large, data-rich economy, combined with substantial government and academic investment in environmental and economic research, likely contributes to the high output. Italy's significant contribution may reflect strong EU research funding for climate-related economics and the country's ongoing exposure to climate risks, particularly in agriculture and coastal regions.

The presence of studies from developing and climate-vulnerable countries such as Bangladesh, Gambia, and Afghanistan is encouraging, though limited in number. These cases are particularly valuable for understanding localised economic vulnerabilities and resilience strategies in the face of environmental stress. However, the overall dominance of high- and middle-income countries suggests a persistent geographical imbalance in the literature. This raises concerns about the generalisability of findings and underscores the need for greater representation of low-income and climate-fragile nations, particularly from Sub-Saharan Africa, small island states, and parts of Southeast Asia and Latin America.

Future research should prioritise cross-country comparative studies and promote capacity-building initiatives that support researchers in underrepresented regions to ensure a more inclusive and globally relevant body of evidence.

## 4.5 Research Sector Analysis

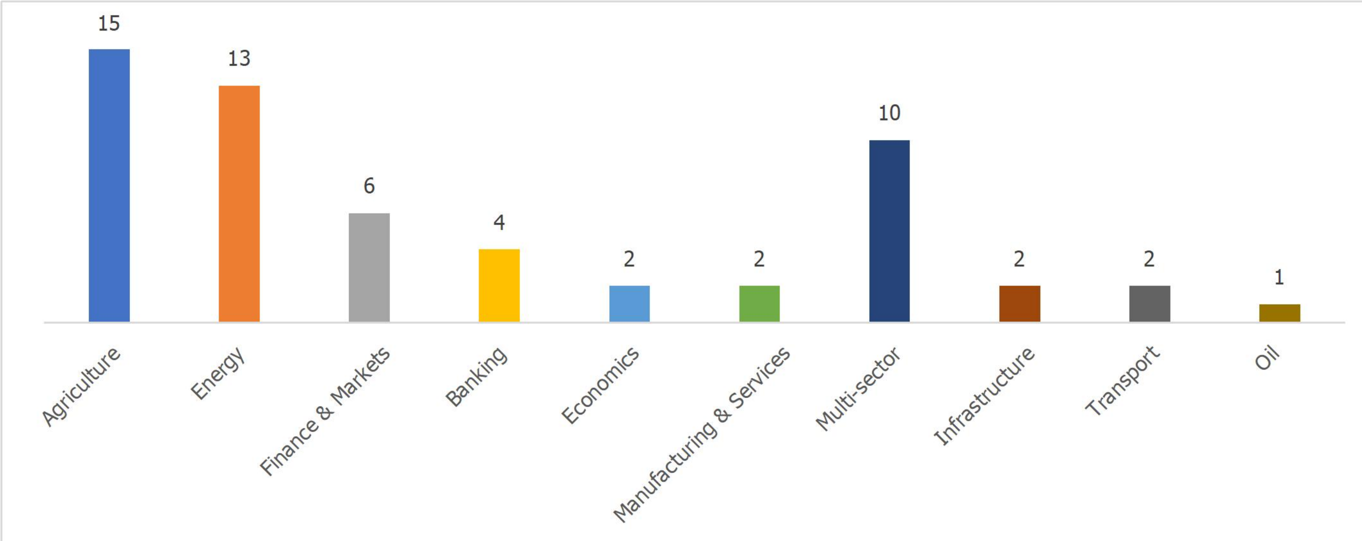


**Figure 6** Research Sector

The reviewed studies, as seen in Figure 6, span a broad and diverse range of economic sectors, illustrating the complex and interconnected ways in which climate change affects macroeconomic stability. Among these, the agriculture sector emerges as the most frequently analysed area, appearing in over ten studies. This dominant presence reflects agriculture's high sensitivity to climate variability, particularly in developing and agrarian economies, where food production, rural employment, and national income are directly linked to weather patterns and environmental sustainability. The frequent attention to agriculture highlights concerns about crop yield reductions, food insecurity, and the need for climate-resilient farming systems.

