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Study on the Effect of Extreme Weather on Bank Credit Risk

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Abstract

In the global economic landscape, the potential impact of extreme weather issues on banks has attracted much attention. This study focuses on the impact of extreme weather on the credit risk of A-share listed banks and explores its role in financial stability. Given China's significant position in the global economy, analyzing the credit risk faced by its banking sector has both theoretical and practical value. By synthesizing bank financial data, weather records and macroeconomic indicators, this study quantifies the potential impact of extreme weather events on bank credit risk, taking into account the moderating effects of heterogeneity among bank types and regional bank competition. The results reveal the existence of an association between extreme weather and bank credit risk-taking and provide a basis for bank risk management and regulatory policies.

Keywords

extreme weather, A-share listed banks, credit risk

1. Introduction

With the increasing severity of global climate problems, we are facing unprecedented environmental challenges. The frequent occurrence of extreme weather events, global warming and other phenomena have not only caused a great impact on the natural ecosystem, but also brought far-reaching effects on the economic activities and financial stability of human society. Against this background, the banking industry, as the core of the financial system, the accurate assessment and strict control of its credit risk is crucial to safeguarding the sound operation of the entire financial system. As the global climate continues to change, the frequent occurrence of extreme weather events not only profoundly affects economic sectors such as agriculture, industry and transport, but also brings unprecedented challenges to the banking sector.

At the international level, the G20 released a report in 2017 encouraging central banks and financial regulators to conduct environmental risk analyses. In December of the same year, China and eight other countries initiated the establishment of the Network of Central Banks and Regulators for Green Finance (NGFS), calling on countries to pay attention to and collaborate on climate change-related risks. Since then, the NGFS has released a series of important reports, including the Synthesis of Environmental Risk Analyses for Financial Institutions and its casebook, released in September 2020, which provide important references for understanding and responding to climate change-related financial risks.

China has demonstrated strong determination and positive action in addressing climate change, and has made clear the country's strategic direction on climate governance through the release of documents such as the White Paper on China's Policies and Actions to Address Climate Change. The Chinese government has put climate change at the centre of its national development agenda and is committed to promoting green, low-carbon and sustainable economic development. In the 14th Five-Year Plan, it has proposed the ambitious goal of achieving carbon peak and carbon neutrality, and has taken practical measures in the areas of energy restructuring, energy conservation and emission reduction, and green finance. In addition, China's active participation in international climate governance, such as the signing and implementation of the Paris Agreement, further highlights China's leadership and sense of responsibility in global climate action. The organic combination of domestic policies and international commitments not only provides the Chinese banking industry with action guidelines to address climate risks, but also brings new opportunities and challenges for its transformation and upgrading.

Although international academics and financial regulators have begun to pay attention to the impact of extreme weather on financial stability, relatively few empirical studies have been conducted on the banking sector. As the world's second largest economy, China's unique economic structure, the diversity of its development stages, and its important position in the global economy make it of great practical significance and theoretical value to study the impact of extreme weather on credit risk in China's banking sector. Therefore, an in-depth study and understanding of the impact of extreme weather on bank credit risk is important for the formulation of effective risk management strategies and policies.

This study relies on bank financial statements, meteorological data and macroeconomic indicators, etc., in order to quantify the impact of extreme weather on bank credit risk by combining the data of key indicators, such as extreme weather events and non-performing loan ratios, in order to reveal the relationship between extreme weather and bank risk-taking. In addition, considering that there may be differences in the sensitivity of different types of banks to extreme weather, heterogeneity analyses are also included in the study to identify the differences in risk-taking among different banks in the face of extreme weather. This not only helps banks to formulate risk management strategies based on their own characteristics, but also provides regulators with a basis for formulating relevant policies and regulatory measures.

2. Literature Review

2.1 Climate Change and the Real Economy

The impact of climate change on the real economy has become an important topic in global economic research. The increase in extreme weather events, such as floods, droughts, and hurricanes, not only causes direct damage to human life, but also has an indirect but far-reaching impact on the real economy. Dell et al. (2014) point out in their study that extreme weather disasters can lead to a decline in consumption and investment, which in turn triggers an economic recession. This impact is not limited to the affected region, but is also transmitted to other economies through global supply chains and financial markets. For example, Hsiang and Burke (2014) revealed the negative impact of extreme weather events on economic growth and investment through cross-country data analysis.

