Extreme Climate Risks and Economic Recovery: Evidence from Chinese Provincial Panel Data

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Abstract. This paper examines the impact of extreme climate risks on provincial economic performance in China using panel data for 31 provinces over the period 2004–2023. It employs a two-way fixed-effects model to estimate the relationship between the Climate Physical Risk Index (CPRI) and provincial GDP. The analysis further explores heterogeneity across four specific disaster types—low temperature, high temperature, rainfall, and drought—and tests whether climate risks exert persistent effects through lagged specifications. The results show that climate physical risk is negatively associated with provincial GDP, indicating that climate-related shocks can weaken regional economic performance. Among the disaggregated indicators, rainfall-related risk appears to be the main driver of this negative effect. By contrast, the lagged-effect results do not provide robust evidence of persistent long-term impacts. Overall, the findings suggest that the economic consequences of climate disasters in China are concentrated mainly in the short run, highlighting the importance of disaster response, regional fiscal support, and climate risk management for improving economic resilience.

Keywords: climate risk; economic recovery; provincial GDP; China

1 Introduction

The frequency and intensity of extreme climate events have increased remarkably over recent years, posing challenges to economic stability and long-term development. Beyond their immediate physical and financial destruction, climate-related disasters generate persistent economic disruptions by interrupting regular industrial production processes. As climate risks intensify, policymakers and researchers have become more concerned not only with the short-term economic losses, but also with the recovery ability of affected economies.

Existing analyses of climate impacts on the economy have largely focused on temporary output losses or changes in average growth rates. However, they provide limited insight into the dynamics of post-shock adjustment. In order to better measure resilience and design more effective policies, it is also important for us to understand whether regional economies can recover back to their long-term trends after experiencing such disasters and how these climate risks may slow this recovery process.

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This issue is especially outstanding in China, which has very regionally diverse economies. Heterogeneities in climate exposure and industrial structure across provinces implies that the economic consequences of climate risks may differ significantly across regions. A systematic empirical research of how extreme climate risks affect regional economic recovery is therefore crucial for informing region-specific climate resilience strategies.

The remainder of this paper is organized as follows. Section 2 reviews the related literature on climate shocks and economic recovery. Section 3 describes the empirical strategy, model specification, data sources, and summary statistics. Section 4 reports the main empirical findings, including the baseline results, the disaggregated analysis of different disaster types, the robustness check, and the lagged-effect analysis. Section 5 concludes with a discussion of the main findings and their policy implications.

2 Literature Review

Existing literature has extensively examined the economic consequences of extreme weather events and natural disasters. A growing body of research shows that climate-related shocks can significantly reduce economic output and growth, particularly in the short run [1][2](Dell et al., 2008; Acevedo et al., 2020). Moreover, these impacts are highly heterogeneous across regions depending on economic structure and development level. Regions with greater exposure to climate-sensitive sectors or weaker adaptive capacity tend to experience larger economic losses [3](Henri Aurélien, 2025). Beyond immediate output declines, recent studies also suggest that climate shocks may generate persistent economic effects that extend beyond the disaster year [4][5] (Burke et al., 2015; Costa & Hooley, 2025).

A related strand of literature focuses on economic recovery following large shocks. Major disruptions can lead to temporary or persistent deviations from long-run growth paths [6](Cerra & Saxena, 2008). In many cases, recovery after severe shocks is incomplete or prolonged, suggesting that economies do not always fully return to their pre-shock growth trajectories [7](Furlanetto et al., 2023). Natural disasters may therefore affect not only the magnitude of economic losses but also the speed at which economies recover [8][9](Cavallo et al., 2013;Deraniyagala, 2016).

Recent empirical studies increasingly employ climate risk indices to measure regional exposure to physical climate risks,such as extreme temperatures, droughts, and floods [10][11][12](Bertrand et al., 2024; Salisu & Oloko, 2023; Maes & Haščič, 2022). However, while existing research has mainly focused on contemporaneous output losses or average growth effects, relatively little attention has been paid to how climate risks influence the ability of regional economies to return to their long-run growth paths. This paper contributes to the literature by examining economic recovery dynamics measured as deviations from long-run output trends.

3 Empirical Strategy and Data

3.1 Empirical Strategy and Model Specification

Baseline Fixed-Effects Model. To examine the relationship between climate physical risk and provincial economic performance, this paper first estimates a two-way fixed-effects model:

$$GDP_{it}=\alpha+\beta CPRI_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \tag{1}$$

where GDP_{it} denotes the gross domestic product of province i in year t, and $CPRI_{it}$ represents the aggregate Climate Physical Risk Index. X_{it} is a vector of control variables, including urbanization rate, population, government expenditure, and industrial profit. μ_i denotes province fixed effects, λ_t denotes year fixed effects, and ε_{it} is the error term.

