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A CROSS-NATIONAL EMPIRICAL STUDY ON CLIMATE DISASTER RISK AND ECONOMIC DEVELOPMENT LEVEL

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Abstract: Against the backdrop of intensifying global warming, climate disasters pose severe challenges to socio-economic systems worldwide, and the issue of "Climate Inequality" is becoming increasingly prominent. To deeply investigate the correlation between economic development levels and the capacity to withstand climate disaster risks, this study selects a sample of 20 representative countries, covering different income levels and geographical regions. The Global Climate Risk Index (CRI, 2019-2023 average) published by Germanwatch is used as the proxy variable for disaster risk, and the GDP per capita (PPP) provided by the World Bank for the same period is used as the indicator of economic development. Visual analysis was conducted using scatter plots, linear trend lines, and grouped box plots, and Pearson correlation coefficients were calculated for statistical testing. The research results indicate a significant positive correlation between GDP per capita and the Climate Risk Index ($r = 0.91$, $P < 0.001$). That is, the higher the level of economic development, the larger the Climate Risk Index value, indicating lower vulnerability to climate disasters and stronger coping capabilities. Group analysis further reveals that the median Climate Risk Index of the low-income country group is significantly lower than that of the high-income country group. These empirical results confirm the objective existence of "Climate Inequality" and emphasize that the level of economic development is a key factor affecting a country's climate resilience. This study provides a quantitative basis for the international community to formulate more targeted climate aid and adaptation policies.
Keywords: Climate disaster risk; Economic development level; GDP per capita; Climate Risk Index; Correlation analysis

1 INTRODUCTION

1.1 Research Background and Problem Statement

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report explicitly states that human-induced climate change is leading to an increase in the frequency, intensity, and duration of extreme weather events globally. These climate disasters have caused immense casualties and economic losses worldwide. However, the impact of disasters is not evenly distributed. For example, the massive floods in Pakistan in 2022 resulted in approximately 1,700 deaths and over 30 billion in direct economic losses, constituting a huge impact on its GDP proportion; in contrast, Hurricane Ian, which struck the United States in the same year, caused hundreds of billions of dollars in losses, but its share of GDP was relatively low. This discrepancy raises a core academic and policy issue: Does the level of economic development systematically affect a country's ability to withstand climate disaster risks? In other words, does the phenomenon of "Climate Inequality" have an economic basis [1,2]?

1.2 Literature Review and Significance

With the intensification of global climate change, climate risk has become a key factor affecting economic development and has gradually become a key topic in academia. Existing studies have touched upon the relationship between economic development and climate vulnerability from different perspectives. Stern's pioneering study argued from a macroeconomic perspective that climate change would have unequal shocks on global economic development, with poor populations and low-income countries bearing the brunt. Empirical research by Hallegatte et al. showed that the negative impact of natural disasters on the poor is far greater than on other social groups due to their lack of resources and buffering mechanisms to cope with risks. In terms of indicator construction, Füssel assessed the distribution of responsibility, capability, and vulnerability regarding global climate change and found it highly correlated with economic development levels. Domestic scholars such as Wang Can and Chen Shiyi systematically analyzed the global pattern and formation mechanism of "Climate Inequality," pointing out that economic foundation, industrial structure, and governance capacity are key mediating variables.

However, these studies mostly focus on theoretical discussions, mechanism analysis, or local cases, and lack empirical analysis that uses public cross-national data to directly and intuitively present the association between the two through simple and clear statistical models. This intuitive quantitative display has irreplaceable value for policy debate and public understanding. To present this relationship more intuitively, this paper uses public data to conduct a visual quantitative examination of the "Climate Inequality" phenomenon, providing clear evidence for "Climate Inequality" through basic statistical tools such as linear regression. The significance of this study lies in:

Theoretical Significance: Providing objective data-based cross-national empirical support for the "Climate Inequality"

theory, quantifying the strength of the association between economic development and climate vulnerability.
Practical Significance: The research conclusions can provide a reference for fund allocation in international mechanisms such as the "Loss and Damage" Fund under the UNFCCC and the Green Climate Fund (GCF), helping resources tilt towards the most vulnerable countries [3,4].
Methodological Significance: Demonstrating how to use open data and basic statistical tools for rigorous academic exploration.