Chen (2020) further pointed out that the impact of climate change on the real economy would be transmitted through the financial system and increase financial risks. The study by Gu and Yu (2019), on the other hand, analyses from the perspective of banking and financial institutions how an increase in the default rate due to climate change can negatively affect the real economy by tightening credit conditions and reducing the scale of lending, which increases the financing constraints and costs of enterprises. This process is also empirically supported in the study of Mishra and Sengupta (2018), who find that climate change increases credit risk for financial institutions and leads to a decrease in credit market efficiency.

2.2 Climate Change and Macrofinancial Risks

Macro-financial risks arising from climate change mainly include physical risks and transition risks. Physical risk involves losses directly caused by climate change, such as business interruptions, increased insurance costs, and higher costs of green investments (Guo, 2020). A study by Liu, Bolin and Li, Linlin (2022) showed that climate catastrophes have increased losses in the insurance industry by more than five times over the past 30 years, and that such risks are characterized by high levels of disruption and difficulty in repair. If multiple catastrophes are concentrated, they may lead to the risk of insolvency of important financial institutions, affecting financial stability and possibly even triggering a financial crisis. Weber (2019) in his study emphasizes the vulnerability of financial institutions to physical risks, especially assets in coastal areas and low-lying areas.

Transformation risk, on the other hand, focuses on the financial risks that firms may encounter during the transformation process in response to climate change pressures. Wang Y. and Wang, W. W. (2021) state that the transformation of firms may lead to stranded assets, asset price volatility, and disruptions in the progress of production and investment. In the context of climate change, asset losses of firms and industries will increase significantly, and the default rate of banking financial institutions is significantly higher. This view is empirically supported by Cerutti et al. (2017), who found that transition risk has a significant impact on the volatility of financial markets.

2.3 Climate Change and Financial Sector Risk

The impact of climate change on financial sector risk is multifaceted. Higher global temperatures may lead to higher levels of risk in the assets of financial institutions, increasing business interruption and operational risk. The presence of climate risks, such as extreme weather and natural disasters, could lead to reputational risk due to the lack of a ‘green’ component in investment and financing structures. At the same time, stranded assets and collateral depreciation may create market and credit risks, exacerbating the problem of illiquidity in capital markets. Wang (2021) emphasizes that the uncertainty of climate change increases the difficulty of financial risk assessment and resistance to financial sector development. Climate change may also increase the likelihood of meteorological disasters, leading to "green swan" events, i.e., high intensity and multiple frequency meteorological catastrophes that are highly susceptible to financial crises. This is exemplified in the study of Battaglini et al. (2017), who analyzed the potential impact of extreme weather events on financial markets through economic modelling.

2.4 Literature Review

In summary, the impact of climate change on the real economy and the financial system is comprehensive and complex. Existing literature has conducted in-depth theoretical studies on climate change-induced risks in the financial sector, but there are relatively few empirical studies. As climate change accelerates, it becomes particularly important to use historical data to predict and assess climate change-induced risks in the financial sector. Future research should further explore the impacts of climate change on different financial products and services, and how these risks can be mitigated through financial innovation and policy interventions. In addition, interdisciplinary research methodologies and more refined econometric modelling are crucial for an in-depth understanding of the economic impacts of climate change, which requires a close integration of various disciplinary fields.