Closely following agriculture, the energy sector also receives significant scholarly attention. At least eight studies focus on energy-related themes, emphasising its dual role as a major contributor to greenhouse gas emissions and a critical target for climate mitigation policies. The research in this area often explores transitions to renewable energy, energy security, fossil fuel dependency, and the macroeconomic implications of decarbonisation. The prominence of the energy sector in the literature reflects its foundational importance to both economic performance and environmental sustainability.

The financial and banking sectors constitute another major area of interest, although they receive comparatively less attention. Studies in this domain focus on how climate risks manifest in credit markets, financial stability, and investment flows. Topics such as green finance, banking sector vulnerability, financial market reactions to climate events, and systemic risk assessments illustrate a growing awareness of the financial sector's exposure to environmental shocks. While these studies are fewer, they represent a critical and emerging strand of research that bridges environmental and monetary concerns.

Several studies also adopt a multi-sectoral approach, integrating insights across various domains such as health, energy, transportation, agriculture, and cultural heritage. These cross-sectoral studies are valuable in capturing the systemic nature of climate impacts and are well-suited to informing integrated economic modelling and policy responses. Other areas covered include manufacturing and services, the stock market, construction, shipping, urban infrastructure, waste management, and tourism—sectors that are essential to national economies but less frequently studied in the climate context.

Overall, the analysis reveals a clear emphasis on sectors with direct exposure to physical climate risks, especially agriculture and energy, while also acknowledging a growing interest in financial system resilience and multi-sectoral vulnerabilities. However, certain critical areas such as urban systems, public health, and cultural heritage remain underexplored. Future research should aim to deepen sector-specific analysis while also broadening the scope to include less-studied yet economically and socially vital domains. An interdisciplinary, systems-based approach will be key to capturing the full complexity of climate-induced macroeconomic disruptions.

## 4.6 Keywords Co-Occurrence Analysis

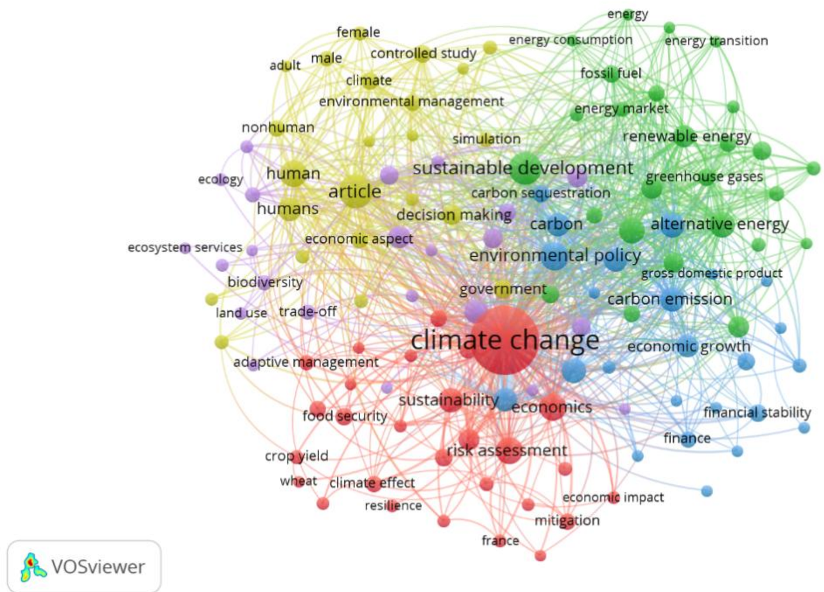


**Figure 7** Keywords Co-Occurrence Analysis

To uncover prevailing themes and conceptual interlinkages in the literature on macroeconomic stability and climate change, a keyword co-occurrence analysis was conducted using VOSviewer. The resulting network visualisation (Figure 7) captures the intellectual structure of the field by mapping keyword density, thematic clusters, and the strength of co-occurrence between concepts. This analysis offers insight into dominant discourses and emerging research directions, aligning with PRISMA-guided evidence synthesis.