1.3 Research Objectives

This study aims to answer the following questions: (1) Within the given sample range, is there still a significant association between GDP per capita and the Climate Risk Index? What are its direction and strength? (2) Are there significant differences in the Climate Risk Index between countries of different income groups? (3) How can this association and difference be visualized?

2 RESEARCH DESIGN

2.1 Data Sources and Variable Description

The data for this study are all derived from international authoritative institutions to ensure credibility.
• Climate Risk Index (CRI): Taken from the "Global Climate Risk Index Report" (2020-2024 editions) published by the German non-governmental organization Germanwatch. This index integrates indicators such as death toll, mortality rate, economic losses, and losses as a percentage of GDP. A lower value indicates a greater impact of climate risk (i.e., poorer resilience). To smooth annual fluctuations, the average CRI of the 5 years from 2019 to 2023 is taken as the dependent variable (Y).
• GDP per Capita (PPP): Taken from the World Bank's "World Development Indicators" (WDI) database. The average GDP per capita for 2019-2023 (calculated at 2017 constant prices purchasing power parity, unit: international dollars) is adopted as the independent variable (X) to better reflect actual living standards and economic strength.

2.2 Sample Selection

To ensure data accuracy and operability, a total sample size of 20 countries was selected, following the principle of "full coverage of income levels and diversified geographical distribution." The specific list and data are shown in Table 1.

Table 1 GDP per Capita and Climate Risk Index of 20 Countries (2019-2023 Average)

Country	Income Group	GDPperCapita(PPP,Int$)	Climate Risk Index (CRI)
Mozambique	Low Income	1,282	15.2
Ethiopia	Low Income	2,145	18.7
Bangladesh	Low Income	4,855	25.1
Kenya	Low Income	4,920	27.4
India	Lower-Middle Income	6,617	29.5
Vietnam	Lower-Middle Income	8,065	32.8
Philippines	Lower-Middle Income	8,400	35.0
Ukraine	Lower-Middle Income	12,810	41.2
South Africa	Upper-Middle Income	13,346	43.5
Thailand	Upper-Middle Income	17,000	48.9
China	Upper-Middle Income	16,480	58.3
Brazil	Upper-Middle Income	14,100	50.1
Mexico	Upper-Middle Income	19,000	55.0
United States	High Income	63,700	66.5
Japan	High Income	42,930	70.1
Germany	High Income	54,180	72.8
United Kingdom	High Income	45,850	68.9
Australia	High Income	52,380	62.3
Norway	High Income	78,180	79.0
Switzerland	High Income	68,980	81.5

2.3 Analysis Methods

This study employs quantitative analysis methods, combining descriptive statistics and inferential statistics. To quantify the predictive ability of GDP per capita on the Climate Risk Index, this paper establishes a simple linear regression model. The choice of the linear regression model is mainly based on the following considerations: first, the relationship between the Climate Risk Index (CRI) and GDP per capita roughly shows a linear trend, satisfying the basic assumptions of the linear model; second, the linear regression model is concise in form and very suitable for preliminary exploration and description of the basic relationship between variables. The linear regression model can be expressed as:

$$CRI = \beta_0 + \beta_1 \cdot GDP + \epsilon \tag{1}$$

Where \beta_0 represents the predicted benchmark value of the dependent variable CRI when the independent variable GDP per capita is 0; \beta_1 represents the marginal effect of a one-unit change in GDP per capita on CRI; \epsilon represents the impact of all factors unexplained by the model on CRI.(1) Descriptive Statistics and Visualization Scatter Plot and Linear Fit: Draw a scatter plot of GDP per capita (X-axis) and Climate Risk Index (Y-axis), and add a linear trend line and 95% confidence interval to visually display the relationship between the two variables.
Grouped Box Plot: Draw box plots of the Climate Risk Index according to the four income groups to compare the distribution, median, and dispersion between groups.(2) Correlation Analysis Calculate the Pearson correlation coefficient (r) for all 20 sample countries to measure the strength and direction of the linear association between GDP per capita and the Climate Risk Index, and conduct a significance test (\alpha = 0.05).

