

Climate Risk and Industrial Structural Upgrading: Evidence from Chinese Urban Panel Data

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Abstract. With the intensification of global climate change, extreme weather events are occurring frequently, and the emergence of extreme temperatures is having a significant impact on all sectors. In China, climate risk has become a major challenge to economic development. This paper explores the impact of extreme temperatures on industrial restructuring using Chinese urban panel data from 2001 to 2021. It is found that (1) extreme temperatures have a positive promotion effect on industrial structure upgrading; (2) extreme temperatures promote industrial structure upgrading by lowering the output of the primary industry and thus promoting industrial structure upgrading; (3) extreme temperatures have a significantly greater promotion effect on industrial structure upgrading in regions with lower per capita income than in regions with higher per capita income levels; (4) extreme temperatures have a heterogeneous effect on regions dominated by different industries, but the effect of extreme temperature on industrial structure upgrading is more obvious for the primary industry-led regions. The above results provide a theoretical basis for the government to formulate policies to cope with climate change for different regions and put forward policy suggestions for climate risk adaptation strategies in industrial structure adjustment, which can better cope with the challenges posed by climate change by optimizing industrial layout and structure.

Keywords: climate risk; extreme temperatures; industrial structural upgrading; policy recommendations.

1. Introduction

The global climate security situation is becoming increasingly severe, and the impact of the increase and enhancement of extreme weather events on China's economic growth and financial stability continues to be highlighted. In recent years, the frequency of extreme weather events around the world has brought serious challenges to human society. 2021 July, Henan suffered a "one-in-a-thousand-years" hefty rainfall; the maximum hourly rainfall in Zhengzhou reached 201.9 mm, breaking through the historical extremes in mainland China, urban flooding, underground inundation, flash floods led to the deaths of hundreds of people and direct economic losses of more than 100 billion yuan. In 2022, the Yangtze River Basin suffered a rare summer and autumn drought, and the water level of Poyang Lake and Dongting Lake dropped to historic lows, affecting agriculture, shipping and ecology; in the same year, Chongqing and Sichuan caused forest fires due to the persistent extreme high temperatures, and the power supply was tense, highlighting the complexity of the climate crisis. In 2023, in the first half of the year, Europe suffered a record-high winter temperature, and the United States experienced a "quick freeze." "In the first half of 2023, Europe was hit by record winter temperatures, the United States experienced a "freezing" cold snap, Tropical Cyclone Gabrielle hit New Zealand, torrential rains hit Brazil, and wildfires spread in Canada. These extreme weather events not only cause massive casualties and property losses locally but also amplify economic losses globally through global supply chains, international trade, etc. Between 1991 and 2020, the average value of China's climate risk index increased by about 58% compared to the average value between 1961 and 1990 (China Meteorological Administration Climate Change Centre, 2021). In 2022, the average summer temperature in the middle and lower reaches of the Yangtze River in China reached the highest level in the same period in history since 1961. The National Strategy for Adaptation to Climate Change 2035 states that the long-term adverse impacts and sudden extreme events brought about by climate change have become important risks facing China in the process of

achieving socialist modernization. The frequent occurrence of extremely high and low temperatures has a significant impact on people's daily production and life, which not only directly affects the stability and yield of agricultural production but also has a wide range of impacts on other economic sectors, such as industry and services. Therefore, in-depth exploration of the economic impacts of extreme weather events has become an important task in China's policies and actions to address climate change.

As the mainstay of the national economy, the transformation and upgrading of industries are directly related to national competitiveness and the quality of development. Against the background of the deep adjustment of the global pattern and the accelerated evolution of the scientific and technological revolution, the optimization of industrial structure has become a strategic pivot for building a modern industrial system and cultivating international competitive advantages. In order to implement the decision-making and deployment of the CPC Central Committee on building a modern industrial system, the National Development and Reform Commission issued a new version of the Guidance Catalogue for the Adjustment of Industrial Structure in December 2023, which makes it clear that with the real economy as the foundation, and innovation drive as the lead, the process of new industrialization will be effectively promoted by strengthening the guidance of investment direction and curbing the expansion of inefficient production capacity. This policy initiative aims to optimize the efficiency of resource allocation, enhance the modernization of the industrial chain, and provide institutional guarantee and path guidance for high-quality economic development. At present, China's economic structure is in a critical period of profound change, and the transformation and upgrading of various fields has been effective. Agricultural production capacity continues to increase, building a solid foundation for guaranteeing national food security; the manufacturing industry is accelerating in the direction of intelligence and low-carbonization, and the leading role of scientific and technological innovation is becoming more and more prominent; the modern service industry is flourishing, and there is a deep integration of the digital economy and traditional industries. In the process of transitioning to high-quality development, the industrial structure has continued to improve. However, there are still obvious shortcomings: there is still a gap between the proportion of modern service industry and the international advanced level, the ecology of high-value-added industries needs to be improved, and there is a lack of coordination of industrial development among regions. Meanwhile, some traditional industries are still facing prominent problems such as high resource consumption, heavy environmental load and low economic efficiency. Therefore, industrial restructuring is an ongoing and long-term topic that requires our continuous attention and concern.

It is of great practical significance to study the impact of extreme temperatures on industrial structures, and its core value is to provide a scientific basis and strategic support for the construction of a climate-resilient economic system. Firstly, with the intensification of global warming, the frequent occurrence of extremely high temperatures and other events forms differentiated impacts on different industries, which directly threatens the stability of the industrial economy. By clarifying the impact mechanism and path of extreme temperature on different industries, we can accurately identify the climate-vulnerable industries and optimize the regional layout to avoid the over-agglomeration of high-risk industries, and at the same time, formulate a graded emergency response plan to protect the operation of key industrial chains. Secondly, by analyzing the mechanism and overall trend of industrial structural adjustment, we can provide theoretical support and policy suggestions for coping with extreme temperatures and achieving sustainable economic development. For example, promoting the transformation of labor-intensive industries to automated industries can not only reduce the sensitivity to climate change but also promote the optimization and upgrading of economic structure. In addition, the study of the impact of extreme temperatures on industrial restructuring is not only an inevitable choice to cope with the climate crisis, but also a key path to promote high-quality economic development, social equity and coordinated regional development, and the results will inject core power for the realization of the "dual-carbon" goal, the construction of a resilient society and the sustainable development of humanity.

Most of the existing literature on the relationship between temperature extremes and specific industries focuses on analyzing the impacts of temperature extremes on a specific industry, primarily agriculture. For example, temperature extremes affect plant photosynthesis, leading to reduced crop yields [1]; global maize and wheat yields declined by 3.8 percent and 5.5 percent, respectively, between 1980 and 2008 as a result of climate change (mainly due to increased temperatures), suggesting that temperature extremes have posed a threat to global food security [2]; There are also macro-level studies that focus on analyzing the impact of climate change risk on regional agricultural economic output, which have found that climate risk can have a direct impact on agricultural economic output, and at the same time it can also adversely affect agricultural economic development by increasing the severity of natural hazards [3,4,5]. The impacts of extreme temperatures on agriculture are heterogeneous, with the impacts concentrated in areas with lower income levels or higher temperatures [6]. There is a gap in existing research in terms of overall industrial structure. Therefore, this paper starts from the overall perspective of the role of extreme temperatures on industrial structure upgrading to reveal the overall impact of extreme temperatures on industrial restructuring and its mechanism path. Using Chinese urban panel data from 2001 to 2021, this paper explores the impact of extreme temperatures on industrial restructuring. It is found that (1) extreme temperatures have a positive promotion effect on industrial structure upgrading; (2) extreme temperatures promote industrial structure upgrading by lowering the output of the primary industry; (3) extreme temperatures promote industrial structure upgrading significantly more than that in regions with lower per capita income levels than in regions with higher per capita income levels; and (4) extreme temperatures have a heterogeneous effect on regions dominated by different industries but the effect on industrial structure upgrading is more obvious in areas dominated by primary industries. This study grasps the specific impact of extreme temperatures on industrial structure from a macro perspective and provides a reference for the government to introduce relevant industrial policies in time and formulate corresponding industrial development strategies to cope with climate risks.

