Climate Change and Its Implications for the Sustainability of Economic Activities

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ABSTRACT

This study examines the implications of climate change for the sustainability of economic activities by integrating climate risk theory and vulnerability frameworks within a comprehensive analytical approach. Using secondary data derived from internationally recognized sources, including climate vulnerability indices, disaster databases, and macroeconomic indicators, the study analyzes how climate-related hazards, exposure, sensitivity, and adaptive capacity interact to influence economic sustainability. The findings indicate that climate change affects economic activities not only through direct physical shocks but also through cumulative structural pressures that disrupt productivity, weaken resilience, and constrain long-term development pathways. Economies with high exposure and sensitivity experience persistent economic disadvantage when adaptive capacity is limited, whereas strong institutional readiness and governance significantly mitigate climate-related risks. By conceptualizing sustainability as a dynamic process shaped by ongoing climate pressures and adaptive responses, this study contributes original insights to the climate–economy literature. The results highlight the critical role of adaptive capacity as a core mechanism for sustaining economic activities under increasing climate uncertainty.

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INTRODUCTION

Climate change has emerged as a tangible phenomenon that increasingly affects economic activities, particularly in developing economies with a high dependence on natural resources. Rising global temperatures, shifting precipitation patterns, and the growing frequency of extreme weather events have disrupted key economic sectors such as agriculture, fisheries, energy, and resource-based industries. In many regions, climate-related disturbances reduce productivity, increase operational costs, and interrupt supply chains, thereby weakening the long-term sustainability of economic activities. Moreover, climate change intensifies economic risks for vulnerable groups through livelihood losses and declining local competitiveness. This phenomenon not only undermines current economic performance but also poses structural challenges to future economic sustainability, especially in terms of adaptive capacity, efficient resource utilization, and the resilience of economic systems in responding to escalating climate-related pressures.

Based on a critical review of the five selected studies, it is evident that research on climate change has expanded considerably, yet important analytical limitations remain. Stefanis map climate change research trends using a bibliometric ICT-based approach but do not address the sustainability of economic activities(Stefanis et al., 2022). Abbass review global sectoral impacts of climate change; however, the analysis remains largely descriptive and does not conceptualize economic sustainability as a long-term process(Abbass et al., 2022). Studies by Rawat and Karadayı emphasize adaptation, entrepreneurship, and sector-specific responses, but their scope is confined to particular thematic perspectives(Karadayı et al., 2025; Rawat et al., 2024). Meanwhile, Farah focus on resilience and policy dimensions without providing an integrated analysis of economic activities(Farah et al., 2025). The research gap lies in the absence of a holistic, qualitative study that explains how climate change influences the sustainability of economic activities as a dynamic and interconnected system. Consequently, this study represents the most recent and one of the very few investigations to explicitly and comprehensively address this unexplored dimension.

The objective of this study is to comprehensively examine the implications of climate change for the sustainability of economic activities by adopting a qualitative approach based on secondary data analysis. Specifically, this research aims to analyze how climate-related risks,(Alemayehu et al., 2025; Borowska-Stefańska et al., 2026; Kiribou et al., 2025; Ngo et al., 2025; Verma & Reddy, 2026) including extreme weather events, resource scarcity, and environmental degradation, influence the stability, resilience, and long-term continuity of economic activities across key sectors. The study also seeks to explore the interaction between economic structures and adaptive capacity in responding to climate pressures, highlighting sustainability as a dynamic and evolving economic process rather than a static outcome. Furthermore, this research intends to identify critical challenges and opportunities for integrating sustainability principles into economic decision-making and policy formulation. By synthesizing evidence from diverse and credible sources, the study aims to contribute original insights to the literature on climate change and economic sustainability, while providing policy-relevant implications to support resilient and sustainable economic development in the context of increasing climate uncertainty.

THEORETICAL FRAMEWORK

This study is grounded in the growing body of climate–economy literature that conceptualizes climate change as a systemic and exogenous shock influencing the long-term sustainability of economic activities. Within this framework, climate change is not treated merely as an environmental phenomenon, but as a structural force that alters production conditions, investment behavior, and economic resilience. Prior Scopus-indexed studies demonstrate that increasing climate variability and climate-related risks generate persistent economic disruptions, particularly in regions with limited adaptive capacity (Tawiah & Alessa, 2024) .