3. Theoretical Mechanism Analysis and Research Hypotheses

3.1 Impact of Extreme Weather events on Bank Credit Risk

The impact of extreme weather events on bank credit risk is mainly transmitted through the following pathways, each of which has its own characteristics and poses a multidimensional challenge to the banking industry: first, corporate profitability, extreme weather events may lead to production disruptions, supply chain disruptions, or asset destruction, which in turn affects corporate profitability. As businesses' revenues fall, their ability to repay bank loans diminishes, increasing banks' credit risk. Second, the financial situation of households, which may be worsened by extreme weather-induced natural disasters that may damage household property and affect employment and income stability. The decline in the solvency of households, as the main borrowers of retail bank loans, directly raises the risk of bank default. Third, insurance penetration, as an important tool for risk diversification, the level of insurance penetration has a direct impact on the financial compensation ability of affected firms and households. Insufficient insurance penetration means that more losses need to be borne by the borrowers themselves, which may increase their financial pressure and thus affect the quality of bank loans. Fourth, changes in credit policies. In response to the risks posed by climate change, regulators may adjust credit policies, such as raising lending standards or restricting lending to certain high-risk areas. These policy changes may affect banks' lending structure and earnings patterns, which in turn may affect their level of risk-taking. Fifth, sectoral exposures, where extreme weather events hit different sectors to varying degrees, resulting in higher exposures to banks' credit portfolios in specific sectors. Particularly for banks that are highly dependent on climate-sensitive industries, their asset quality may be severely affected by industry risk concentration.

Based on the above theoretical framework, the first hypothesis of this paper is formulated.

H1: An increase in the frequency of climate extremes leads to an increase in the level of risk in the banking sector.

3.2 Heterogeneity Analysis of Extreme weather events Affecting Banks' Credit Risk

In this study, we delve into the impact of extreme weather events on bank risk and pay special attention to the differences in risk resilience among banks of different ownership (including public enterprises, central state-owned enterprises and local state-owned enterprises). Public enterprise and central state-owned enterprise banks, benefiting from the breadth of their services, the diversity of their businesses and their mature organisational and management systems, are perceived to have a stronger ability to adapt to and mitigate extreme weather risks. In contrast, local state-owned enterprise banks, especially those whose businesses are concentrated in specific regions and closely linked to the local economy, may exhibit lower risk resilience in the face of extreme climate events and are more susceptible to the adverse impacts of extreme climate events due to the limitations of their scope of business, the homogeneity of their industries, and the insufficiency of their risk management resources.

Accordingly, the second hypothesis is proposed in this study.

H2: Public and central state-owned enterprise banks are significantly more resilient to extreme climate risks than local state-owned enterprise banks.

3.3 Analysis of the Moderating Role of Extreme Weather Events Affecting Banks' Credit Risk

The theoretical framework of this study is rooted in the financial theory of bank risk management, with a special focus on the key economic indicator of regional bank competitiveness. Regional bank competitiveness refers to a bank's competitiveness and market share within a given region, and it is a measure of a bank's competitive position in the local financial market. Regions with higher regional bank competitiveness are likely to have more financial service providers, which promotes financial innovation and service quality, and may also exacerbate competitive pressures among banks. A higher degree of regional bank competition may mitigate the negative impacts of extreme weather events by fostering innovation and efficiency in financial services and by increasing the ability of banks to adapt and be resilient to these events. However, it may also exacerbate banks' risk-taking behavior if competition is too intense, which requires further empirical testing to determine the exact direction and intensity of its effects.

For this reason, we propose a third hypothesis.

H3: The degree of regional bank competition has a moderating effect on the impact of extreme weather events on bank risk.

4. Research Design

4.1 Data Sample

This paper mainly focuses on the impact of climate change on bank risk, with 42 A-share listed banks from 2007 to 2022 as the research object, and the definition of variables is shown in Table 1.