Province fixed effects control provincial characteristics which might affect both climate risk exposure and economic performance, while year fixed effects absorb common macroeconomic shocks and national-level time trends, which affect all provinces simultaneously. As a result, instead of measuring simple cross-sectional differences, the model identifies the relationship between changes in climate physical risk and changes in GDP within provinces over time.

Disaggregated Disaster Model. To further explore heterogeneity across disaster types, the aggregate risk index is replaced with four sub-indices:

$$\mathrm{GDP_{it}}=\alpha+\beta_1\mathrm{LowTemp_{it}}+\beta_2\mathrm{HighTemp_{it}}+\beta_3\mathrm{Rain_{it}}+\beta_4\mathrm{Drought_{it}}+\gamma \mathrm{X_{it}}+\mu_\mathrm{i}+\lambda_\mathrm{t}+\varepsilon_\mathrm{it} \tag{2}$$

In this model, the overall climate risk index is decomposed into four sub-components: low temperature risk($LowTemp_{it}$), high temperature risk($HighTemp_{it}$), rainfall risk($Rain_{it}$), and drought risk($Drought_{it}$). This disaggregated specification makes it possible to examine whether some disaster types have stronger economic effects than others.

Lagged-Effect Model. To examine whether climate risk has persistent economic effects, this paper also estimates models with lagged risk variables:

$$GDP_{it}=\alpha+\beta CPRI_{i,t-k}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \tag{3}$$

where k=1,2 , corresponding to the one-year and two-year lag of the Climate Physical Risk Index.

A lagged disaggregated model is also estimated:

$$\mathrm{GDP_{it}}=\alpha+\beta_1\mathrm{LowTemp_{i,t-1}}+\beta_2\mathrm{HighTemp_{i,t-1}}+\beta_3\mathrm{Rain_{i,t-1}}+\beta_4\mathrm{Drought_{i,t-1}}+\gamma \mathrm{X_{it}}+\mu_\mathrm{i}+\lambda_\mathrm{t}+\varepsilon_\mathrm{it} \tag{4}$$

These lagged specifications are designed to test whether the economic consequences of climate disasters extend beyond the current year.

3.2 Data Sources

The climate risk variables, including the Climate Physical Risk Index (CPRI) and its four sub-components (extreme low temperature, extreme high temperature, rainfall, and drought), are obtained from the ISETS Energy Finance Network (IEFN). All other economic and demographic variables are collected from the National Bureau of Statistics of China (NBS). After merging these sources, the final dataset forms a balanced province-year panel.

3.3 Summary for Data

Table 1. Summary Statistics of Main Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	620	1948.586	2094.570	18.820	13254.710
CPRI	620	45.444	8.184	25.810	84.340
Low temperature risk	620	42.413	18.189	0	100
High temperature risk	620	63.139	14.555	22.690	119.580
Rainfall risk	620	41.144	21.788	0	190.530
Drought risk	620	35.081	14.261	3.410	100
GDP per capita	620	47791.380	34361.250	4303	216722
Population	620	43885.600	28388.020	2760	127060
Urban population	589	24541.260	17314.630	580	95830
Government expenditure	620	404.197	330.940	12.300	1853.310
Industrial profit	620	181.455	208.274	-52.880	1159.520
Industrial value added	620	737.018	807.762	1.600	4764.270

Notes: The sample consists of 31 Chinese provinces over the period 2004–2023. All variables are measured at the provincial level.

Table 1 reports the summary statistics of the main variables used in this study. The sample consists of 620 province-year observations. On average, provincial GDP is 1948.6 billion RMB, with substantial variation across regions, reflecting large differences in economic scale. The Climate Physical Risk Index (CPRI) has a mean value of 45.44, indicating moderate but heterogeneous exposure to climate risks across provinces. Among the disaggregated indicators, high temperature and rainfall risks exhibit relatively higher mean values, while drought risk shows comparatively lower variation. Overall, the descriptive statistics suggest significant cross-province heterogeneity in both economic performance and climate risk exposure, which provides a suitable basis for panel regression analysis.

4 Empirical Results

4.1 Baseline Results: Aggregate Climate Risk and GDP

This section presents the baseline regression results on the relationship between climate physical risk and provincial economic performance.

Table 2. Baseline Fixed-Effects Results: Climate Physical Risk and Provincial GDP

Variables	GDP
cpri	-6.425**
	(2.716)
urban_rate	346.318
	(1024.532)
population	0.038**
	(0.017)
gov_exp	4.281***
	(0.568)
ind_profit	1.520**
	(0.593)
Year FE	YES
Province FE	YES
N	465
R-squared	0.954

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2 reports the baseline fixed-effects estimation results. The coefficient on the Climate Physical Risk Index is negative and statistically significant, indicating that higher levels of climate-related physical risk are associated with lower provincial GDP. This result suggests that climate-related physical shocks can cause a negative impact on regional economic output.