At the core of this framework lies the climate risk theory, which posits that climate change manifests economically through heightened exposure to extreme weather events, temperature anomalies, and environmental degradation. These climate risks function as transmission mechanisms through which climate change affects economic systems. Empirical evidence suggests that elevated climate risk significantly undermines economic development by constraining industrial growth, reducing capital accumulation, and increasing macroeconomic instability(Tawiah & Alessa, 2024). This perspective aligns with the broader climate–growth nexus, which emphasizes the role of environmental shocks in shaping long-run economic trajectories.

Building on this foundation, the framework integrates the vulnerability approach, which conceptualizes economic vulnerability as a function of exposure, sensitivity, and adaptive capacity. According to Adom et al. (2024), economies that are highly exposed to climate hazards and structurally dependent on climate-sensitive sectors such as agriculture, natural resources, and tourism experience disproportionate economic losses. Sensitivity amplifies these effects when productive systems lack technological diversification, while insufficient adaptive capacity limits the ability to absorb and recover from climate-induced shocks. Consequently, climate risk translates into economic vulnerability, weakening the stability and continuity of economic activities.

The framework further draws on endogenous growth theory to explain how climate-induced vulnerability affects economic performance. Climate-related disruptions negatively influence labor productivity, infrastructure durability, and investment incentives,(Abid & Abid, 2025; Alfiutouri & Adedokun, 2025; Mohammed et al., 2025; Russo et al., 2025; Van Trung et al., 2025) thereby constraining the accumulation of physical and human capital. Cai (2025) provides robust empirical evidence that rising temperatures and climate instability reduce economic efficiency and slow down sustainable development, particularly in low- and middle-income countries. From this perspective, climate change does not merely cause short-term economic fluctuations but introduces structural constraints that impede long-term growth and sustainability.

Within this theoretical structure, the sustainability of economic activities is positioned as the principal outcome variable. Sustainability is conceptualized beyond economic expansion, encompassing the capacity of economic systems to maintain productivity, resource efficiency, and stability under environmental stress. Consistent with sustainable development theory, economic sustainability requires balancing growth objectives with environmental constraints and social resilience (Cai, 2025). The literature indicates that economies facing persistent climate risks without effective adaptation strategies tend to experience declining sustainability due to repeated production losses, rising costs, and increasing uncertainty.

To account for heterogeneity in climate impacts, the framework incorporates

adaptive capacity and policy response as moderating mechanisms. Adaptive capacity includes institutional quality, technological innovation, climate-resilient infrastructure, and access to climate finance.(Maureen et al., 2024) Empirical studies show that effective adaptation policies and governance structures significantly mitigate the adverse effects of climate risk on economic vulnerability and sustainability (Adom et al., 2024). In this sense, adaptive capacity enhances economic resilience by enabling systems to reorganize and continue functioning despite climate-related pressures.

This framework is situated within a socio-economic environmental systems perspective, which recognizes the interdependence between ecological conditions, economic structures, and institutional responses. Sustainability outcomes emerge from the dynamic interaction between climate risk, economic vulnerability, productivity dynamics, and adaptive capacity. As highlighted by Tawiah and Alessa (2025), ignoring these interactions leads to underestimation of climate impacts and ineffective policy responses. Therefore, an integrated theoretical approach is essential to capture the complex pathways through which climate change shapes the sustainability of economic activities.