For climate risk measurement indicators, this paper refers to the research method of Ren et al. (2010) to construct the core explanatory variables. This paper selects 1981-2010, which is the most widely used in the world, as the 30-year climate benchmark, and defines the 90th percentile and 10th percentile temperatures as extreme high temperature thresholds and extreme low temperature thresholds, and the 95th percentile precipitation values as extreme heavy precipitation thresholds, respectively. Day-by-day temperature and precipitation data from meteorological stations across the country were collected during the baseline period, and the percentile method was applied to calculate the number of days of extreme weather events and extreme precipitation events per year in the cities where the banks are located during the sample period of 2007-2022, with the source of data being the National Meteorological Information Centre. In addition, for bank risk indicators, this paper chooses the non-performing loan ratio (NPL) as an explanatory variable, representing the level of bank risk-taking; and major indicators such as the capital adequacy ratio (CAR), cost-to-income ratio (CIR), gearing ratio (DAR), and banking industry boom index (BankingI) are selected as control variables. The data sources are CSMAR China Economic and Financial Research Database and Wind Information Financial Terminal, and some missing data are filled in by consulting China Statistical Yearbook and China Environmental Statistical Yearbook, etc. The sample frequency is annual. The sample frequency is annual. In order to prevent the extreme values of some variables from being too large, the relevant variables are rounded up to the nearest 1%.

Table 1. Description of Variable Names and Meanings

	Variable	Meaning of variable
Explained Variable	NPL	Non-performing loan ratio, i.e. non-performing loans/total loans
Explanatory variable	Htd	Number of days of extreme heat
	Ltd	Number of extreme low temperature days
	Ipd	Extreme precipitation days
Moderating Variables	HHI	Regional bank competitiveness
Bank level	CAR	Capital adequacy ratio, i.e. core capital/risk-weighted assets
	CIR	Cost-to-income ratio, i.e. operating costs/total revenue
	DAR	Gearing ratio, i.e. total liabilities/total assets of the bank
Macro level	BankingI	Banking Sentiment Index, which reflects the general health of the

		banking sector and market sentiment
	GDP	Cumulative year-on-year GDP growth rate of the province
	M2	The year-on-year growth rate of money supply M2
	CPI	Cumulative year-on-year CPI growth rate in China

4.2 Model Setting

This study relies on a panel regression model, and the Hausman test shows that the panel models used are all fixed effect models, so the following benchmark regression model is constructed:

$$NPL_{i,t} = \beta_0 + \beta_1 \times Climate_{s,t} + \beta_2 \times BankControls_{i,t} + \beta_3 \times MacroControls_{i,t} + u_{i,t} + v_{i,t} + \varepsilon_{i,t}$$

Where $NPL_{i,t}$ is the non-performing loan ratio of bank at time ; $Climate_{s,t}$ is bank i's region s in year t, including the number of days with extreme high temperature, the number of days with extreme low temperature, and the number of days with extreme heavy precipitation; $BankControls_{i,t}$ is a bank-level control variable, $MacroControls_{i,t}$ is a macro-level control variable, is a moderator variable, $u_{i,t}$ is an individual fixed effect, $v_{i,t}$ is a time fixed effect; and $\varepsilon_{i,t}$ is a random error term.

5. Empirical Results and Analyses

5.1 Descriptive Statistics

Table 2 below reports the results of descriptive statistics of the explanatory variables, core explanatory variables, and control variables of A-share listed banks from 2007-2022. It can be seen that the level of bank risk shows significant variability among different regions, and there are differences in the frequency and intensity of extreme weather events in each region.

Table 2. Descriptive Statistics of Main Variables

VARIABLES	mean	sd	min	max
NPL	1.474	1.431	0	23.57
Htd	56.05	13.67	22	115
Ltd	31.19	12.37	3	59
Ipd	10.94	4.734	2	28
HHI	0.1	0.0371	0.0517	0.267

CAR	13.18	2.539	3.4	40.3
CIR	32.27	6.595	17.7	72.68
DAR	93.19	1.917	76.48	113.7
BankingI	74.43	8.754	60.5	89.1
GDP	8.514	3.394	-0.2	17.1
M2	13.47	4.95	8.1	27.68
CPI	2.585	1.614	-0.7	5.9

5.2 Benchmark Regression

Table 3 shows the results of the benchmark regression of the effect of extreme weather on the level of credit risk of banks. The results show that the number of extreme low temperature days is significantly positive at the 5 per cent level. This indicates that there is a positive association between extreme weather events and bank risk level, providing empirical support for hypothesis H1. The credit risk faced by banks increases when extreme low temperature weather occurs.