The marginal contributions of this paper are of far-reaching significance at both the theoretical and practical levels. First, at the theoretical level, this paper is the first to systematically assess the impact of extreme temperatures on the economic system from the perspective of the industrial structure as a whole and deeply analyze the mechanism of how extreme temperatures affect the output path of the primary industry and then contribute to the upgrading of the industrial structure. It fills the theoretical gap between the relationship between extreme temperature and industrial structure upgrading in the existing research, and at the same time, provides a new perspective and analytical framework for the cross-research in the fields of climate change economics and industrial economics and improves the related research system. Secondly, in order to analyze more precisely the differences between different regions affected by extreme temperatures, this paper carries out the heterogeneity analysis from two key dimensions, namely, per capita income and industrial structure, and reveals the unique performance and challenges of economically developed and underdeveloped regions as well as different types of industries in coping with extreme temperatures, which provides a solid scientific basis for the government to formulate differentiated and targeted policies according to the actual situation of the regions and industries. Thirdly, in terms of practical significance, in the face of the increasingly severe climate security situation, the research results of this paper are crucial for the government to control the trend of industrial structure change, which can help to anticipate and respond to the opportunities and challenges brought by industrial restructuring in advance; by strengthening the climate monitoring and early warning, enhancing the capacity of emergency management, and promoting the innovation of green technology and other measures, the government can respond to the uncertainty changes brought by the risk of extreme weather more proactively and rapidly. By strengthening climate monitoring and early warning, enhancing emergency management capacity, and promoting green technology innovation, the government will be able to respond more actively and quickly to the uncertainties caused by extreme weather risks, optimizing macroeconomic policy control based on the findings of the study, and flexibly using fiscal, monetary, industrial and

other policy tools to guide the reasonable flow of resources, which will promote sustainable economic and social development; and, ultimately, these efforts will reduce the negative impact of extreme weather on people's livelihoods, safeguard the basic needs and well-being of the people, and maintain social harmony and stability.

2. Literature review

Temperature extremes. In terms of the impact of temperature extremes on industrial development, extreme temperatures have a direct impact on agriculture. The negative impact of extreme heat on maize and soybean yields in the Midwestern United States is two to three times greater than the impact of average temperature increases, with yields potentially being reduced by 30-80 percent, and irrigation is unable to fully offset this negative impact [7,8]; temperature extremes, through their impact on plant photosynthesis, result in crop yields [1]; global maize and wheat yields declined by 3.8% and 5.5%, respectively, between 1980 and 2008 as a result of climate change (mainly temperature increases), suggesting that temperature extremes have posed a threat to global food security [2]. Extreme high temperatures in China's North China Plain significantly accelerated the wheat senescence process, leading to yield decline. For every 1°C increase in temperature, the wheat growing season is shortened by about 7 days, and yields are reduced by about 4-7% [9]. There are also macro-level studies that focus on analyzing the impact of climate change risk on regional agricultural economic output, which have found that climate risk can have a direct impact on agricultural economic output, and at the same time, it can also adversely affect agricultural economic development by increasing the severity of natural disasters [3,4,5]. The impacts of extreme temperatures on agriculture are heterogeneous, with their effects concentrated in areas with lower income levels or higher temperatures [6].

Climate risks can affect the structure of labor force employment in two main ways. On the one hand, climate shocks can directly alter the structure of the labor force. Most non-agricultural sectors are significantly and negatively affected by extreme heat, while high-energy cyclones negatively affect other sectors of the economy, as well as mining and utilities, which can offset the positive output effects of construction [10]. There is also a strong link between temperature and industrial activity (Dell et al., 2012). During hot weather, such as extreme heat, the supply of outdoor labor is reduced, which can lead to significant declines in employment in industries such as agriculture, forestry, mining and construction [11]. On the other hand, policies to combat climate change can also lead to changes in the industrial structure of the labor force. These studies suggest that policy measures to address climate change will not only affect employment in specific industries but will also trigger a restructuring of the labor force at a broader economic level.

Upgrading of industrial structure. Industrial structure upgrading: In the field of economics, industrial structure upgrading is a concept that has received widespread attention. Its core concept refers to the gradual evolution and upgrading of the composition and proportion of industries in the economic system from lower to higher forms. This transformation not only involves the adjustment and evolution of shares among industries but also represents the improvement of production efficiency and innovation capacity. And the concept was further deepened in 2008. It was believed that the advanced industrial structure manifests itself in the transfer of resources and factors from sectors with lower labor productivity to sectors with higher labor productivity and that this process of transfer not only promotes the increase of industrial shares of sectors with higher labor productivity but also promotes the increase of the overall labor productivity, thus realizing significant enhancement of "structural efficiency"[12]. This process of transfer not only promotes an increase in the share of industries in sectors with higher labor productivity but also promotes an increase in overall labor productivity, thus achieving a significant increase in "structural efficiency." With the change of the times and social progress, the transformation and upgrading of industrial structure has become an important topic of academic research in the context of the new normal economy, which has triggered in-depth discussions by many scholars. Existing studies have concluded that the

upgrading and evolution of industrial structure is essentially a simultaneous deepening of social, industrial and modernisation processes, and is the core driving force to promote stable economic growth and maintain sustainability [13,14]; the upgrading of industrial structure can contribute to the balancing of the industrial structure, and enhance the degree of industrial synergies and associations; and the optimisation of the industrial structure in the double-cycle economic model can effectively expand the domestic consumer market, activate consumer demand, and stimulate economic growth by increasing employment opportunities and improving income distribution [15,16]; existing studies have found that upgrading the industrial structure can effectively alleviate the poverty problem and promote balanced inter-regional development through spatial transmission effects; there is also an increasingly close synergistic relationship between upgrading the industrial structure and ecological optimisation, the Through economic development, urbanisation process and policy guidance, the two can be synchronised [17,18]. Industrial structure upgrading plays a significant role in promoting the new urbanization process and, at the same time, has a more significant impact on the improvement of the quality and quantity of employment in the northeastern and southeastern coastal regions of China, while the impact on the central and western regions is relatively small [19,20]. Research results have shown that industrial structure upgrading is not an isolated economic phenomenon but a complex process that is deeply intertwined and comprehensively influenced by multiple factors. It is closely related to regional characteristics, policy orientation and technological innovation, and its core objective is to achieve a harmonious symbiosis and comprehensive development pattern of economic prosperity, social stability and environmental sustainability.