Population has a positive and statistically significant association with GDP, consistent with the idea that provinces with more people tend to have larger labor forces and greater economic scale. Government expenditure and industrial profit are also positively and significantly related to GDP, indicating the importance of fiscal support and industrial performance for regional output. By contrast, the urbanization rate is not statistically significant in the baseline model, possibly because its effect is partly absorbed by province fixed effects and other controls.

Overall, the baseline results suggest that climate physical risk is negatively associated with provincial economic performance. Provinces facing higher climate-related physical risk tend to exhibit lower GDP, providing initial evidence for the adverse economic effect of climate shocks and motivating the subsequent analysis of disaster-specific and lagged effects.

4.2 Disaggregated Results: Specific Disaster Types and GDP

To further examine which types of climate-related disasters drive the negative relationship between climate physical risk and economic performance, this section uses four disaggregated risk components: low temperature, high temperature, rain, and drought.

Table 3. Disaggregated Fixed-Effects Results: Specific Climate Disaster Types and Provincial GDP

Variables	(1) LowTemp	(2) HighTemp	(3) Rain	(4) Drought
low_temp	-1.529			
	(1.109)			
high_temp		-1.019		
		(1.090)		
rain			-2.119**	
			(0.995)	
drought				-0.975
				(1.279)
population	0.037**	0.037**	0.038**	0.036**
	(0.016)	(0.016)	(0.016)	(0.017)
gov_exp	4.241***	4.271***	4.194***	4.263***
	(0.571)	(0.578)	(0.565)	(0.575)
ind_profit	1.786***	1.787***	1.749***	1.796***
	(0.589)	(0.581)	(0.594)	(0.590)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	496	496	496	496
Provinces	31	31	31	31
R-squared	0.9562	0.9561	0.9571	0.9561

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 reports the results of the disaggregated fixed-effects model. Among the four specific climate disaster variables, rain is the only variable that shows a negative and statistically significant coefficient. This finding suggests that rainfall-related climate shocks may be the main factor driving the negative effect of aggregate climate physical risk on provincial GDP. Additionally, the coefficient on rain indicates that greater rainfall-related physical risk is associated with lower economic output at the provincial level.

By contrast, the coefficients on low temperature, high temperature, and drought are not statistically significant in this specification. However, this does not necessarily mean that these climate risks have no economic consequences. It is possible that some of these risks affect economic performance through longer-term structural channels that are not fully reflected in contemporaneous GDP levels.

Overall, the disaggregated results suggest that the negative economic effect of climate physical risk is mainly driven by rainfall-related shocks.

4.3 Robustness Checks with Alternative Dependent Variables

To examine whether the baseline findings are sensitive to the choice of dependent variable, this section conducts the robustness check using GDP per capita.

Table 4. Robustness Check Using GDP per Capita as the Dependent Variable

Variables	GDP per capita
cpri	-142.850*
	(70.356)
gov_exp	3.033
	(11.732)
ind_profit	34.075***
	(11.906)
Year FE	Yes
Province FE	Yes
N	465
R-squared	0.918

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 presents the robustness check using GDP per capita as the dependent variable. The coefficient on climate physical risk remains negative and is only weakly significant, suggesting that the adverse effect still exists but is less robust than in the baseline GDP model. This result indicates that climate risk may reduce average economic performance across provinces, although the relationship is less stable when GDP per capita is used instead of total GDP.

4.4 Lagged Effects of Climate Risk

To examine whether the economic effects of climate physical risk persist beyond the current period, this section examines lagged climate risk variables with the regression framework. This additional analysis helps distinguish between short-term contemporary shocks and more persistent effects that may continue to affect provincial GDP in subsequent years.

Table 5. Lagged Effects of Climate Risk on Provincial GDP

Variable	GDP (cpri, t−1)	GDP (cpri, t−2)	GDP (Disaster Types)
Lagged cpri (t−1)	-3.347		
	(3.011)		
Lagged cpri (t−2)		-3.803	
		(2.725)	
Lagged low_temp			-0.374
			(0.927)
Lagged high_temp			-0.239
			(1.333)
Lagged rainfall			-1.623
			(1.254)
Lagged drought			-0.406
			(1.125)
urban_rate	383.873	482.152	418.003
	(998.406)	(1117.578)	(1001.684)
population	0.039**	0.038**	0.039**
	(0.017)	(0.018)	(0.017)
gov_exp	4.303***	4.400***	4.278***
	(0.593)	(0.621)	(0.598)
ind_profit	1.557**	1.344**	1.560**
	(0.605)	(0.615)	(0.608)
Province FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	465	434	465
N	31	31	31
R-squared	0.953	0.948	0.953

Notes: Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 reports the results of the lagged-effect models. The coefficients on the one-year lagged and two-year lagged aggregate Climate Physical Risk Index are both negative, which is consistent with the expectation that climate-related shocks may continue to exert downward pressure on economic output after the initial period. However, neither coefficient is statistically significant. Similarly, the coefficients on all lagged disaggregated disaster variables are generally negative in direction, but none of them is statistically significant.