Extreme cold weather, which is often accompanied by other natural phenomena such as frost and rain, has far-reaching impacts on agricultural output and business operations that often extend beyond hot weather events in scope and magnitude. In addition, the knock-on effects of these weather events, ranging from reductions in agricultural production to declines in business revenues, are ultimately reflected in the quality of banks' assets, increasing their credit risk.

Table 3. Benchmark Model Regression Results

	(1)	(2)	(3)
VARIABLES	NPL	NPL	NPL
Htd	-0.008*		
	(-1.87)		
Ltd		0.011**	
		-2.24	
Ipd			0.027*
			-1.85
CAR	-0.144**	-0.142**	-0.143**
	(-2.55)	(-2.48)	(-2.51)
CIR	0.023	0.023	0.024
	-1.17	-1.17	-1.2
DAR	-0.092	-0.081	-0.088
	(-1.33)	(-1.15)	(-1.24)
BankingI	0.049	0.07	0.06

	-0.98	-1.43	-1.22
GDP	-0.011	-0.015	-0.025
	(-0.18)	(-0.26)	(-0.43)
M2	0.007	-0.098**	0.004
	-0.21	(-2.30)	-0.1
CPI	0.094	0.239*	0.107
	-0.67	-1.76	-0.72
Observations	626	626	626
Company FE	YES	YES	YES
Year FE	YES	YES	YES
r2_a	0.242	0.242	0.244
F	13.81	14.21	14.08

5.3 Robustness Test

In this study, given the dynamic nature of bank risk levels, i.e., banks' exposures in earlier periods may have a significant continuum effect on their current risk profile, we introduced a lagged period of bank risk levels as a core explanatory variable in our analytical model. And to ensure that the findings are not only statistically significant but also remain robust under different model settings, we adopt a dynamic panel data model and conduct a series of robustness tests using the generalised method of moments (GMM) estimation. The GMM method, as a widely recognised technique in the analysis of dynamic panel data, is able to effectively deal with the potential endogeneity problem and thus enhance the accuracy and credibility. As shown in Table 4, the coefficients of the lagged terms are statistically significant and have the same sign as expected, indicating that bank risk is time-continuous. The significance and sign of the core explanatory variables have not changed significantly from the previous results, further confirming the robustness of our empirical results.

Table 4. Robustness Test

	(1)	(2)	(3)
VARIABLES	NPL	NPL	NPL
L.NPL	0.309***	0.310***	0.311***
	(12.32)	(12.41)	(12.39)
Htd	-0.003		
	(-0.91)		
Ltd		0.008*	
		(1.67)	
Ipd			0.004

			(0.39)
CAR	-0.083***	-0.082***	-0.083***
	(-3.00)	(-2.96)	(-2.99)
CIR	-0.005	-0.005	-0.005
	(-0.55)	(-0.52)	(-0.57)
DAR	-0.074*	-0.068	-0.073*
	(-1.73)	(-1.60)	(-1.70)
BankingI	-0.004	0.001	0.001
	(-0.11)	(0.04)	(0.02)
GDP	0.016	0.015	0.014
	(0.49)	(0.46)	(0.42)
M2	-0.016	-0.079	-0.023
	(-0.25)	(-1.15)	(-0.36)
CPI	0.114	0.193	0.130
	(0.83)	(1.38)	(0.95)
Observations	587	587	587
R-squared	0.366	0.369	0.366
Company FE	YES	YES	YES
Year FE	YES	YES	YES
F test	0	0	0
r2_a	0.293	0.295	0.292
F	15.18	15.34	15.13

5.4 Heterogeneity Analysis

In considering the heterogeneity analysis of the impact of extreme weather on banking, we can classify the observed data into three main categories according to the nature of the banks: public enterprises, central state-owned enterprises and local state-owned enterprises. Regression analyses for each of these three categories can reveal the different responses and adaptive capabilities of different types of banks in the face of extreme weather events.