Many scholars have carried out in-depth studies on the factors affecting the upgrading of industrial structures. The following are some of the representative results: Fixed asset investment plays a key role in the adjustment of industrial structure, which can adjust the weights of various fields of the economy and promote the transfer of labor to the service industry [21]. Changes in the domestic industrial structure are influenced by multiple factors, such as supply and demand, technological innovation, policy orientation, urbanization process and the role of economic globalization [22]. There is a significant role of labor mobility in industrial structure upgrading, which is mainly divided into two perspectives: horizontal mobility and vertical mobility. From the perspective of horizontal mobility, the differences in the upgrading of China's regional industrial structure are mainly due to the cross-regional mobility of labor [23], which is because the rationalization and advanced industrial structure is greatly determined by the industries in which the inflow and outflow of labor are engaged [24]. At the early stage of urbanization, the inflow of labor from rural to urban areas can significantly promote the optimization and upgrading of the regional industrial structures [25,26]. From the perspective of vertical flow, the analysis mainly focuses on inter-industry flow, and through inter-industry labor flow, it can promote the shift of production factors from low-efficiency industries to high-efficiency industries, which in turn upgrades the industrial structure [27,28]. The inflow of labor triggers the agglomeration of factors at the regional level, which promotes the increase of the level of specialization and agglomeration of the regional economy. Its positive impact is manifested through the endowment effect, consumption demand effect, human capital effect and resource allocation effect, injecting impetus for regional economic development. In addition, the government's fiscal expenditure strategy also plays a key role in the transformation and upgrading of industrial structure [29]; the development of education can promote the mobility of labor between different industries and the upgrading within industries [30]. With the progress of science and technology, technological innovation has gradually become the decisive driving force in industrial structure upgrading, and through the spatial spillover effect, it drives the synergistic development of neighboring regions. With the increasing improvement of market mechanisms, the positive role of Internet technology in the transformation and upgrading of industrial structures is becoming more and more obvious, and its influence should not be ignored [31]. Together, these studies show how science and technology, policy and market environment jointly affect the transformation and upgrading of industrial structure.

Throughout the existing research, there have been many scholars who have conducted detailed studies on the specific impact of climate change-related risks on various aspects of China's real

economy and analyzed and sorted out the role, nature and influencing factors of industrial structure upgrading. In terms of the climate risk and industrial structure, the existing literature mainly focuses on the impact on a specific kind of industry, such as the impact on agriculture, industry and other industries, but there is no clear conclusion on how the overall. However, there is no clear conclusion on how the overall industrial structure changes. Given this, this paper, based on existing studies, comprehensively measures the extreme temperature indicators at the municipal level in China, introduces the index of industrial structure upgrading, examines the mechanism of extreme weather risk on industrial structure upgrading through the mechanism analysis, and carries out the heterogeneity analysis according to different per capita incomes and industrial structures, and researches the regional variability of the impacts of extreme temperature on industrial structure upgrading in different levels of economic development and based on different industrial structures. It also analyses the heterogeneity according to different per capita incomes and industrial structures and studies the regional differences in the impact of extreme temperatures on industrial structure upgrading under different degrees of economic development and different industrial structures. Under the gradually severe climate security situation, the research in this paper is of great significance for us to control the trend of industrial structure change, actively and quickly respond to the uncertainty brought by extreme weather risk, optimize the government's macroeconomic policy regulation, proactively guard against the adverse impacts brought by extreme weather risk, and safeguard people's livelihood and welfare.

3. Theoretical analysis and research hypotheses

This paper analyses the impact mechanism of extreme temperature on the evolution of industrial structure based on the unique perspective of industrial share change. Extreme temperature, as an important natural environmental variable, has a profound impact on people's production activities, especially on the primary industry, which directly relies on the exploitation and use of natural resources. The primary industry covers a wide range of natural resource-extracting fields such as agriculture, mining, fishery, etc. The operation of these industries is highly dependent on the stability and suitability of the natural environment and is therefore very vulnerable to the direct disturbance of natural environmental changes such as extreme temperatures.

Take agriculture as an example; as the core component of the primary industry, it can be subdivided into two major segments, namely, planting and breeding. In the plantation sector, rising temperature extremes have significantly exacerbated climate risks, as evidenced by increased crop spikelet sterility and reduced assimilate accumulation, which in turn have led to a direct decline in crop yields and a severe impact on the agricultural economy [32,33]. In farming, temperature extremes also pose a serious challenge by affecting the normal development and reproductive cycles of livestock, which ultimately leads to reduced production of livestock and related products [34,35].

Labor and capital, as important factors of production, will spontaneously flow from the primary sector to industry and services in search of higher returns and more stable production environments, thus mitigating the economic losses caused by the damage to the primary sector [36].

From the perspective of industrial linkage theory, the impact of extreme temperatures on an industry does not exist in isolation. However, through the transmission mechanism of the industrial chain, it will spread to other industries that are closely linked to it, thus triggering an overall adjustment of the industrial structure. Extreme temperatures will also indirectly affect a number of industries by influencing people's consumption preferences and demand structure. In the construction industry, extreme temperatures may lead to deterioration of outdoor construction conditions and reduced construction efficiency, while people's demand for housing comfort and disaster resilience increases, prompting the construction industry to pay more attention to energy efficiency, heat preservation, disaster prevention and other properties during the design and construction process, leading to changes in the demand for related technologies and materials [37]. The energy sector will also be affected, with extremely high temperatures increasing the demand for cooling and extremely

low temperatures increasing the demand for heating, driving the restructuring of energy production and consumption. For the tertiary sector, extreme temperatures may affect people's willingness to travel and consume, as well as generate emerging demand for services such as climate disaster warning services and disaster prevention and mitigation advisory services.

The frequent occurrence of extreme temperatures not only directly damages the natural environment but also has far-reaching negative impacts on primary industries such as agriculture, mining and fisheries, as well as on the lower end of the secondary sector. When extreme temperatures significantly suppress the output of the primary sector, a series of knock-on effects ensue. Primary sector output shrinks, and its economic efficiency is significantly reduced due to lower production and possible market price volatility, with significantly lower comparative earnings. This multidimensional impact prompts a reallocation of labor between industries. In pursuit of more stable economic income and a better working environment, labor and capital, as important factors of production, will spontaneously shift from the low-level, weather-prone traditional production end, such as the agricultural production segment of the primary industry and the open-cast mining operation of the mining industry in the secondary industry, to the more advanced and less weather-prone part of the industrial chain in search of higher earnings and a more stable production environment, thus alleviating the impact of the economic losses caused by damage to the primary industry, such as high-end manufacturing in industry and finance, science and technology, and education in the service sector [36]. This process of labor mobility is accompanied by a large concentration of factors of production, with more capital, technology and talents converging in the industrial and service sectors, while the changing needs of people for the secondary industry and the increasing demand for the tertiary industry, such as climate disaster early warning services, further promote the development and expansion of these two industries. With the continuous development of the industrial and service sectors, their share in the national economy has gradually expanded. In contrast, the share of the primary industry has relatively decreased due to the suppression of extreme temperatures and the outflow of production factors. This dynamic change in the share of industries marks the gradual transformation of the industrial structure from one dominated by the primary industry to one dominated by the secondary and tertiary industries and the realization of an advanced industrial structure.

Based on the above analysis, the following hypotheses are proposed in this paper:

Hypothesis 1: Extreme temperatures have a positive contribution to industrial structural upgrading.

Hypothesis 2: Extreme temperatures accelerate the optimization and upgrading of the industrial structure by reducing the output of the primary industry and inducing the transfer of resources and factors to other industries.

In addition, the impact of temperature extremes on industrial structural upgrading is not static but is characterized by significant heterogeneity. Existing studies have analyzed this issue in depth from two dimensions: per capita income and different industries. On the one hand, regions with lower per capita incomes often face lagging infrastructure development, such as agriculture, forestry and water conservancy, as well as insufficient awareness and capacity to cope with climate risks, which makes them more vulnerable to extreme temperatures, and the process of upgrading their industrial structure may be accelerated as a result [3,6]. On the other hand, the impacts of extreme temperatures on both agricultural and industrial outputs cannot be ignored [38,9]; therefore, when analyzing the impacts of extreme temperatures on industrial structure, the differences in the dominant industries in different regions should also be fully considered in order to reveal the specific effects of extreme temperatures in the context of different industrial structures.

Based on this, the paper further proposes the following hypotheses:

Hypothesis 3: Temperature extremes contribute significantly more to the upgrading of the industrial structure in areas with lower levels of per capita income than in areas with higher levels of per capita income.

Hypothesis 4: Temperature extremes have different effects on areas dominated by different industries. However, it is more pronounced in areas dominated by primary industries.