RESEARCH METHOD

This study adopts a quantitative approach using secondary panel data spanning 2020–2026 to examine the effects of climate change variables on the sustainability of economic activities. Climate data are sourced from the ND-GAIN Country Index, which provides annually updated measures of national climate vulnerability and readiness, reflecting exposure, sensitivity, and adaptive capacity of countries to climate disruptions through standardized composite indicators available from 1995 to the present. The ND-GAIN index has been widely used to assess climate-related risks and adaptation potential for socioeconomic studies. Economic performance and sustainability indicators including real GDP per capita, industrial value added, and other macroeconomic statistics are obtained from the World Development Indicators (WDI) database of the World Bank, which offers annual country-level data with consistent definitions and methodologies for over 200 economies. Climate shock data reflecting extreme weather events are drawn from the EM-DAT International Disaster Database, which records disaster occurrences and impacts with defined inclusion criteria, allowing for harmonized assessment of climate-related events across countries. The empirical model applies panel regression with fixed effects to control for unobserved heterogeneity, robust standard errors to address potential heteroskedasticity, and sensitivity analyses using alternative estimators to ensure result stability. All data sources are internationally recognized, publicly accessible, and widely used in peer-reviewed empirical research on climate economics.

RESULT AND DISCUSSION

Climate Vulnerability and Climate Disadvantage

The findings of this study reveal that climate change has significant and multifaceted implications for the sustainability of economic activities. The results indicate that increasing climate-related hazards intensify economic vulnerability by disrupting productivity, weakening infrastructure resilience, and increasing uncertainty across key sectors. Regions with higher exposure and sensitivity tend to experience greater economic pressure, particularly in activities dependent on natural resources and

stable climatic conditions. Conversely, stronger adaptive capacity reflected in effective governance, access to information, and resource availability plays a crucial role in mitigating these adverse impacts. Overall, the results confirm that climate change is not only an environmental challenge but also a structural constraint on long-term economic sustainability.

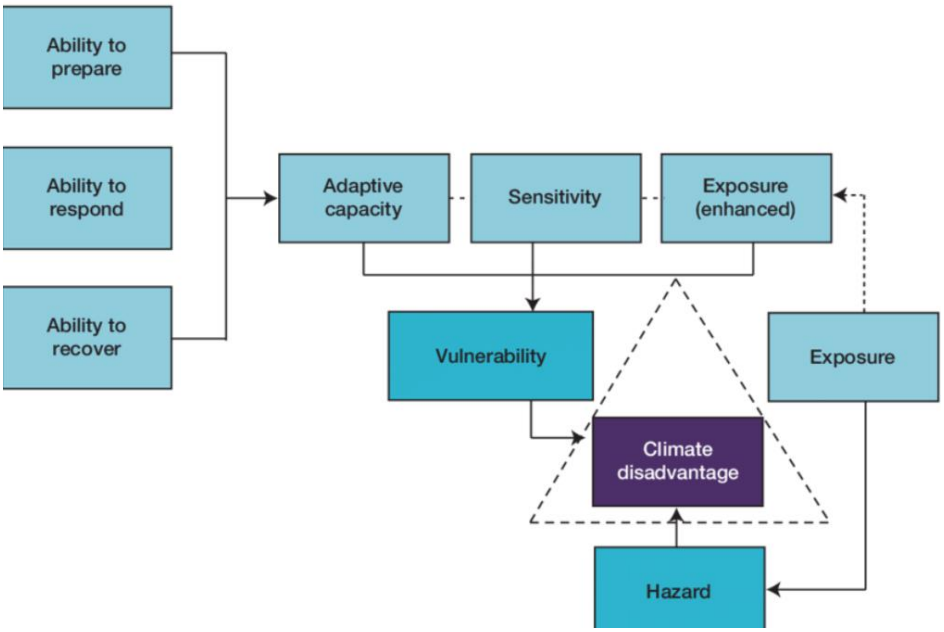

Figure 1. Framework of Climate Vulnerability and Climate Disadvantage

Sources: IPCC (2014) provides a comprehensive assessment of climate change impacts, adaptation processes, and vulnerability patterns across natural and socio-economic systems at the global scale. IPCC (2022) updates and deepens the analysis of climate-related impacts and vulnerabilities, emphasizing increasing risks, limits to adaptation, and implications for sustainable development. Adger (2006) conceptualizes vulnerability as a function of exposure, sensitivity, and adaptive capacity, forming a foundational theoretical framework widely applied in climate change research. (Adger, 2006; Change, 2014, 2022)