As shown in Table 5, the Htd coefficient is the largest in public enterprises, i.e., the impact of extreme hot weather on the risk level of banks is most significant in public enterprises. This may reflect the fact that public firms may feel the change in risk level more quickly when faced with extreme weather events due to their more flexible mode of operation and higher market sensitivity.The coefficient of Ltd is the largest in local state-owned enterprises (SOEs), i.e., the coefficient of extreme low-temperature weather is the largest in local SOEs, indicating that these banks may be more susceptible to the impact of extreme low-temperature events. This may be due to the fact that local SOEs are more closely linked to the local economy, which may be more dependent on climate-sensitive industries such as agriculture or tourism.Ipd coefficients are largest for local SOEs, i.e., among local SOEs, suggesting that extreme precipitation may have the greatest impact on the level of risk for such banks. This may be due to the fact that extreme precipitation events may lead to natural disasters such as floods, which can cause damage to local infrastructure and property, which in turn affects the banks' asset quality and loan recovery. Therefore, hypothesis 2 is tested.

Table 5. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Public Enterprise	Central State-owned Enterprise	Local State-owned Enterprise	Public Enterprise	Central State-owned Enterprise	Local State-owned Enterprise	Public Enterprise	Central State-owned Enterprise	Local State-owned Enterprise
VARIABLES	NPL	NPL	NPL	NPL	NPL	NPL	NPL	NPL	NPL
Htd	-0.017**	-0.001	-0.009						
	(-2.15)	(-0.19)	(-1.23)						
Ltd				0.007	-0.001	0.020**			
				(0.53)	(-0.22)	(2.03)			
Ipd							0.003	0.011	0.050***
							(0.14)	(0.64)	(2.75)
CAR	-0.194***	-0.184***	-0.179***	-0.209***	-0.183***	-0.163***	-0.206***	-0.185***	-0.173***
	(-3.00)	(-5.08)	(-3.96)	(-3.21)	(-4.97)	(-3.58)	(-3.18)	(-5.10)	(-3.88)
CIR	0.023	0.007	0.025	0.025	0.007	0.022	0.024	0.006	0.027
	(1.20)	(0.73)	(1.17)	(1.31)	(0.77)	(1.02)	(1.24)	(0.69)	(1.25)
DAR	-0.201**	0.070	-0.102	-0.209**	0.071	-0.065	-0.206**	0.070	-0.094
	(-2.02)	(1.12)	(-1.23)	(-2.08)	(1.13)	(-0.78)	(-2.04)	(1.11)	(-1.14)
Banking	-0.104	0.078	0.103**	-0.125	0.073	0.138**	-0.120	0.085	0.102**

I						*			
	(-1.05)	(0.62)	(2.03)	(-1.25)	(0.56)	(2.79)	(-1.19)	(0.71)	(2.09)
GDP	0.157	-0.060	-0.056	0.202	-0.056	-0.071	0.191	-0.072	-0.069
	(1.23)	(-0.48)	(-1.06)	(1.58)	(-0.44)	(-1.38)	(1.48)	(-0.59)	(-1.34)
M2	-0.081	-0.017	0.047	-0.186	-0.010	-0.104	-0.147	-0.023	0.127
	(-0.53)	(-0.28)	(0.35)	(-1.12)	(-0.13)	(-0.78)	(-0.97)	(-0.42)	(0.96)
CPI	0.387	-0.103	0.003	0.695	-0.107	0.201	0.610	-0.094	-0.082
	(0.94)	(-0.26)	(0.01)	(1.62)	(-0.28)	(0.75)	(1.50)	(-0.25)	(-0.31)
Observations	228	124	274	228	124	274	228	124	274
Company FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
F test	0.0494	0	0	0.136	0	0	0.144	0	0
r2_a	-0.0108	0.756	0.361	-0.0337	0.756	0.368	-0.0351	0.756	0.377
F	1.628	20.36	9.575	1.380	20.36	9.810	1.365	20.45	10.12