Four major thematic clusters emerged from the analysis:

### 1. Red Cluster – Core Nexus of Climate Change, Risk, and Macroeconomics

Central to this cluster is the keyword "climate change," which emerges as the most frequent and densely connected term. It is surrounded by strongly co-occurring terms such as "economics," "risk assessment," "sustainability," "resilience," and "food security." This cluster represents the core intersection between environmental shocks and economic vulnerability, focusing on how climate risks—especially those affecting agriculture and resource management—impact economic resilience, mitigation strategies, and long-term sustainability. The inclusion of terms like "adaptive management" and "crop yield" highlights the strong emphasis on agricultural productivity and food systems within macroeconomic discourse.

### 2. Green Cluster – Energy Transition and Emissions Governance

The green cluster is structured around the transition to a low-carbon economy, featuring key terms such as "renewable energy," "greenhouse gases," "fossil fuel," "energy transition," "carbon sequestration," and "alternative energy." These co-occurrences reflect the increasing scholarly focus on how energy policy and emissions control mechanisms (e.g., carbon pricing, clean energy investments) influence economic stability. Interconnected terms like "energy market" and "energy consumption" suggest an integrated view of supply-demand dynamics, infrastructure adaptation, and decarbonisation strategies.

### 3. Blue Cluster – Fiscal Stability and Economic Policy under Climate Stress

The blue cluster emphasises macroeconomic governance and financial outcomes in the face of climate-related disruptions. It includes terms such as "financial stability," "economic impact," "carbon emission," "economic growth," "gross domestic product," and "finance." This cluster points to the direct and indirect economic consequences of climate risks, including their influence on public finance, investment flows, and regulatory systems. The frequent appearance of terms like "environmental policy" and "economic growth" underscores the central tension between development goals and ecological constraints.

### 4. Yellow and Purple Clusters – Human Dimensions and Ecological Trade-Offs

Emerging keywords in the yellow and purple clusters emphasise human and ecological systems, with terms such as "human," "biodiversity," "land use," "ecosystem services," "economic aspect," and "trade-off." These clusters reflect an expanding interest in the social, ethical, and ecological underpinnings of climate-economy interactions, including the need to balance economic development with ecosystem integrity. The appearance of demographic terms like "female" and "adult" suggests increasing attention to distributional effects, while "decision making" and "controlled study" point toward experimental and behavioural dimensions in environmental economics research.

This keyword network reveals a diverse and evolving research landscape at the intersection of climate change and macroeconomic stability. While central themes such as emissions, risk, and sustainability remain dominant, the clustering also shows growing academic engagement with energy transitions, fiscal resilience, and ecological trade-offs. The integration of human and governance dimensions suggests a shift toward interdisciplinary frameworks that accommodate complexity, uncertainty, and social impact. Future research should deepen exploration into regional disparities, climate-finance linkages, and the validation of economic forecasting models, particularly in the Global South and among vulnerable sectors. These clusters collectively offer a roadmap for expanding empirical, theoretical, and policy-oriented work in climate-informed macroeconomics.

## 5 Discussion of Results

### 5.1 Key environmental risks associated with climate change that impact macroeconomic stability (RQ1)

This review synthesises findings from 30 peer-reviewed studies that examined the link between climate-induced environmental risks and macroeconomic stability. Evidence spans diverse sectors such as agriculture, energy, finance, and infrastructure, and encompasses multiple geographic contexts. The analysis identifies seven dominant themes through which environmental risks driven by climate change exert destabilising effects on macroeconomic systems.