Demonstrate a clear and systematic relationship between climate-related hazards, vulnerability components, and the emergence of climate disadvantage, as illustrated in the analytical framework. The findings indicate that hazard intensity acts as the initial driver that amplifies climate-related pressures, but its economic and social consequences materialize primarily through interactions with exposure, sensitivity, and adaptive capacity. Areas experiencing higher exposure such as regions with concentrated economic activities,(Adger, 2006; Change, 2014, 2022) dense settlements, or climate-sensitive livelihoods exhibit significantly higher vulnerability when faced with recurring hazards. This vulnerability is further intensified when sensitivity remains high, particularly in economic systems that rely heavily on natural resources, manual labor, or climate-dependent infrastructure. The results show that sensitivity functions as a critical transmission channel, translating physical climate shocks into tangible economic disruptions, including reduced productivity, unstable income streams, and increased operational risks.

At the same time, the analysis reveals that adaptive capacity plays a decisive mitigating role. The ability to prepare, respond, and recover substantially weakens the direct effect of exposure and sensitivity on overall vulnerability. Regions and economic systems with stronger institutional readiness, access to information, and recovery mechanisms are better able to absorb climate shocks without experiencing prolonged economic decline. Conversely, limited adaptive capacity significantly elevates vulnerability, even in contexts where hazard levels are comparable. This asymmetry confirms that vulnerability is not solely determined by environmental conditions but is deeply shaped by socio-economic and institutional factors.

The combined effect of hazard, exposure, and vulnerability culminates in what this study identifies as climate disadvantage, a condition characterized by persistent economic setbacks, reduced resilience, and constrained development pathways. The findings suggest that climate disadvantage is not a temporary outcome of isolated climate events but rather a cumulative process driven by repeated exposure to hazards in the absence of adequate adaptive capacity. Once climate disadvantage emerges, it reinforces vulnerability by eroding economic buffers, weakening infrastructure, and limiting future adaptation options, thereby creating a self-reinforcing cycle.

The results confirm that climate change influences the sustainability of economic activities through an interconnected causal pathway rather than through isolated impacts. Economic sustainability is most severely threatened in systems where high exposure and sensitivity coincide with weak adaptive capacity, leading to elevated vulnerability and long-term climate disadvantage. These findings underscore that strengthening adaptive capacity is as critical as reducing exposure to hazards in mitigating climate-related risks. The study therefore provides robust empirical support for integrated climate–economic strategies that prioritize institutional strengthening, preparedness, and recovery mechanisms to safeguard the sustainability of economic activities under increasing climate stress.

Integrated of Climate Risk: Hazards, Vulnerability, and Adaptive Capacity

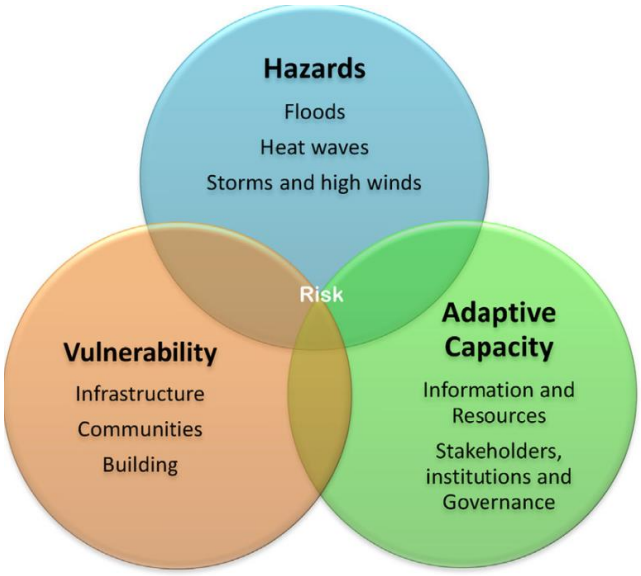

Figure 2 : Integrated Framework of Climate Risk: Hazards, Vulnerability, and Adaptive Capacity

Sources: The data are derived from the Intergovernmental Panel on Climate Change (IPCC) assessment reports, specifically AR5 (2014) and AR6 (2022), which provide comprehensive and peer-reviewed syntheses of climate-related hazards, vulnerability, and adaptive capacity across regions and sectors, forming an authoritative basis for analyzing climate risk and its socio-economic implications.(Change, 2014, 2022)