5.5 Analysis of Moderating Effects

This paper uses the bank Herfindahl index HHI as a moderating variable, which is calculated as:

$$HHI_i = \sum_{i=1}^{n} S_i^2 = \sum_{i=1}^{n} \frac{N_i^2}{N}$$

Where is the share of branches of a bank *i* of all bank branches in the city *s* where the bank is located, and represents the number of branches of a bank *i*. The bank Herfindahl index, HHI, is a key measure of competitiveness, with a range of values from 0 to 1. Ideally, a HHI index of 0 implies that the bank exhibits a high degree of competitiveness, with bank branches spread all over the place, and with customers enjoying a wide range of choices. In contrast, a HHI of 1 suggests monopolization by a single bank and a lack of competition. Lower values of the HHI reflect more competitive banks and better protection of customers‘ interests, while higher values imply an increased monopoly by the bank, which may pose a threat to consumers' interests. The data source for calculating the Herfindahl Index is the financial licensing information released by the China Banking and Insurance Regulatory Commission (CBIRC), and the time horizon is also 2007-2022.

The regression results are shown in Table 6. The interaction terms Htd×HHI and Ltd×HHI are significantly negative at the 5% level, and Ipd×HHI is significantly positive at the 5% level, suggesting that both climate extremes are moderated by the degree of regional bank competition on bank risk.

The negative effect of regional competition on bank risk-taking is mainly reflected in its ability to promote banks to improve the efficiency and effectiveness of risk management. In a competitive market, banks tend to focus more on risk assessment and control mechanisms in order to maintain market share and attract customers. This competitive pressure prompts banks to adopt diversified business strategies to reduce the impact of a single event on their overall business by diversifying their investment and credit portfolios. In addition, intense market competition has also incentivized banks to be more innovative and develop new financial products and services to meet the challenges posed by extreme weather events, thus mitigating to some extent the potential negative impact of extreme low and high temperature events on their business.

However, regional competition may also exacerbate the impact of extreme weather events on bank risk in some cases. For example, during extreme precipitation events, banks may be exposed to increased credit risk due to damage to customer assets, as well as liquidity risk due to increased demand for liquidity caused by the disaster. Therefore, while regional competition can improve banks' risk management capabilities, when faced with specific extreme weather events, banks still need to take additional measures, such as strengthening disaster contingency plans and improving capital adequacy ratios, to ensure that they are able to withstand the risks associated with these events.

In summary, the impact of regional competition on banks' risk-taking is multidimensional. On the one hand, it helps to mitigate the negative impact of extreme weather events on banking operations by facilitating banks to improve their risk management, business diversification and market adaptability. On the other hand, specific types of extreme weather events, such as extreme precipitation, may exacerbate the risks faced by banks in highly competitive regions, possibly in terms of asset quality, liquidity, etc.

Table 6. Moderating Effects of Regional Bank Competitiveness

	(1)	(2)	(3)
VARIABLES	NPL	NPL	NPL
Htd	0.019**		
	(1.99)		
Ltd		0.011	
		(1.00)	
Ipd			-0.055**
			(-2.04)
HHI	11.851**	9.230**	-7.041*

	(2.37)	(2.51)	(-1.69)
Htd×HHI	-0.200**		
	(-2.12)		
Ltd×HHI		-0.216**	
		(-2.05)	
Ipd×HHI			0.565**
			(2.19)
CAR	-0.140***	-0.136***	-0.138***
	(-5.03)	(-4.91)	(-4.98)
CIR	0.006	0.008	0.008
	(0.87)	(1.03)	(1.06)
DAR	-0.104**	-0.100**	-0.104**
	(-2.42)	(-2.34)	(-2.43)
BankingI	-0.032***	-0.030***	-0.033***
	(-3.17)	(-2.98)	(-3.35)
GDP	0.064***	0.050**	0.066***
	(3.18)	(2.49)	(3.26)
M2	0.023	0.027*	0.028*
	(1.46)	(1.84)	(1.84)
CPI	0.156***	0.182***	0.164***
	(4.23)	(4.90)	(4.49)
Constant	626	12.690***	14.538***
	0.120	(2.99)	(3.43)
Observations	626	626	626
R-squared	0.120	0.129	0.120
F test	0	0	0
r2_a	0.106	0.115	0.106
F	8.382	9.118	8.417