This finding implies that the economic consequences of climate disasters may happen more in the short-term period rather than persisting into subsequent years. It is possible that local economies can partially recover after the initial shock.

Overall, the lagged-effect analysis does not provide robust support for a persistent long-term impact of climate physical risk on provincial GDP. This pattern is consistent with the view that climate risk mainly affects short-run output conditions, while longer-term effects are weaker or less directly observable in annual provincial panel data.

5 Conclusion

This paper examines the impact of extreme climate risks on provincial economic performance in China using a two-way fixed-effects model. The results show that climate physical risk is negatively associated with provincial GDP, suggesting that climate-related shocks can significantly reduce regional economic output. Among different types of climate risks, rainfall-related shocks appear to be the main driver of this negative effect. By contrast, the lagged-effect analysis provides limited evidence of persistent long-term impacts, indicating that the economic consequences of climate disasters are mainly concentrated in the short run.

These results also imply several practical policy directions. First, improving disaster response capacity, especially for rainfall-related events, would help reduce immediate economic disruption after climate shocks. Mechanisms such as flood control infrastructure and early warning systems should be applied. In addition, more targeted regional fiscal support may be needed to help vulnerable provinces recover more quickly when disasters occur. At the same time, strengthening climate risk management in regional planning and public investment can further enhance economic resilience and better prepare local economies for future climate-related challenges.

Overall, this study provides empirical evidence that climate-related physical risks can weaken regional economic performance in China, particularly through rainfall-related shocks. This highlights the need for more effective adaptation and risk management policies to reduce the economic costs of future climate events.

References

1. Dell, M., Jones, B., & Olken, B. (2008). Climate Change and Economic Growth: Evidence from the Last Half Century. National Bureau of Economic Research. https://doi.org/10.3386/w14132.
2. Acevedo, S., Mrkaic, M., Novta, N., Pugacheva, E., & Topalova, P. (2020). The Effects of Weather Shocks on Economic Activity: What are the Channels of Impact? Journal of Macroeconomics, 65, 103207. https://doi.org/10.1016/j.jmacro.2020.103207.

3. Henri Aurélien, A. (2025). Vulnerability to climate change in sub-Saharan Africa countries. Does international trade matter? Heliyon, 11(4), e42517. https://doi.org/10.1016/j.heliyon.2025.e42517.
4. Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(7577), 235–239. https://doi.org/10.1038/nature15725.
5. Costa, H., & Hooley, J. (2025). The macroeconomic implications of extreme weather events. https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/08/the-macroeconomic-implications-of-extreme-weather-events_6d00a073/5e24a2d8-en.pdf.
6. Cerra, V., & Saxena, S. C. (2008). Growth Dynamics: The Myth of Economic Recovery. American Economic Review, 98(1), 439–457. https://doi.org/10.1257/aer.98.1.439.
7. Furlanetto, F., Lepetit, A., Robstad, Ø., Rubio-Ramírez, J., & Ulvedal, P. (2021). Estimating Hysteresis Effects. Finance and Economics Discussion Series, 2021(058), 1–35. https://doi.org/10.17016/feds.2021.059.
8. Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic Natural Disasters and Economic Growth. Review of Economics and Statistics, 95(5), 1549–1561. https://doi.org/10.1162/rest_a_00413.
9. Deraniyagala, S. (2016, May). Economic Recovery after Natural Disasters | United Nations. United Nations; United Nations. https://www.un.org/en/chronicle/article/economic-recovery-after-natural-disasters.
10. Bertrand, J.-L., Chabot, M., Brusset, X., & Courquin, V. (2024). Identifying assets exposed to physical climate risk: A decision-support methodology. International Journal of Production Economics, 276, 109355–109355. https://doi.org/10.1016/j.ijpe.2024.109355.
11. Salisu, A., & Oloko, T. (2023). Climate Risk Measures: A Review. Asian Economics Letters, 4(Early View). https://doi.org/10.46557/001c.39728.
12. Maes, M. J. A., & Haščič, I. (2022). Monitoring exposure to climate-related hazards. OECD Environment Working Papers. https://doi.org/10.1787/da074cb6-en.

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