#### $CO_2$ Emissions and the Economic Growth–Environment Trade-Off

A recurring theme in the reviewed literature is the tension between economic expansion and environmental sustainability. Studies such as Liza et al. (2024), Khurshid et al. (2024), and Di Febo et al. (2023) emphasise that rising $CO_2$ emissions, often a by-product of industrial growth, contribute directly to environmental degradation and climate instability. These emissions exacerbate ecosystem stress and infrastructure vulnerability, ultimately undermining long-term macroeconomic resilience. The evidence suggests that without structural decoupling of economic growth from carbon intensity, macroeconomic stability remains at risk.

#### Physical Climate Risks

Droughts, Flooding, and Temperature Extremes: Several studies underscore the macroeconomic threats posed by climate-induced physical risks, such as droughts, floods, heatwaves, and sea level rise (e.g., Hamza et al., 2024; Safi et al., 2024; Praveen & Kunnampalli, 2024; Di Noia et al., 2025). These events disrupt agricultural productivity, damage critical infrastructure, and strain public services, particularly in low-income or agriculture-dependent regions. The cumulative impact of these physical shocks manifests in higher adaptation costs, reduced output, and displacement, all of which compromise economic stability.

Climate-Induced Financial System Vulnerabilities: Climate-related environmental risks also destabilise financial systems. Studies by Fan et al. (2024), Naseer et al. (2024), He et al. (2024), and Lu et al. (2024) demonstrate that rising temperatures and regulatory transitions contribute to increased loan defaults, equity risk, and financial market volatility. These dynamics are especially pronounced in economies where financial institutions maintain strong linkages with carbon-intensive sectors. The evidence highlights the financial sector's systematic susceptibility to climate risks, both physical and transitional.

**Sector-Specific Exposure: Agriculture as a High-Risk Sector**

The agricultural sector emerges as particularly susceptible to climate change impacts. For instance, Negri et al. (2024) illustrate that crops with high water demands, such as maize, are increasingly vulnerable to drought conditions. In contrast, crops such as millet and sorghum offer climate-resilient alternatives due to greater water efficiency. Similarly, Hassna et al. (2024) underscore how climate change disrupts global food supply chains, leading to increased costs and reduced food security. These sectoral vulnerabilities underscore agriculture's centrality in the climate–macroeconomy nexus.

**Inequality and Resource Distribution as Amplifiers of Risk**

Environmental and income inequality also amplify macroeconomic vulnerability. Sahu and Mahalik (2024) reveal that carbon inequality is defined by unequal emissions distribution, which contributes to economic volatility, particularly when coupled with income disparity. Liza et al. (2024) further argue that geopolitical competition for resources and energy security weakens multilateral cooperation on climate mitigation, compounding instability.

**Intersectoral and Geopolitical Spillovers**

The spillover effects of climate risks, particularly those emanating from the brown sector, emerge as a salient threat to macroeconomic stability. He et al. (2024) and Lu et al. (2024) highlight that climate policy measures targeting high-emission sectors often transmit risk to other interconnected sectors, such as finance and insurance. Additionally, Liza et al. (2024) note that geopolitical tensions over environmental priorities can further distort economic signals and policy coherence.

**Mixed Effectiveness of Climate Mitigation Instruments**

While green finance and renewable energy investments are recognised as mitigation tools (Liza et al., 2024), their stabilising influence appears insufficient relative to the scale of climate risk. Additionally, environmentally friendly policy tools like cap-and-trade systems and carbon tariffs can lead to financial instability for manufacturers and insurers (Lu et al., 2024), demonstrating the intricacy of aligning environmental objectives with economic stability.

### 5.2 How does climate change affect the economic costs and fiscal stability of different sectors and regions (RQ2)

The findings indicate that climate change exerts diverse economic and fiscal pressures across sectors and regions, with the severity and nature of impacts shaped by factors such as policy environments, economic development levels, and sectoral exposure.

**Sectoral Cost Burdens and Financial Spillovers**

Climate policy instruments like cap-and-trade regulations and carbon tariffs increase operational and equity risks, particularly for carbon-intensive industries (Lu et al., 2024). These risks cascade into the financial sector, affecting insurer stability and increasing compliance costs. He et al. (2024) further emphasise that financial markets, closely tied to brown sectors, become increasingly vulnerable to regulatory and market shifts triggered by climate adaptation policies.