4. Empirical design

4.1. Sample selection.

This paper is based on the panel data of 292 prefecture-level cities in 34 provinces across China from 2001 to 2021. The data come from the National Bureau of Statistics, provincial statistical yearbooks, China Urban Statistical Yearbook, China Regional Economic Statistical Yearbook, and China Weather Network.

4.1.1 Description of variables

Explanatory variables. Temperature extremes (dummy). Temperatures are significantly affected by geographic regional differences, with different cities having different geographic conditions such as latitude, longitude and slope, leading to differences in average annual temperatures across the region. In addition, this study focuses on the impact of extreme climate change risks on industrial restructuring, with a particular focus on how the magnitude of extreme changes in temperature affects macroeconomic variables.

In recent years, a growing body of literature has used climate variance to measure the risk of climate warming [5]. Accordingly, in this paper, the standardized mean annual temperature is selected as the core explanatory variable to measure the risk of extreme climate change. Standardized annual mean temperature is the difference between the annual mean temperature of a city and the annual mean temperature of the city's historical reference period (2001-2005), divided by the annual mean temperature of that historical period. It is used to measure the magnitude of temperature change or the degree of anomaly relative to historical levels. The data used in this paper are derived from the daily climate data of the China Weather Network, covering the annual average temperatures (in terms of annual mean) from 2001 to 2021.

It is taken into account that a significant impact on the industrial structure is only possible when temperature changes reach a certain magnitude, i.e., extreme temperatures. In this paper, the standardized annual mean temperature is treated as a dummy variable (*temp*) in the following way. First, the first dummy variable (*temp_high*) is constructed using the 90% quantile of the standardized annual mean temperature, i.e., observations greater than the 90% quantile are assigned a value of 1 (indicating the risk of extreme warming), and vice versa, 0. Second, the second dummy variable (*temp_low*) is constructed using the 50% quantile of the observations for which the change of the temperature is negative (cooling of the climate), where the values of the observations that are less than the negative 50% quantile of the observation are 1 (indicating extreme climate cooling risk) and zero otherwise. Finally, a new dummy variable $temp = temp_high + temp_low$ is constructed, which is 1 (indicating extreme climate change risk) if the observation is greater than the 90% quantile or less than the negative 50% quantile, and zero otherwise.

Explained Variables. Industrial structure upgrading (*INDU*): Concerning the existing literature [39], the industrial structure hierarchy coefficient is introduced to explain the level of industrial structure upgrading in each province and city, and the measurement formula is: $q_1 \times 1 + q_2 \times 2 + q_3 \times 3$. q_i is the proportion of output value of the *i*th industry.

Mediating variables. Agricultural output (*lgrain*). Based on the previous theoretical analyses, agricultural output is selected as the mediating variable in this paper.

Control variables. In order to prevent the existence of omitted variables from biasing the model estimation results, several control factors have also been included in the paper: the level of economic development (*lgdp*), the size of the population (*lpopu*), the average wage of employees (*income*); the use of foreign capital (*lfdi*); the government's self-interested capacity (*fiscalp*); the level of science and technology (*tech*); and the level of information technology (*dig*).

Table 4-1 Variable Definitions

Variable type	variable name	variable symbol	Description of variables
explanatory variable	Upgrading of industrial structure	indu	$\sum_{i=1}^3 q_i \times i$, i is the share of industry.
explanatory variable	extreme temperatures	dummy	1 if there are local temperature extremes; 0 otherwise.
	Primary sector output		
	Level of economic development	gdp1	
	Size of population	lpopu	
intermediary variable	The average wage of employees	income	Natural logarithm of gross regional product Natural logarithm of household population
	Use of foreign capital	lfdi	Natural logarithm of the average wage of employees Natural logarithm of the amount of foreign capital used in the year
control variable	Government self-reliance	fiscalp	Expenditure from the general budget of the local treasury in the amount of RMB 10,000,000/ Revenue from the general budget of the local treasury in the amount of RMB 10,000,000
		tech	Expenditure on science in yuan/ Expenditure from the general budget of local finance in yuan
	scientific technological level	dig	Natural logarithm of the number of mobile phone subscribers at the end of the year
	information level		

4.1.2 Descriptive statistical analyses

Table 4-2 demonstrates the results of descriptive statistics for the variables. The mean value of extreme temperature is 0.354 with a standard deviation of 0.478, reflecting the concentration trend and data fluctuation of the sample regions on this indicator. The mean value of the level of industrial structure upgrading is 225.1, the standard deviation is 15.27, the minimum value is 176.6, and the maximum value is 283.6, indicating that the level of industrial structure upgrading varies greatly among regions. For other control variables, their sample data also fluctuate around the mean value.

Table 4-2 Descriptive Statistics of Variables

	(1)	(2)	(3)	(4)	(5)
variant	number of individuals	average value	(statistics) standard deviation	minimum value	maximum values
dummy	6,153	0.354	0.478	0	1
indu	6,009	225.1	15.27	176.6	283.6
lgdp	6,009	16.02	1.157	12.24	19.88
Income	6,007	10.37	0.761	2.283	12.21
fiscalp	6,025	2.753	1.756	0.649	21.53
lfdi	5,280	9.421	2.064	0.693	14.94
dig	5,954	5.476	1.547	0	13.36
tech	5,441	0.0132	0.0152	0	0.207

4.1.3 Univariate analysis

Regions with and without extreme temperatures differ in many ways. In order to visualize the differences between the two types of enterprises, this paper divides the enterprises into two groups according to whether they have extremely high or low temperatures and conducts the test of differences between groups. Table 4-3 shows the results of the test of differences between groups. From the table, we can see that the mean value of the industrial structure upgrading level in the region with extreme temperature is 232.3, which is higher than the mean value of the industrial structure upgrading level in the region without extreme temperature, which is 230.1. It is significantly negative at the level of 1 percent. The above results show that the industrial structure upgrading in regions with extreme temperatures is significantly higher than that in regions without extreme temperatures. From the perspective of control variables, the difference between foreign capital dependence and informationisation level is not evident in the two groups of samples. The level of economic development, the average wage of employees and the population size of regions with extreme temperatures are slightly higher than those without extreme temperatures. The above results indicate that there are significant differences in the characteristics of regions with and without extreme temperatures.

Table 4-3 Tests for Differences in Means

Variables	G1(0)	Mean1	G2(1)	Mean2	MeanDiff
indu	1460	230.1	664	232.3	-2.224***
lgdp	1460	16.50	664	16.72	-0.215***
Income	1460	10.38	663	10.65	-0.262***
fiscalp	1460	1.907	664	1.862	0.0460
lfdi	1325	10.50	593	10.58	-0.0760
dig	1448	5.865	663	6.122	-0.257***
tech	1272	0.0190	650	0.0180	0.002**

4.2. Modelling

Before the model selection, this paper carried out the fixed effect estimation and random effect estimation of panel data, respectively, and selected the estimation methods through the Hausman test. Finally, the Hausman test supported the estimation results of fixed effects on each model. In order to

systematically analyze the impact of extreme temperatures on the advanced industrial structure, the following two-way fixed-effects benchmark models for year and city are designed.

$$\begin{aligned} indu_{it} = & \alpha + \beta_1 dummy_{it} + \beta_2 lgdp_{it} + \beta_3 lpopu_{it} + \beta_4 income_{it} + \beta_5 fiscalp_{it} + \beta_6 tech_{it} \\ & + \beta_7 dig_{it} + \lambda_i + \mu_t + \varepsilon_{it} \end{aligned} \quad (1)$$

In equation (1), the explanatory variable *indu* denotes the industrial structure upgrading of region *i* in year *t*, and the main explanatory variable *dummy* is the extreme temperature situation of region *i* in year *t*. The control variables include data on the level of economic development (*lgdp*), population size (*lpopu*), the average wage of employees (*income*), foreign investment dependence (*lfdi*), government self-conscience ability (*fiscalp*), level of science and technology (*tech*); and level of informatization (*dig*). In addition, λ_i denotes area fixed effects, μ_t denotes time fixed effects, and ε_{it} is the error term.