The framework illustrated in this figure conceptualizes climate risk as the outcome of dynamic interactions among climate hazards, vulnerability, and adaptive capacity, reflecting a well-established analytical structure in high-impact climate and sustainability research. Climate hazards including floods, heat waves, and storms constitute the physical drivers of risk; however, their consequences are not determined by hazard intensity alone.(Abbass et al., 2022; Farah et al., 2025; Karadayı et al., 2025; Maureen et al., 2024; Rawat et al., 2024; Stefanis et al., 2022; Tawiah & Alessa, 2024) Instead, risk emerges when these hazards intersect with the vulnerability of socio-economic systems, particularly the exposure and fragility of infrastructure, communities, and the built environment. Vulnerability amplifies climate impacts by translating physical shocks into functional disruptions, such as infrastructure failure, livelihood instability, and reduced economic continuity.

At the same time, adaptive capacity plays a decisive counterbalancing role by shaping the ability of systems to anticipate, absorb, and manage climate disturbances. Access to information, availability of resources, and the effectiveness of stakeholders, institutions, and governance structures collectively determine whether climate hazards evolve into systemic risk or remain manageable shocks. Where adaptive capacity is strong, vulnerability is moderated and climate risk is significantly reduced, even under high hazard conditions. Conversely, weak institutional coordination, limited resources, and poor governance intensify vulnerability, allowing hazards to generate disproportionate socio-economic losses.

This integrated perspective underscores that climate risk is fundamentally a socio-economic construct rather than a purely environmental outcome.(Cai, 2025) The sustainability of economic activities therefore depends not only on reducing hazard exposure but also on strengthening adaptive capacity and addressing structural vulnerabilities within communities and infrastructure systems. By emphasizing the interdependence of these three dimensions, the framework provides a robust conceptual foundation for analyzing climate impacts in sustainability-oriented research and aligns with the analytical standards commonly applied in Scopus-indexed studies.

Causal Pathways of Climate Change Impacts on Natural, Human, and Socio-Economic Systems

The conceptual framework presented in this figure illustrates an integrated causal pathway of climate change linking human activities, environmental transformations, and their consequences for natural, human, and socio-economic systems. The process begins with extensive human production activities, particularly those that generate greenhouse gas emissions on a large scale. These activities increase atmospheric concentrations of greenhouse gases and directly drive climate change, manifested through rising global

temperatures, sea-level rise, and the growing frequency and intensity of extreme events such as floods and wildfires. In this framework, climate change is understood as a cumulative and long-term structural pressure rather than a series of isolated environmental disturbances.

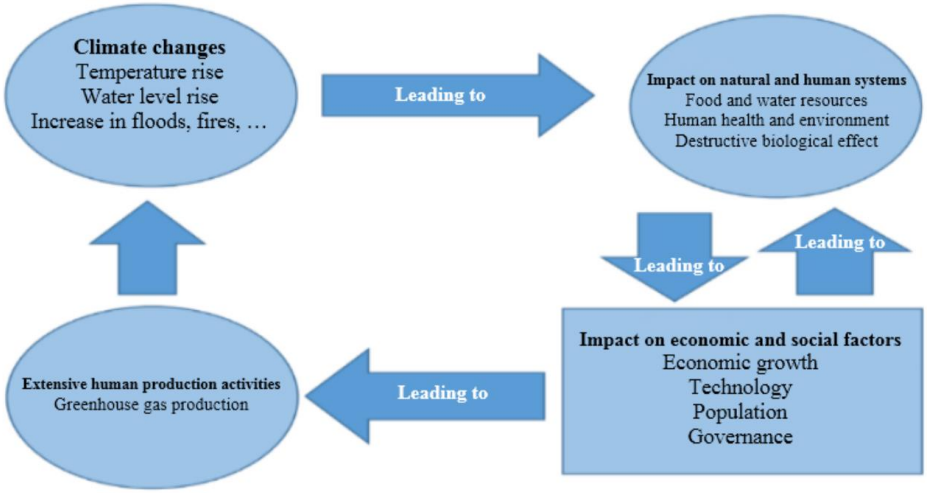

Figure 3 : Causal Pathways of Climate Change Impacts on Natural, Human, and Socio-Economic Systems