### Regional Fiscal Vulnerability and Inequality

Regions with lower per capita income and weak environmental infrastructure—such as certain provinces in China (Fan et al., 2024) or agricultural regions like Kerala, India (Praveen & Kunnampalli, 2024)—face amplified fiscal instability. This is as a result of higher frequency of climate shocks, reduced tax revenue from struggling sectors, and growing public spending on disaster response and social safety nets.

### Agriculture and Food Systems

Agriculture-dependent regions are disproportionately affected. Negri et al. (2024) show that climate-driven water scarcity raises crop production costs and fiscal risks, especially for maize growers. Similarly, Safi et al. (2024) and Hassna et al. (2024) document crop failures, food insecurity, and disruption of food supply chains, all of which strain public resources and increase economic losses, particularly in fragile economies like Afghanistan and Qatar.

### Energy and Infrastructure

The energy sector is also exposed to both transition and physical risks. Khurshid et al. (2024) link $CO_2$ emissions and oil price volatility to reduced GDP and sectoral instability. Infrastructure-heavy sectors in fossil-fuel-reliant economies face increased capital costs as they adapt to rising temperatures and regulatory shifts (Liza et al., 2024; Di Febo et al., 2023).

### Macroeconomic and Credit Market Impacts

Climate-related risks influence credit availability and mortgage markets. Baranyai and Banai (2022) observe that areas facing extreme heat see higher interest rates and reduced loan terms due to increased credit risk. Financial institutions, especially non-bank lenders, are more responsive to these localised risks.

### Adaptation Costs and Policy Gaps

High adaptation costs, especially in developing economies, challenge fiscal sustainability. For instance, Safi et al. (2024) and Naseer et al. (2024) highlight how public finance is strained by disaster relief, displacement, and food insecurity. Wu and Lin (2024) show that once climate-induced damage surpasses a threshold, its financial consequences overwhelm regional stabilisation efforts.

## 5.3 What forecasting models are used to predict the economic impact of climate change, and how accurate are these models in real-world applications? (RQ3)

The reviewed literature reveals diverse forecasting approaches for modelling climate change's economic impacts, though few directly compare model accuracy in real-world applications.

### Integrated Climate–Energy–Economic Models

Hatamkhani et al. (2025) utilise an integrated climate–energy–economic modelling framework to estimate streamflow reduction effects on hydropower generation, linking environmental changes to macroeconomic outcomes. These models are essential for long-term energy planning, although their precision is challenged by unpredictable climate variables.

### Scenario-Based and Optimisation Models

Hassna et al. (2024) use multi-objective optimisation to assess climate impacts on global food supply chains. Similarly, Shoaei et al. (2025) apply Monte Carlo simulations to explore various long-term scenarios, incorporating ethical considerations. These methods are suitable for uncertainty-rich contexts but often lack precise validation against historical climate-economic data.

### Macroeconomic Simulation and Policy Evaluation Tools

He et al. (2025) applies macro-level simulation to evaluate how pollution taxes and environmental investment interact with socio-economic growth. These models capture complex feedback loops but depend heavily on assumptions about technology uptake and policy stringency.

### Market-Based Models and ESG-Adjusted Forecasting

Naseer et al. (2024) and Lu et al. (2024) consider financial market models sensitive to environmental, social, and governance (ESG) factors. These models help forecast asset-level risks and stock volatility, but their accuracy is contingent on reliable climate risk disclosures and governance data.

### Limitations and Gaps

While models vary in complexity and focus (from regional to sectoral to macroeconomic), few studies offer formal accuracy assessments. Real-world applicability is hindered by data limitations, geopolitical uncertainty, and unpredictable policy shifts. Thus, forecasting models provide directional insight rather than exact predictions.