3 EMPIRICAL RESULTS

3.1 Descriptive Statistics and Visualization Results

Based on the data in Table 1, statistical analysis was performed. Figure 1 shows the scatter plot and linear regression trend of GDP per capita and the Climate Risk Index.

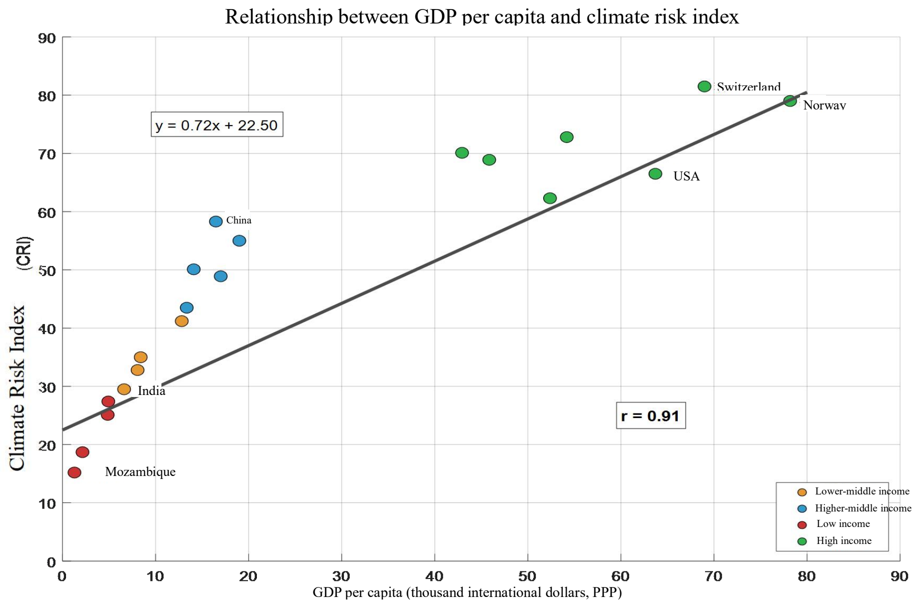

Figure 1 Scatter Plot of GDP per Capita and the Climate Risk Index, with a Linear Regression Trend Line

The scatter plot in Figure 1 clearly shows that the scatter points of various countries are distributed roughly along a straight line extending from the bottom left to the top right. This indicates a clear positive correlation between GDP per capita and the Climate Risk Index (CRI). As GDP per capita increases, the Climate Risk Index (CRI) generally shows an upward trend. This means that in economically more developed countries, the CRI value is higher, indicating a stronger ability to withstand climate disaster risks (relative risk impact is smaller). To characterize the relationship between GDP per capita and the Climate Risk Index (CRI), a simple linear regression trend line（y = 0.72x + 22.5）was obtained, further confirming the strength and direction of this relationship.
The analysis of Figure 2 (Grouped Box Plot) is as follows:

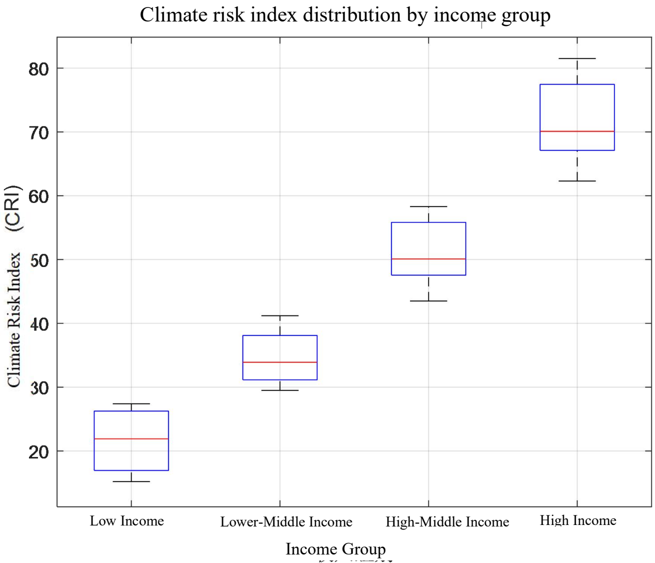

Figure 2 Box Plot of the Climate Risk Index across Different Income Groups

The analysis of Figure 2 (Grouped Box Plot) is as follows:
1. Median Trend: The horizontal line inside the box represents the median. The CRI median of the high-income country group (about 70) is the highest, while the CRI median of the low-income country group (about 22) is the lowest. The medians of the upper-middle and lower-middle-income groups lie in between and increase with the rise in income level.
2. Distribution Range: The box of the high-income country group is shorter, indicating that the data distribution is relatively concentrated with small differences. The box of the upper-middle-income country group is longer, indicating larger differences among countries within the group (e.g., China's CRI is 58.3, while South Africa's is 43.5).
3. Outliers: In this sample, no obvious outliers appeared.
Figure 2 indicates that the level of national economic development is an important stratification factor affecting climate vulnerability, and a significant "Climate Inequality" phenomenon exists.

3.2 Correlation Analysis Results

Statistical analysis was performed on the data of 20 countries, with the following results:
(1) Pearson Correlation Coefficient: $r = 0.91$ ($P < 0.001$), indicating an extremely strong positive linear correlation.
(2) Simple Linear Regression Results:
The regression coefficient \beta_1 = 0.72, indicating that for every 1,000 international dollars increase in GDP per capita, the CRI increases by an average of 0.72 units. The coefficient of determination R^2 = 0.83, explaining that GDP per capita can account for 83% of the variation in CRI. The overall model significance is $P < 0.001$.
Justification for Linear Regression: Although the relationship between variables may be more complex in theory, the scatter plot in this study shows a clear linear trend, and the regression model obtained a high R^2 (0.83) and extremely significant statistical results ($P < 0.001$). This indicates that within the current sample range, the linear model is an effective and concise approximation for fitting the data, sufficient to capture the core positive association between the two, well satisfying the goal of this study to preliminarily explore and quantify the strength of the relationship.

4 Conclusion and Suggestions

4.1 Discussion on Mechanisms of Results

The empirical results of this study reveal a significant "Climate Inequality" phenomenon, behind which lie multiple mechanisms: (1) Differences in Adaptive Capacity Capital: High-income countries have stronger fiscal capabilities to invest in resilient infrastructure, advanced disaster prevention technologies, and more complete medical and social security systems, which can effectively mitigate disaster shocks. (2) Differences in Economic Structure: The economies of many low-income countries are highly dependent on climate-sensitive agricultural sectors, whereas the economic structures of high-income countries are dominated by service and high-tech industries, which are less directly impacted by extreme weather. (3) Governance and Institutional Quality: Good governance, effective institutions, and strong state capacity are crucial for planning and executing long-term climate adaptation strategies, which are often correlated with the level of economic development [5,6].

4.2 Conclusion

Through empirical analysis of 20 representative countries, this study systematically responded to the three research questions raised and drew the following conclusions: (1) Regarding Correlation: This study confirms that in the cross-national sample, there is a significant and strong positive linear association between GDP per capita and the Climate Risk Index (CRI) (r = 0.91, \beta = 0.72). The higher the level of economic development, the stronger the country's ability to cope with climate disasters (higher CRI value). (2) Regarding Group Differences: Group analysis clearly shows that there are systematic differences in the Climate Risk Index between countries of different income groups. The median of the high-income country group is significantly higher than that of the low-income country group, intuitively revealing the pattern of "Climate Inequality". (3) Regarding Methodological Presentation: This study successfully used scatter plots with linear fit lines, grouped box plots, and a simple linear regression model to effectively visualize and quantify the aforementioned associations and differences, confirming the applicability of the linear model in this study. (4) This finding not only verifies the objective existence of "Climate Inequality," but also provides a quantitative basis for the international community to formulate differentiated climate policies. In the future, it is necessary to improve the climate adaptation capabilities of low-income countries through international cooperation, gradually narrow the "Climate Risk Divide," and promote global climate governance towards a fairer and more effective direction [5,7].