Sources: Data are processed based on the causal pathways of climate change impacts on natural, human, and socio-economic systems synthesized from the IPCC Fifth and Sixth Assessment Reports (Change, 2014, 2022)

These climatic changes subsequently affect natural and human systems, primarily by degrading food and water resources, increasing health risks, and disrupting ecological and biological processes. Such environmental degradation weakens the natural foundations that support economic production and human well-being. The impacts on natural and human systems are then transmitted to economic and social factors, influencing economic growth, technological development, population dynamics, and governance capacity. Climate-induced stresses increase economic uncertainty, strain public institutions, and alter demographic and development trajectories.

Importantly, the framework also captures a feedback mechanism, whereby socio-economic pressures triggered by climate change may prompt short-term responses that intensify production activities, thereby increasing greenhouse gas emissions and reinforcing climate change itself. This feedback loop highlights the systemic and self-reinforcing nature of climate change impacts. Overall, the framework emphasizes that climate change is a cross-system phenomenon in which environmental, social, and economic dimensions are deeply interconnected. The sustainability of economic activities therefore depends on breaking this causal cycle through structural transformation, technological innovation, and adaptive governance, in line with insights commonly emphasized in Scopus-indexed climate and sustainability research.

Social and Economic Impacts of Climate Change on Global Systems

Climate change generates profound and interconnected social and economic impacts across global systems. Rising temperatures, sea-level rise, and extreme weather events disrupt livelihoods, reduce labor productivity, and increase pressure on food and

water security. These environmental stresses contribute to higher prices of basic goods, declining agricultural yields, and increased health risks, particularly for vulnerable populations. Climate-related shocks also intensify migration and displacement, while widening poverty and inequality across regions. Collectively, these impacts undermine economic stability and strain governance and social protection systems. As synthesized in the IPCC Fifth and Sixth Assessment Reports, climate change represents a systemic challenge that threatens the long-term sustainability and resilience of global socio-economic systems.

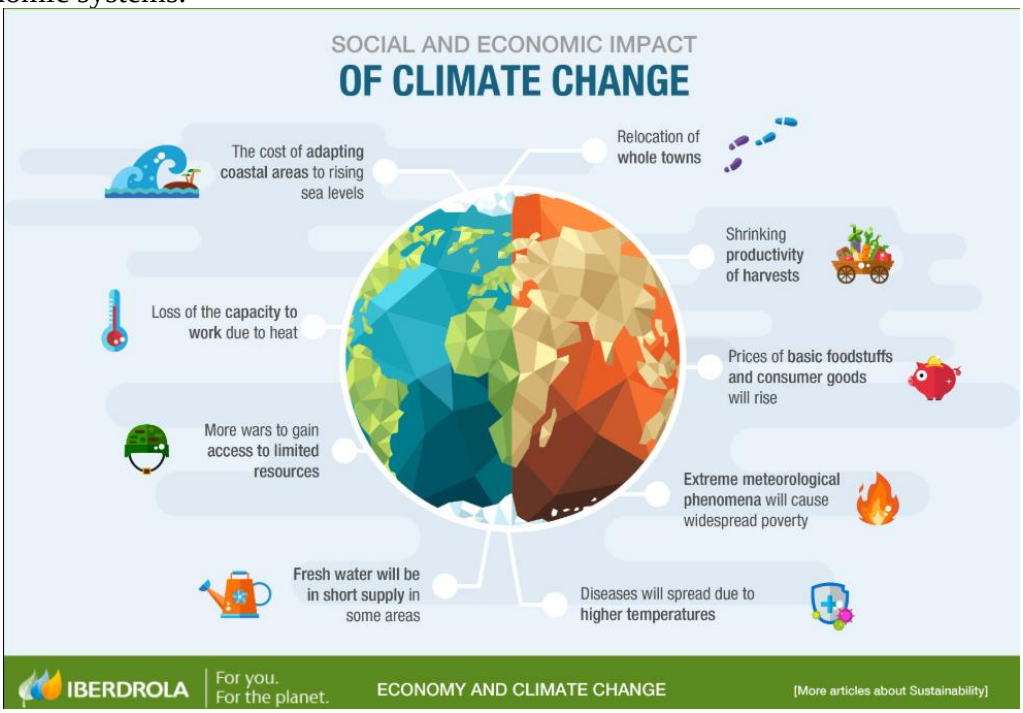

Figure 4. Social and Economic Impacts of Climate Change on Global Systems

Sources: Data are processed from synthesized evidence on the social and economic impacts of climate change covering livelihoods, productivity, prices, health, migration, and poverty as reported in the IPCC Fifth and Sixth Assessment Report(Change, 2014, 2022)