5. Empirical results and analyses

5.1. Baseline regression results

Before proceeding to model testing, the paper first conducted a Hausman test on the estimated fixed and random effects of the model, which supported the use of a fixed effects model.

Table 5-1 reports the empirical results of the effect of extreme temperatures on industrial structure upgrading under two-way fixed effects, where column (1) of Table 5-1 demonstrates the regression results without the inclusion of control variables and column (2) demonstrates the regression results with the inclusion of control variables. The coefficient of the effect of extreme temperature on industrial structure upgrading is 0.962 when no control variables are added, and the coefficient is 0.900 when control variables are added, both of which are positive and significant at the 1% level, and Hypothesis 1 is verified. The regression results in column (2) show that extreme temperature plays a significant role in promoting the upgrading of industrial structure, which may be due to the negative impact of extreme temperature on the primary industry, which will directly promote the transfer of labor and factors of production to the secondary and tertiary industries. The aggregation of factors of production will further promote the expansion of the share of the secondary and tertiary industries. At the same time, people's demand for the secondary industry and the tertiary industry demand for climatic disaster warning services and so on is increasing. Finally, hypothesis 1 can be verified. At the same time, people's demand for the secondary industry changes and the demand for the tertiary industry's climate disaster warning service increases, which finally leads to the advanced industrial structure.

Table 5-1 Impact of temperature extremes on industrial structure upgrading

	(1)	(2)
VARIABLES	indu	indu
dummy	0.962***	0.900***
	(3.56)	(3.43)
lgdp		-0.828
		(-0.62)
Income		1.329***
		(3.18)
fiscalp		-0.316*
		(-1.82)
lfdi		0.043
		(0.27)
dig		1.878***
		(3.29)
tech		10.589
		(0.72)
Constant	224.761***	214.138***
	(2,356.93)	(10.43)
Observations	6,009	4,729
R-squared	0.902	0.926
id FE	YES	YES
Year FE	YES	YES

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5.2. Robustness tests

To ensure the reliability and robustness of the model conclusions and research findings, this paper conducts robustness tests in three ways: replacing the explanatory variables, shrinking the tail treatment, lagging the explanatory variables by one period, and testing for endogeneity by the instrumental variable method.

Replacement of explanatory variables. In terms of industrial share, industrial structure upgrading often implies that the share of the tertiary industry gradually increases. Therefore, this paper uses the share of the added value of the tertiary industry in GDP to replace the original explanatory variable industrial structure upgrading index. From the empirical results in Table 5-2, it can be seen that after replacing the explanatory variables, extreme temperature still positively promotes industrial structure upgrading, and the research conclusions are still valid.

Table 5-2 Replacement of explanatory variables

	(1)
VARIABLES	y
dummy	0.4903**
	(0.204)
lgdp	-8.6927***
	(1.075)
Income	0.4285
	(0.591)
fiscalp	-0.0460
	(0.132)
lfdi	0.0350
	(0.114)
dig	0.6484
	(0.449)
tech	49.8410***
	(14.369)
Constant	169.6111***
	(17.754)
Observations	4,729
R-squared	0.884

Robust t-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Treatment of indentations. In order to exclude the influence of outliers on the regression results, the variables are trimmed down and then regressed. The specific regression results are shown in Table 4-3, which show that after trimming down, the extreme temperature still promotes the upgrading of industrial structure significantly. The conclusion of the study is still valid.

Table 5-3 Indentation Processing

	(1)
VARIABLES	y
dummy	0.8607***
	(0.258)
lgdp	-1.2121
	(1.222)
Income	1.9311
	(1.276)
fiscalp	-0.4346*
	(0.221)
lfdi	0.0585
	(0.150)
dig	1.9586***
	(0.589)
tech	18.1370
	(21.705)
Constant	213.6684***
	(18.277)
Observations	4,729
R-squared	0.924

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Explanatory variables: Explanatory variables lagged by one period. In policy assessment and empirical analyses, there may be bidirectional causality between control variables and core explanatory variables. In order to avoid potential endogeneity due to the simultaneous effect of the control variables on both the explained and explanatory variables, this paper lags the control variables by one period for robustness testing.

Table 5-4 Variable Lags

	(1)
VARIABLES	y
fdummy	0.9191*** (0.254)
lgdp	-0.5963 (1.176)
Income	2.8208** (1.257)
fiscalp	-0.4246** (0.205)
lfdi	0.1507 (0.155)
dig	2.0577*** (0.604)
tech	17.5006 (20.154)
Constant	194.2160*** (17.250)
Observations	4,729
R-squared	0.928

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Changing fixed effects. In order to test whether the current city-year clustering double fixed-effects model is the most accurate, this paper uses five different fixed-level regression and compares its coefficients with the change in confidence intervals; the specific changes are shown in Figure 1; the specific five fixed-effects models are as follows:

- (1) Model a: Ordinary OLS regression without any fixed effects or clustering.
- (2) Model b: controlling for year-fixed effects only.
- (3) Model c: controlling for province and year interaction fixed effects.
- (4) Model d: controlling for city and year-fixed effects and clustering at the city level.
- (5) Model e: controlling for province and year-fixed effects and clustering at the city level.

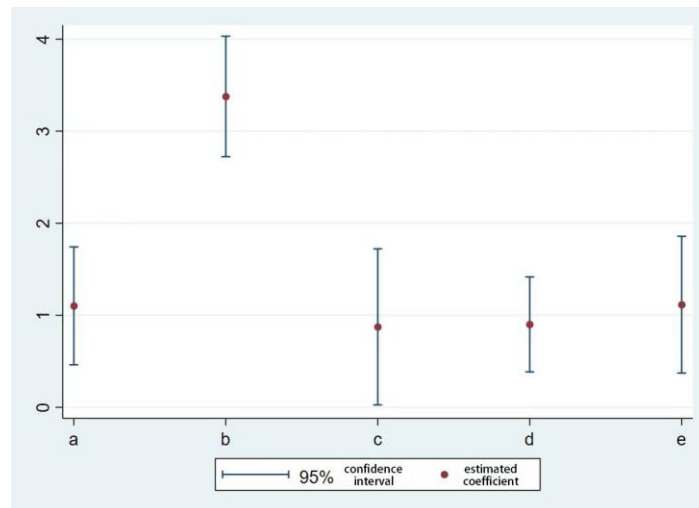


Fig. 1 Plot of confidence intervals for different fixed effects estimates

Based on the analysis of the results of the confidence intervals of the different fixed effects model tests, it can be seen that model d, i.e., the city-year two-way fixed effects and clustering of the model at the city level, has the narrowest confidence intervals, which indicates that the estimation of this model is the most accurate and verifies the robustness of the regression results.

Changing the clustering hierarchy. In order to test whether the estimation of the core variable (dummy) is affected by the way the standard errors are calculated, this study uses five different clustering levels for regression. It compares the coefficients with the changes in the confidence intervals, which are shown in Fig. 2, and the specific five clusters are as follows:

- (1) Model a: Baseline model (no clustering): controls only for city and year fixed effects, does not take into account within-group correlations, and may lead to standard error underestimation.
- (2) Model b: Heteroskedasticity robust standard errors relax the homoskedasticity assumption but do not deal with temporal or spatial autocorrelation.
- (3) Model c: province-year interaction clustering controls for correlations within the same year in the same province and applies to disturbances in provincial time trends that may arise from policy shocks.
- (4) Model d: City-level clustering relaxes the assumption of time-series correlation within cities and applies to the case of significant individual city differences.
- (5) Model e: dual clustering of cities and provinces: considers both individual city and province-year level clustering effects, providing the most rigorous standard error estimates.