## 5.4 How does uncertainty about climate projections impact policy decisions related to macroeconomic stability? (RQ4)

Climate projection uncertainty significantly influences the design, credibility, and implementation of policies aimed at maintaining macroeconomic stability.

### Policy Hesitancy and Regulatory Delay

Lu et al. (2024) and Yang et al. (2024) find that uncertainty about the impact of climate policies such as carbon tariffs or environmental taxes creates hesitation among investors and regulators. This hesitation undermines confidence in long-term green investments, delaying the transition and destabilising expectations in financial and energy markets.

### Sectoral Investment Instability

Liu et al. (2024) highlight that climate policy uncertainty in the oil sector leads to fluctuations in fossil fuel demand, affecting prices and investment decisions. In the short term, it discourages green transition; in the long term, it can paradoxically stabilise fossil fuel use due to underinvestment in alternatives.

### Agricultural and Coastal Adaptation Complexity

Praveen and Kunnampalli (2024) and Negri et al. (2024) show that climate uncertainty complicates regional planning, especially in agriculture—making it difficult to commit to resilient crop strategies or infrastructure development. This raises the risk of maladaptation and economic misallocation.

### Macroeconomic Policy Framework Gaps

Hungerland and Altmeppen (2024) argue that tools like the EU's Macroeconomic Imbalance Procedure (MIP) fail to incorporate climate risks, creating blind spots in economic governance. Similarly, Jackson and Bailey (2024) show how central banks struggle to integrate climate risk without compromising their financial stability mandates.

### Modelling and Governance Limitations

Lamperti and Roventini (2022) critique cost–benefit models for inadequately capturing climate uncertainty and urge for innovation-led policies. Shoaei et al. (2025) and Fasolino et al. (2025) advocate for complexity-aware planning systems that better incorporate feedback loops and uncertainties.

## 6 Discussion of Results

This systematic review demonstrates that climate change presents a profound and multifaceted threat to macroeconomic stability, impacting nations through both direct physical risks and complex transition dynamics. Physical climate events such as extreme weather, rising sea levels, droughts, and floods disrupt key sectors including agriculture, infrastructure, and public services, particularly in low-income and climate-vulnerable regions. Simultaneously, transition risks stemming from regulatory changes, carbon pricing, and climate policy uncertainty pressure carbon-intensive industries and the financial systems connected to them. The interconnected nature of these risks results in financial market volatility, fiscal strain, and reduced economic predictability. While various forecasting models are used to anticipate the economic effects of climate change, their real-world applicability remains limited due to challenges in validation and underlying data uncertainties. Furthermore, uncertainty about future climate scenarios impedes timely and confident policy responses, weakening institutional capacity to manage long-term economic risk. Taken together, the findings highlight the urgent need for integrated climate and macroeconomic planning, with stronger commitments to resilience-building, sustainable investment, and the refinement of economic forecasting tools. Ensuring macroeconomic stability in the era of climate change will require not only better data and governance but also a proactive, adaptive approach to fiscal and financial policymaking.

### 6.1 Research Gap Identified

Despite the growing body of evidence linking climate-induced environmental risks to macroeconomic instability, several research gaps remain evident. First, empirical investigations remain unevenly distributed across sectors and regions. While the agriculture, finance, and energy sectors have received substantial attention, the intersectoral transmission of climate shocks on how, specifically how disruptions in one sector propagate to others, remains insufficiently examined. Moreover, much of the available data originates from high-income economies, creating a significant gap in understanding the macroeconomic implications of climate change in low- and middle-income regions, particularly in Africa, South Asia, and small island states. These regions often experience the most severe physical and fiscal consequences of climate change but remain underrepresented in the empirical literature.