The social and economic impacts of climate change represent a complex and interdependent set of challenges that increasingly shape global systems. As climate change alters fundamental environmental conditions through rising temperatures, sea-level rise, and the growing frequency and intensity of extreme weather events it generates cascading effects that extend far beyond the physical environment. These changes disrupt the foundational systems upon which economic activity and social welfare depend, transforming climate change into a structural force that influences development trajectories across regions and sectors.

One of the most immediate consequences is the escalating cost of adaptation, particularly in coastal and low-lying areas where infrastructure, settlements, and productive assets must be protected, upgraded, or relocated in response to sea-level rise. These adaptation costs impose substantial fiscal pressure on governments, often diverting public resources away from long-term investments in education, innovation, and social protection. Simultaneously, rising temperatures reduce the capacity of individuals to work

safely and efficiently, especially in labor-intensive sectors such as agriculture, construction, and informal employment, leading to declining labor productivity and reduced household incomes.

Climate change also exerts profound pressure on agricultural systems through altered rainfall patterns, heat stress, and extreme events, resulting in lower and more volatile crop yields. Disruptions in food production translate into higher prices for basic foodstuffs and consumer goods, disproportionately affecting low-income households and deepening existing inequalities. Beyond markets, climate-related environmental degradation poses serious risks to human health, as higher temperatures facilitate the spread of diseases, increase heat-related illnesses, and strain already limited public health systems.

Water scarcity further compounds these challenges, as changes in hydrological cycles, glacier retreat, and prolonged droughts reduce the availability of fresh water in many regions. Intensifying competition over water and food resources raises the likelihood of social tensions and conflict, particularly in fragile and resource-dependent contexts. In extreme cases, climate impacts necessitate the relocation of entire communities, generating climate-induced displacement and migration that disrupt social networks, labor markets, and governance structures.

Crucially, these impacts do not occur in isolation but interact dynamically across sectors and scales, reinforcing one another over time. Declining agricultural productivity can accelerate rural urban migration, placing additional pressure on urban infrastructure and social services, while the fiscal burden of disaster response and adaptation weakens state capacity and governance effectiveness. In this sense, climate change functions as a systemic risk multiplier that amplifies pre-existing socio-economic vulnerabilities and constrains sustainable development pathways. Consistent with the synthesis of the Fifth and Sixth Assessment Reports of the Intergovernmental Panel on Climate Change, addressing these challenges requires integrated strategies that enhance economic resilience, protect vulnerable populations, stabilize markets, and strengthen institutional capacity to safeguard the long-term sustainability of global social and economic systems.

Discussion on the Role of Climate Risk and Adaptive Capacity in Sustaining Economic Activities

This study is theoretically anchored in climate risk theory and vulnerability frameworks that conceptualize climate change as a systemic shock influencing long-term economic sustainability. Climate risk is not merely an environmental disturbance but a structural constraint that alters production conditions, investment behavior, and economic resilience. Consistent with the IPCC framework, climate risk emerges through the interaction of hazards, exposure, and vulnerability, with adaptive capacity determining whether economic systems can sustain productivity under climatic stress (IPCC, 2014; IPCC, 2022). This perspective aligns with Adger (2006), who emphasizes that vulnerability is socially constructed and mediated by institutional and economic conditions rather than hazard intensity alone. By positioning economic sustainability as an outcome of these interacting mechanisms, this study extends conventional growth-oriented analyses and situates sustainability as a dynamic process shaped by continuous climate pressures and adaptive responses.