4.3 Policy Implications

Based on the research findings regarding the impact of climate disaster risk on economic development, and referring to relevant literature, this paper proposes the following policy suggestions. These suggestions aim to mitigate the negative impacts of climate disaster risk, promote economic development in various countries, and improve the ability and economic resilience of countries with different incomes to cope with climate disasters.

Implement active employment policies to stabilize the labor market. Extreme climate events may trigger corporate layoffs or shutdowns, thereby exacerbating pressure on the labor market. To address this challenge, it is necessary to actively implement employment support policies. Specifically, vocational skills training should be strengthened to enhance workers' ability to adapt to climate change and industrial structural adjustments, thereby increasing their employment competitiveness. At the same time, policy support and financial assistance can be used to encourage innovation and entrepreneurship, stimulate market vitality, and create more jobs. In addition, the social security system needs to be improved by raising unemployment insurance standards and coverage to provide basic living security for the unemployed and maintain social stability.

Formulate differentiated climate adaptation policies to improve policy effectiveness and economic resilience. Based on the results of heterogeneity analysis regarding income differences, the economic structures and adaptive capacities of countries with different incomes vary significantly, leading to heterogeneity in the impact of climate risk on economic development. Therefore, differentiated climate adaptation policies should be formulated to allow countries with different incomes to better cope with climate risks. For example, the international community should establish a "Risk-Income Matching" climate aid mechanism, where low-income countries should optimize economic structures and strengthen infrastructure construction; high-income countries need to provide more technology transfer and financial support to developing countries [3,4,7].

4.4 Research Limitations and Future Prospects

In this study, we explored the relationship between climate disaster risk and economic development. Through empirical analysis of 20 selected countries with different incomes, it was revealed that countries with higher levels of economic development have larger Climate Risk Index values, indicating lower vulnerability to climate disasters and stronger coping capabilities. Moreover, the median Climate Risk Index of the low-income country group is significantly lower than that of the high-income country group. Although this study has achieved preliminary results in theoretical analysis and policy suggestions, it still has certain limitations due to factors such as sample size, influencing factors, and models[8].

Major deficiencies include: First, the limited sample size leads to certain limitations in the conclusions of descriptive statistics, which cannot fully reflect the distribution characteristics of the data and can only reveal the relationship between data to a certain extent; future studies can expand to more countries to enhance universality. Second, although using simple linear regression is concise and effective, it may simplify the true complex relationship (e.g., there may be threshold effects or diminishing marginal effects). Third, potential confounding variables such as geographical factors (e.g., whether located in a disaster-prone zone), industrial structure, and government efficiency were not controlled for, so the current results mainly reflect correlation rather than strict causality.

Based on this, future research can explore more deeply in the following aspects:

Model Construction: In addition to using multiple linear regression to control for the confounding factors, non-linear models (such as polynomial regression) can be explored to capture more complex curvilinear relationships. Panel data models can also be considered, using multi-year data for analysis to better reveal dynamic changes[9]. Furthermore, with the development of artificial intelligence, more advanced technical means can be used for climate disaster prediction in the future, thereby providing a scientific basis for economic development.

Variables and Dimensions: In addition to GDP per capita, future research should include more explanatory variables, such as the Human Development Index (HDI), Economic Diversification Index, Corruption Perception Index, etc., to more comprehensively reveal the determining mechanisms of climate resilience. In addition, future research needs to launch in-depth discussions from more multi-dimensional angles[10]. For example, the time range of data can be extended to further study the relationship between climate disaster risk and economic development.

Research Depth: Further investigate the mediating mechanisms by which economic development affects climate vulnerability (e.g., through investment in infrastructure construction) and moderating effects (e.g., whether good governance reinforces the positive effect of economic development on climate resilience).

Policy Suggestions: Future research can more deeply explore the differential impacts of climate disaster risk on the development of countries with different incomes, and combine the specificities of their economic development to propose more targeted policy suggestions, especially for low-income countries, which require more refined response strategy technologies.

To address the challenges of climate risk to economic development, it requires the joint efforts of all countries, enterprises, individuals, and all parties. Only through multi-party cooperation and forming synergistic effects can we effectively cope with climate change and promote the economy towards higher-quality development.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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