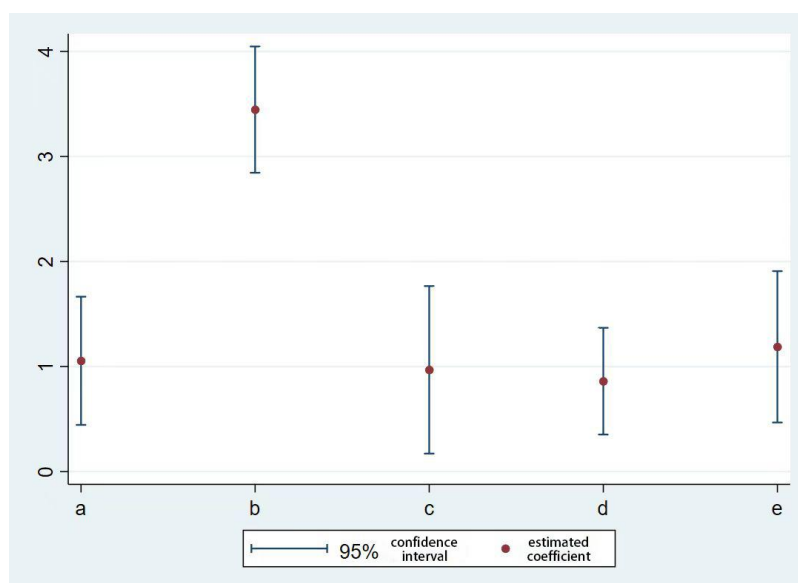


Fig. 2 Plot of confidence intervals for different clustering levels

According to the analysis of the results of the confidence intervals of the tests at different clustering levels, it can be seen that the clustering intervals of all levels do not contain zero values. The confidence interval of the clustering at the city level is the narrowest, which indicates that the clustering results at this level are the most accurate and verify the robustness of the regression results.

5.3. Mechanism testing

In the theoretical hypothesis part of this paper, it is argued that extreme temperatures, by reducing the output of the primary industry, cause labor and capital to be reallocated and industrial shares to change, thus promoting industrial structure upgrading. For this reason, This article adopts the two-step test method[40]. The first step on the relationship between the core explanatory variables and the mediating variables to verify, and the second step adopts the theoretical interpretation of the relationship between the mediating variables and the explanatory variables to discuss.

In the following model, $lgdp$ is the mediating variable, and the specific test results are shown in Table 4-5.

$$indu_{it} = \beta_0 + \beta_1 dummy + \gamma_1 \sum Controls + \lambda_i + \mu_t + \varepsilon_{it} \quad (2)$$

$$lgdp_{it} = \beta_0 + \beta_2 dummy + \gamma_2 \sum Controls + \lambda_1 + \mu_t + \varepsilon_{it} \quad (3)$$

Table 5-5 Mechanism Tests

	(1)
VARIABLES	y
dummy	-0.0215*** (0.008)
lgdp	0.3641*** (0.055)
lpopu	0.1141 (0.254)
Income	0.0482 (0.037)
lsale	-0.0058 (0.018)
fiscalp	0.0295*** (0.006)
lfdi	0.0131** (0.005)
Constant	6.6780*** (1.304)
Observations	5,275
R-squared	0.973

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

From the empirical analysis results presented in Table 5-5, it can be seen that the coefficient of the impact of extreme temperatures on the output of the primary industry is 0.0215, which is significantly negative at a statistical level of 1 percent. This data result has a clear economic meaning, which clearly indicates that extreme temperatures have a significant inhibitory effect on the output of the primary industry. From the perspective of real economic logic, abnormal changes in extreme temperatures, whether extreme high or extreme low weather, can cause severe damage to the natural production conditions on which the primary industry relies. Taking agriculture as an example, in extremely hot

weather, soil moisture evaporation is accelerated, crops face serious water shortage dilemmas, and photosynthesis efficiency is reduced, leading to disruption of the crop growth cycle and may even lead to widespread drought disasters, causing crop yields to fall sharply. In freezing weather, crops are prone to frost damage, affecting their normal growth and development, which will also result in reduced yields. About fisheries, extreme temperatures can affect the ecological environment of marine and freshwater waters, altering key factors such as water temperature and dissolved oxygen content, which in turn affects the growth, reproduction and migration of fish, resulting in a decline in fisheries catches.

When extreme temperatures significantly suppress primary sector output, a series of knock-on effects ensue. The output value of the primary sector shrinks, and its economic efficiency is significantly reduced due to the decline in output and the possible volatility of market prices, with a significant reduction in comparative earnings. In this case, the market mechanism will play an adjusting role. Labor and capital, as important factors of production, will spontaneously flow from the primary sector to industry and services in search of higher returns and more stable production environments so as to mitigate the economic losses caused by the damage to the primary sector [36].

From the perspective of industrial linkage theory, the impact of extreme temperatures on an industry does not exist in isolation. However, through the transmission mechanism of the industrial chain, it will spread to other industries that are closely linked to it, thus triggering an overall adjustment of the industrial structure. Extreme temperatures will also indirectly affect a number of industries by influencing people's consumption preferences and demand structure. In the construction industry, extreme temperatures may lead to deterioration of outdoor construction conditions and reduced construction efficiency, while people's demand for housing comfort and disaster resilience increases, prompting the construction industry to pay more attention to energy efficiency, heat preservation, disaster prevention and other properties during the design and construction process, leading to changes in the demand for related technologies and materials [37]. The energy sector will also be affected, with extremely high temperatures increasing the demand for cooling and extremely low temperatures increasing the demand for heating, driving the restructuring of energy production and consumption. For the tertiary sector, extreme temperatures may affect people's willingness to travel and consume, as well as generate emerging demand for services such as climate disaster warning services and disaster prevention and mitigation advisory services.

The frequent occurrence of extreme temperatures not only directly damages the natural environment but also has far-reaching negative impacts on primary industries such as agriculture, mining and fisheries, as well as on the lower end of the secondary sector. When extreme temperatures significantly suppress the output of the primary sector, a series of knock-on effects ensue. Primary sector output shrinks, and its economic efficiency is significantly reduced due to lower production and possible market price volatility, with significantly lower comparative earnings. This multidimensional impact prompts a reallocation of labor between industries. In pursuit of more stable economic income and a better working environment, labor and capital, as important factors of production, will spontaneously shift from the low-level, weather-prone traditional production end, such as the agricultural production segment of the primary industry and the open-cast mining operation of the mining industry in the secondary industry, to the more advanced and less weather-prone part of the industrial chain in search of higher earnings and a more stable production environment, thus alleviating the impact of the economic losses caused by damage to the primary industry, such as high-end manufacturing in industry and finance, science and technology, and education in the service sector [36]. This process of labor mobility is accompanied by a large concentration of factors of production, with more capital, technology and talents converging in the industrial and service sectors, while the changing needs of people for the secondary industry and the increasing demand for the tertiary industry, such as climate disaster early warning services, further promote the development and expansion of these two industries. With the continuous development of the industrial and service sectors, their share in the national economy has gradually expanded. In contrast, the share of the primary industry has relatively decreased due to the suppression of extreme

temperatures and the outflow of production factors. This dynamic change in the share of industries marks the gradual transformation of the industrial structure from being dominated by the primary industry to being dominated by the secondary and tertiary industries, realizing the advanced industrial structure. The advanced industrial structure not only implies the optimization and upgrading of the industrial structure but also represents the enhancement of the overall efficiency of the economy, the strengthening of the ability to resist risks and the improvement of the quality of development, laying a solid foundation for the sustainable development of the economy.