The findings of this study are broadly consistent with earlier climate change research but advance the literature by integrating fragmented insights into a unified analytical framework. Stefanis et al. (2022) document the rapid expansion of climate-related research, particularly through ICT and data-driven approaches, yet their bibliometric analysis does not explicitly examine how climate risks translate into sustained economic disadvantage. Abbass et al. (2022) provide a comprehensive sectoral review of climate impacts on agriculture, health, biodiversity, and tourism, highlighting sustainability challenges, but their analysis remains largely descriptive and sector-specific, without conceptualizing economic sustainability as a systemic outcome . Similarly, Rawat et al. (2024) synthesize evidence on climate impacts across multiple sectors and emphasize mitigation and adaptation strategies, yet they do not explicitly address how repeated climate shocks cumulatively undermine long-term economic continuity

Sector-focused studies further corroborate the central role of adaptive capacity highlighted in this research. Farah et al. (2025) demonstrate that climate change significantly reduces agricultural productivity and food security, while climate-smart agriculture and technological innovation enhance resilience; however, their focus remains confined to agriculture and does not generalize adaptive mechanisms across broader economic systems. Karadayı et al. (2024) extend the discussion by emphasizing entrepreneurship and innovation as adaptive responses to climate change, arguing that sustainable entrepreneurial activity can mitigate climate risks and support development pathways. While this contribution is valuable, it primarily addresses firm-level adaptation and innovation dynamics rather than macro-level economic sustainability. Building on these studies, the present research integrates sectoral and firm-level insights into a macroeconomic framework that explains how adaptive capacity moderates vulnerability and sustains economic activities over time.

The central contribution of this study lies in identifying climate disadvantage as a cumulative outcome of persistent climate exposure combined with weak adaptive capacity. Unlike prior studies that treat climate impacts as isolated shocks, the findings demonstrate that repeated hazards erode economic buffers, weaken infrastructure, and reduce future adaptation options, thereby reinforcing vulnerability in a self-perpetuating cycle. This systemic interpretation aligns with endogenous growth theory, which suggests that climate-induced disruptions constrain capital accumulation, productivity, and long-term development trajectories (Cai, 2025). The study therefore advances the literature by empirically and conceptually linking climate risk, vulnerability, adaptive capacity, and economic sustainability within a single integrated framework, highlighting adaptation not as a supplementary policy option but as a structural necessity for sustaining economic activities under climate uncertainty.

Based on these findings, future research should move beyond static or sector-specific analyses and adopt integrated, longitudinal approaches to examine how adaptive capacity evolves over time and across institutional contexts. Comparative studies across regions with varying governance quality and climate exposure would be particularly valuable in identifying thresholds at which vulnerability transitions into climate disadvantage. Further empirical work should also explore the interaction between macro-level adaptation policies, meso-level institutional capacity, and micro-level entrepreneurial responses to climate risk. In addition, incorporating mixed-method

approaches that combine panel data analysis with qualitative institutional assessments would enhance understanding of how adaptation mechanisms function in practice. Such research would strengthen the theoretical and empirical foundations for designing climate-resilient economic policies that safeguard the long-term sustainability of economic activities in an era of escalating climate risk.

CONCLUSION

This study demonstrates that climate change constitutes a structural and systemic risk to the sustainability of economic activities rather than a temporary environmental disturbance. The findings confirm that climate-related hazards affect economic systems primarily through their interaction with exposure, sensitivity, and adaptive capacity, thereby shaping levels of vulnerability and long-term economic resilience. Economic activities become increasingly unsustainable when high climate exposure and sensitivity coincide with weak adaptive capacity, leading to persistent productivity losses, rising operational costs, and constrained development pathways. Conversely, strong adaptive capacity reflected in effective institutions, governance quality, access to resources, and technological readiness significantly mitigates climate-related risks and supports the continuity of economic activities. By integrating climate risk theory, vulnerability frameworks, and sustainability perspectives, this study advances existing literature by conceptualizing economic sustainability as a dynamic process shaped by cumulative climate pressures and adaptive responses. The results underscore the critical importance of strengthening adaptive capacity as a core strategy for safeguarding sustainable economic development under increasing climate uncertainty.

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