5.6 Conclusions and Policy Recommendations

5.6.1 Main Conclusions

Based on the panel data of A-share listed banks from 2007 to 2022, this study provides insights into the impact of extreme weather events on banks' risk-taking levels. The specific conclusions are as follows:

There is a positive relationship between extreme weather and bank risk. The number of extreme low temperature days in the region where the bank is located has a significant positive impact on the bank's non-performing loan ratio. This indicates that the occurrence of extreme weather events increases the probability of bank credit defaults, thus increasing the level of bank risk. What's more, differences in risk resilience of banks of different ownership. The impact of climate change shows significant heterogeneity among public enterprises, central state-owned enterprises and local state-owned enterprises. It is found that local SOEs are more vulnerable to extreme weather than public and central SOEs. After that, the moderating effect of the degree of regional bank competition. The positive effect is reflected in the fact that competition stimulates banks to improve their risk assessment and response mechanisms, increasing their adaptability and resilience to external shocks such as extreme weather. By diversifying their businesses, banks have effectively diversified their risks and improved the stability of the financial system.

However, competition may also bring negative impacts, e.g., under extreme weather conditions, fierce market competition may prompt banks to adopt riskier strategies, increasing asset quality and liquidity risks. Therefore, in this competitive environment, banks need to find a balance between pursuing market share and maintaining risk control, to make full use of the innovation and efficiency gains brought about by competition, while guarding against the risks that may accumulate as a result of competition, and to achieve sustainable development.

5.6.2 Policy Recommendations

Improvement and integration of climate risk assessment models. The banking industry must recognise the far-reaching impact of climate change on credit risk and improve its risk assessment models on this basis. This requires banks to adopt more advanced methods for quantifying climate risk, such as climate sensitivity analysis and Climate Value at Risk (Climate VaR) models, as well as structured stress tests based on different climate scenarios. These tools not only provide a quantitative assessment of climate risk, but also reveal the interactions between climate risk and other financial risks. Regulators should promote the establishment of industry standards and best practices for climate risk assessment to ensure that banks are able to consistently identify, assess and report climate risk and integrate it into their overall risk management framework.

Capital adequacy and climate risk buffer alignment. Given the potential long-term impact of climate change on banks' capital adequacy, regulators need to revisit current capital requirements and consider introducing the concept of climate risk-weighted assets (CRWA). This measure would require banks to hold additional capital for assets with higher climate risk exposure, thereby increasing their absorptive capacity for climate-related losses. At the same time, regulators should encourage banks to establish a dynamic capital planning process to adapt to future changes in climate risk and to ensure banks' capital adequacy under different climate scenarios.

Climate risk stress testing and financial system resilience enhancement. The banking industry and regulators should regularly conduct stress tests that incorporate climate factors to assess the potential impact of different climate scenarios on banks' balance sheets and profitability. These stress tests should cover both physical and transition risks and consider their potential impact on bank liquidity, funding costs and credit losses. Through these tests, banks will be able to identify their vulnerabilities and put in place appropriate risk mitigation measures to improve the resilience of the financial system to climate shocks. In addition, banks should develop business continuity plans based on the results of the stress tests to ensure that critical operations can be maintained in the event of extreme climate events.

Standardise climate risk disclosure and improve market transparency. Regulators should set strict norms for climate risk disclosure, requiring banks to disclose key information on their climate risk exposure, risk management strategies, and the financial impact of climate risk. This will enhance market transparency, boost investor and stakeholder confidence in banks' climate risk management capabilities, and facilitate more informed investment decisions. Transparent disclosure will also help the market price and diversify climate risk, thereby reducing risk across the financial system.

Promotion of green financial products and sustainable investments. The banking sector should actively promote the development of green finance by providing green credit, green bonds and other climate-related financial products. At the same time, banks should incorporate environmental, social and governance (ESG) factors into the investment decision-making process and support sustainable development projects and enterprises through responsible investment strategies. This will not only help direct capital flows to more environmentally friendly and socially responsible sectors, but also help banks play an active role in supporting global climate governance and the SDGs. Through these measures, the banking sector will be able to better manage climate risks while contributing to environmentally and socially sustainable development.

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