5.4. Heterogeneity analysis

The above findings verify the theoretical assumptions and prove that extreme temperatures can effectively promote industrial restructuring through the mechanism of reducing the output of the primary industry. Whether this promotion effect will be heterogeneous due to the different qualities between the levels of economic development of the region, this paper further investigates the extreme temperature's effect on the upgrading of the industrial structure at the levels of different per capita incomes [5] and different industrial structures. Different promotion effects.

Per capita income heterogeneity.Regions with different levels of economic development have different per capita incomes and are affected by extreme temperatures. In this paper, the sample is divided into two groups for regression according to whether the per capita income of the prefecture-level city where it is located in that year is higher than the different per capita income levels in the country in the same year and the specific regression results are shown in Table 4-6.

Table 5-6 Per capita income heterogeneity

	(1)	(2)
VARIABLES	indu	indu
dummy	0.267	0.998***
	(1.31)	(3.52)
lgdp	-4.699***	3.702
	(-4.64)	(1.62)
Income	1.830	1.134**
	(1.29)	(2.57)
fiscalp	0.330	-0.138
	(1.08)	(-0.65)
lfdi	0.310**	0.041
	(2.09)	(0.17)
dig	0.961	0.966
	(1.39)	(1.58)
tech	3.792	24.373
	(0.31)	(1.20)
Constant	282.110***	143.235***
	(14.20)	(4.16)
Observations	2,330	2,380
R-squared	0.959	0.893
id FE	YES	YES
Year FE	YES	YES

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In Tables 5-6, column (1) is for regions with per capita income higher than the national median per capita income for all cities, and column (2) is for regions with per capita income lower than the

national median per capita income for all cities; the coefficient of column (1) is not significant, and the coefficient of column (2) is significantly positive. We can thus learn that extreme temperatures are more significant for the level of industrial structure upgrading in regions with lower per capita income, in line with Hypothesis 3.

Leading industries are different.Regions with different dominant industries are affected differently when facing extreme temperatures, and they also have different industrial bases. Therefore, this paper divides the samples into four groups for regression based on the regions with primary industry output greater than the national median, primary industry output and secondary industry output greater than the national median, and the specific regression results are shown in Tables 5-7.

Table 5-7 Heterogeneity of Dominant Industries

	(1) Primary industry as the leading industry	(2) Non-primary sector is dominant	(3) Secondary industry as the leading industry	(4) Non-secondary sector is dominant
VARIABLES	indu	indu	indu	indu
dummy	1.350*** (3.23)	0.428* (1.97)	0.554*** (2.86)	1.313*** (2.74)
lgdp	3.326 (1.33)	-4.759*** (-3.67)	-4.294*** (-3.14)	7.195*** (2.61)
Income	1.212** (2.08)	0.896** (2.00)	2.021 (1.38)	1.098*** (3.16)
fiscalp	-0.240 (-1.11)	-0.103 (-0.48)	-0.290 (-1.26)	-0.283 (-1.25)
lfdi	0.100 (0.41)	0.090 (0.59)	0.111 (0.86)	-0.197 (-0.74)
dig	2.051** (2.33)	0.591 (1.10)	0.719* (1.72)	2.000** (2.22)
tech	48.293 (1.46)	20.502 (1.35)	13.322 (0.79)	8.724 (0.37)
Constant	139.864*** (3.86)	298.839*** (13.46)	268.675*** (10.61)	90.189** (2.13)
Observations	2,311	2,402	2,584	2,118
R-squared	0.807	0.943	0.932	0.941
id FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

According to the regression results, the coefficient of extreme temperature affecting industrial structure upgrading is 1.350 for the areas dominated by the primary industry and 0.554 for the areas dominated by the secondary industry, both of which are significantly positive at the 1 percent level. The former coefficient is larger than the latter one, which can be learned that the extreme temperature promotes the more obvious effect of the areas dominated by the primary industry. At the same time, in the area not dominated by the primary industry, the coefficient of the influence of extreme temperature on industrial structure upgrading is 0.428, which is significantly positive at the 10% level. The coefficient is smaller and less significant probably due to the high level of economic development of the place; the tertiary industry accounts for a higher proportion, and the ability to resist the natural risk is stronger; in the area not dominated by the secondary industry, the coefficient of the influence of extreme temperature on industrial structure upgrading is 1.313, which is significantly positive at

the 1% level. The former one is larger than the latter one. The coefficient is significantly positive at the 1% level, and the reason for the larger coefficient may be due to the fact that it includes areas dominated by the primary industry, which has a more obvious role in promoting industrial structure upgrading and thus increases the coefficient to a certain extent. In summary, the extreme temperature has different promotion effects on different industry-led areas, and its promotion effect on primary industry-led areas is more obvious, which verifies hypothesis 4.

6. Conclusions and policy recommendations

The long-term adverse effects and sudden extreme events brought about by climate change have become important risks facing China in the process of achieving socialist modernization. It has also become an important task for China now to deeply explore the economic impacts of extreme weather events and formulate reasonable policies to cope with climate change promptly. Against the above background, this paper verifies the impact of extreme temperatures on industrial structure upgrading. It analyses the intermediate path of the mechanism of action through a two-way fixed-effects model using data from 2001 to 2021. The paper draws the following main conclusions: (1) Extreme temperatures have a positive effect on industrial structure upgrading. (2) Extreme temperatures promote industrial structure upgrading by reducing the output of primary industry. (3) The promotion effect of extreme temperature on industrial structure upgrading in regions with lower per capita income levels is significantly greater than that in regions with higher per capita income levels. (4) Extreme temperatures have different promotional effects on regions dominated by different industries. However, the promotion effect is more obvious in areas dominated by primary industries.

Based on the above research, this paper makes the following policy recommendations:

(1) For primary industry-dominated areas (e.g., central and western agricultural provinces), promote agricultural intensification and climate-smart transformation by subsidizing the promotion of high-temperature/drought-resistant crop varieties (e.g., water-saving wheat, drought-resistant maize), and supporting innovative irrigation systems, to reduce the impact of extreme temperatures on agricultural output. Establish an agriculture-non-agriculture industry linkage mechanism to encourage deep processing of agricultural products (e.g., cold chain logistics, biomass energy). Timely introduction of relevant policies to take advantage of the transfer of agricultural labor forced by extreme temperatures and guide farmers to move to secondary and tertiary industries in an orderly manner.

(2) For high-income or secondary- and tertiary-industry-dominated regions (e.g., the eastern seaboard), strengthen the "climate resilience" of the service industry and green technological innovations and incentivize enterprises to research and develop high-temperature-adaptive technologies (e.g., energy-saving materials for buildings, liquid-cooling technologies for data centers) through tax incentives, to reduce the negative impact of temperature extremes on the efficiency of industrial production. Developing "climate service-oriented" new industries and fostering services such as climate insurance and carbon asset management to turn climate risks into new business opportunities.

(3) Optimizing the factor allocation mechanism in extreme weather conditions and improving labor mobility policies across regions. Concerning labor migrating due to reduced agricultural production, establish an employment information platform for "climate migrants" and give priority to guiding them to local industrial parks or neighboring cities in the service sector and setting up notable climate-adaptation credits, providing low-interest loans to small and medium-sized enterprises in regions severely affected by extreme temperatures, and supporting their transformation into high-value-added industries (e.g., eco-tourism, renewable energy).

(4) Strengthening regional synergies and compensation mechanisms and establishing a system for sharing the benefits of cross-regional industrial transfers. For example, eastern provinces have built green industrial parks in western agricultural areas through the "enclave economy" model, sharing the benefits of industrial upgrading and mitigating regional development imbalances under climate

shocks. Pilot "horizontal transfer payments for climate adaptation," whereby funds are provided from high-income to low-income regions at the provincial or inter-provincial level, earmarked for the construction of disaster-resistant infrastructure in agriculture (e.g., reservoirs, protective forests).