A second critical gap lies in the theoretical and modelling frameworks used to capture the climate–macroeconomy nexus. Many forecasting models treat climate change as an exogenous shock rather than as an endogenous factor embedded within macroeconomic systems. This oversimplification limits the ability of models to capture feedback loops, nonlinear dynamics, and tipping points that characterise real-world climate–economic interactions. Traditional cost–benefit and equilibrium-based models, while useful for policy analysis, often fail to capture the uncertainties and complex behavioural adaptations that influence long-term macroeconomic outcomes. Additionally, the accuracy and robustness of existing forecasting models are rarely validated against historical or real-world data, reducing their predictive reliability and policy relevance.

Policy integration and governance represent another significant area of weakness. Despite growing awareness of the economic risks posed by climate change, macroeconomic governance frameworks such as fiscal policy rules, debt sustainability analyses, and monetary stability mechanisms largely omit climate considerations. Institutions such as central banks and finance ministries have yet to fully integrate climate variables into their risk assessment and decision-making frameworks. This omission contributes to fragmented policy implementation and limits governments' ability to anticipate or mitigate macroeconomic volatility caused by environmental shocks. Furthermore, adaptation and fiscal planning remain inadequately localised, as vulnerable regions often lack the institutional capacity and financial resources to design and implement climate-resilient strategies.

The financial dimension of climate risk also remains insufficiently understood. Although the literature acknowledges that climate shocks can destabilise financial systems, empirical evidence on the pathways through which such risks transmit across financial networks is still sparse. Similarly, while green finance initiatives, transition funds, and ESG-based investment instruments have emerged as mitigation tools, their macroeconomic stabilising effects remain poorly quantified. The inconsistency and unreliability of ESG data further undermine the ability of financial institutions to assess exposure accurately, leading to information asymmetry and market inefficiency.

Finally, institutional and human capacity constraints persist, especially in developing economies. Policymakers and planners in these contexts often lack the technical expertise and analytical infrastructure necessary to interpret and apply climate-economic models for evidence-based decision-making. Cross-sectoral coordination is equally weak, resulting in fragmented responses to what is inherently a systemic challenge. Compounding this problem is the uncertainty surrounding climate projections, which breeds policy hesitancy and delays in investment, particularly in carbon-intensive and transition-sensitive sectors. Most existing studies have yet to examine how uncertainty itself influences investment behaviour, risk perception, and macroeconomic outcomes. Addressing these gaps will require integrated, empirically grounded, and regionally inclusive approaches that combine economic modelling with institutional strengthening to enhance climate resilience and fiscal stability in the global economy.

**Policy Implications**

Climate risks must be systematically integrated into macroeconomic frameworks. Institutions such as central banks, finance ministries, and regulatory bodies should incorporate these risks into their economic surveillance tools, including stress testing, public debt modelling, and investment policy assessments. Doing so will enhance preparedness for climate-induced shocks and bolster economic resilience. Moreover, governments need to expand transition finance mechanisms. This includes strengthening green finance initiatives and employing strategies such as blended financing and carbon revenue recycling to lessen the fiscal burden of climate adaptation. These financial innovations can help fund low-carbon infrastructure and climate-resilient development. In addition, targeted adaptation planning should be prioritised at the regional level. Vulnerable regions must receive dedicated fiscal support to develop infrastructure that can withstand climate impacts and to promote sustainable agricultural practices that ensure food and livelihood security.

**Practical Implications**

Practically, capacity building remains a pressing need, especially in low-income and climate-vulnerable economies. Economic planners and policymakers in these contexts often lack the technical training and tools required to interpret and apply climate-economic forecasts effectively. Strengthening institutional capabilities through training programs and decision-support systems can improve the quality of climate-informed economic planning. Furthermore, effective climate risk management requires robust cross-sectoral coordination. Sectors such as agriculture, finance, trade, and infrastructure are deeply interconnected, and climate strategies must be harmonised across these domains. Establishing integrated institutional frameworks can help ensure coherent and comprehensive responses to the multifaceted nature of climate risk.

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**Data Availability Statement**

The data used in this study are publicly accessible through online repositories such as Google Scholar and Scopus.

**Conflict of Interest**

The authors declare no conflicts of interest.

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