(5) Dynamic monitoring and policy evaluation: construct a database on extreme temperature-industry upgrading response, integrate satellite remote sensing, enterprise electricity consumption and employment data, and monitor in real-time the trend of industrial changes in different regions to provide a basis for policy adjustment. Post-assessment of the effects of climate adaptation policies will be introduced to regularly assess the actual contribution of policies (e.g., agricultural subsidies, industrial transfer) to industrial structure upgrading so as to avoid the mismatch of resources caused by the "one-size-fits-all" approach.

References

- [1] Wahid, A., Gelani, S., Ashraf, M., 2007. Heat tolerance in plants: An overview. *Environmental and Experimental Botany* 61(3), 199-223.
- [2] Lobell, D.B., Schlenker, W., Costa-Roberts, J., 2011. Climate trends and global crop production since 1980. *Science* 333(6042), 616-620.
- [3] Dell, M., Jones, B.F., Olken, B.A., 2012. Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics* 4(3), 66-95.
- [4] Chen, S., Gong, B., 2021. Response and adaptation of agriculture to climate change: Evidence from China. *Journal of Development Economics* 148, 102557.
- [5] Ding, Y., Sun, Q., 2022. Impact of climate risk on China's agricultural economic development: Heterogeneity and mechanism analysis. *Financial Studies* 9(0), 1-18.
- [6] Kalkuhl, M., Wenz, L., 2020. The impact of climate conditions on economic production: Evidence from a global panel of regions. *Journal of Environmental Economics and Management* 103, 102360.
- [7] Williams, A.N., Nearing, M., Habeck, M., 2001. Global climate change: Implications of extreme events for soil conservation strategies and crop production in the midwestern United States. In: *Sustaining the Global Farm, ISCO Meeting*, pp. 509-515.
- [8] Schlenker, W., Roberts, M.J., 2009. Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences* 106(37), 15594-15598.
- [9] Chen, Y., Zhang, Z., Tao, F., 2018. Impacts of climate change and climate extremes on major crops productivity in China at a global warming of 1.5 and 2.0°C. *Earth System Dynamics* 9(2), 543-562.
- [10] Hsiang, S.M., 2010. Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. *Proceedings of the National Academy of Sciences* 107(35), 15367-15372.
- [11] Graff Zivin, J., Neidell, M., 2014. Temperature and the allocation of time: Implications for climate change. *Journal of Labour Economics* 32(1), 1-26.
- [12] Liu, W., Zhang, H., Huang, Z., 2008. An examination of the height of China's industrial structure about the process of industrialisation and regional differences. *Economics Dynamics* (11).
- [13] Jiang, Z., Bai, Y., 2006. Analysis of the connotation and influencing factors of industrial structure upgrading. *Contemporary Economic Research* (10).
- [14] Wu, F., Liu, R., 2013. Industrial upgrading and the construction of independent innovation capacity: An empirical study based on interprovincial panel data in China. *Chinese Industrial Economy* (5).
- [15] Tang, D., 2014. Research on the power of sustained economic growth under the perspective of industrial optimization and upgrading. *Yunnan Social Science* (4).
- [16] Hou, J.Y., 2022. The influence effect and trend of industrial structure upgrading on the expansion of domestic consumption. *Business and Economics Research* 22(1).
- [17] Zhang, H., 2021. Inclusive financial development, industrial structure upgrading and poverty alleviation: An empirical analysis based on spatial spillovers and threshold effects. *Research on Financial Development* (6).
- [18] Xu, X., Kou, J., Zheng, Z., 2022. Coupled coordination of industrial structure upgrading and ecological environment optimisation. *Macroeconomic Research* (8).

- [19] Tu, J., Jiang, L., Xu, G., Han, M., 2021. The interactive impacts of scientific and technological innovation, industrial structure upgrading, and new urbanisation in the Yangtze River Delta city cluster. *Urban Development Research* (12).
- [20] Liu, Q., Li, Z., 2021. Consumption upgrading, industrial structure and employment structure. *Mathematical Statistics and Management* (6).
- [21] Geng, X., 2010. Analysis of the impact of fixed asset investment on changes in industrial structure. *Mathematical Statistics and Management* (6).
- [22] Guo, H., Wang, X., 2019. Research on the transformation and upgrading of China's industrial structure under the new normal. *Research on Business Economy* (1).
- [23] Ren, D., 2015. Research on the relationship between economic agglomeration and industrial structure upgrading under the perspective of labour mobility. *Inner Mongolia Social Science (Chinese Edition)* (2).
- [24] Pan, S., 2016. Analysis of the impact of labour mobility on regional industrial structure: Based on the comparison of net labour inflow and net outflow. *Business and Economics Research* (8).
- [25] Zhao, R., Shen, C., 2019. Capital mobility, industrial agglomeration and industrial structure upgrading: An empirical analysis based on panel data of 16 central cities in the Yangtze River Delta. *Exploration of Economic Issues* (6).
- [26] Zhao, N., 2016. Study on the spatial effect of labor mobility and industrial restructuring. *Statistical Research* (2).
- [27] Guo, W., Li, Z., 2009. Labour mobility, service sector growth and economic structural transformation: An empirical study based on interprovincial panel data in China. *Studies in Quantitative Economics and Technical Economics* (11).
- [28] Ye, L., Xie, C., Zhang, H., 2022. Turning extrusion into complementarity: An empirical analysis of the spatial spillover effect of agglomeration of productive services on industrial structure: Taking 21 prefectural-level cities in Guangdong Province as an example. *Operation and Management* (1).
- [29] Gan, X., Li, Y., Jiang, B., 2020. Fiscal decentralisation, local government behaviour and industrial structure transformation and upgrading. *Reform* (10).
- [30] Wu, J., Min, W., 2022. The mechanism of education's role in industrial structure upgrading. *Educational Research* (1).
- [31] Liu, Z., Zhang, S., 2021. Internet development, marketization level and the transformation and upgrading of China's industrial structure. *Studies in Economics and Management* (12).
- [32] Welch, J.R., Vincent, J.R., Auffhammer, M., 2010. Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceedings of the National Academy of Sciences* 107(33), 14562-14567.
- [33] Zhu, H., Zhou, S., 2010. Vulnerability analysis of southern rice to climate change: Taking Jiangxi Province as an example. *Journal of Agro-Environment Science* (29).
- [34] Amundson, J.L., Mader, T.L., Rasby, R.J., 2006. Environmental effects on pregnancy rate in beef cattle. *Journal of Animal Science* 84(12), 3415-3420.
- [35] Bryant, D.A., Costas, A.M.G., Maresca, J.A., 2007. *Candidatus Chloracidobacterium thermophilum*: An aerobic phototrophic acidobacterium. *Science* 317(5837), 523-526.
- [36] Colmer, J., 2021. Temperature, labour reallocation, and industrial production: Evidence from India. *American Economic Journal: Applied Economics* 13(4), 101-124.
- [37] Alshebani, M.N., Wedawatta, G., 2014. Making the construction industry resilient to extreme weather: Lessons from construction in hot weather conditions. *Procedia Economics and Finance* 18, 635-642.
- [38] Chen, X., Yang, L., 2019. Temperature and industrial output: Firm-level evidence from China. *Journal of Environmental Economics and Management* 95, 257-274.
- [39] Xu, M., Jiang, Y., 2015. Can the upgrading of China's industrial structure narrow the urban-rural consumption gap? *Journal of Quantitative & Technical Economics* 32(03), 3-21.
- [40] Jiang, T., 2022. Mediation and moderation effects in causal inference empirical research. *China Industrial Economics* (05), 100-120. DOI: 10.19581/j.cnki.ciejournal.2022.05.005.