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Better understanding of climate catastrophe insurance in China: issues and opportunities, international insights, and directions for development

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Abstract
Climate catastrophe insurance is an important tool for advancing China's comprehensive disaster prevention and mitigation efforts and an important part of modernizing China's national emergency management capabilities. Based on the understanding of the definition of catastrophe and China's climate catastrophe, this paper systematically analyzes the main problems and challenges faced by China's climate catastrophe risk management and elaborates on the characteristics of the current opportunities for the development of China's climate catastrophe insurance. The paper then summarizes the development features of international catastrophe insurance systems, compares the features of the Shenzhen and Ningbo pilots of catastrophe insurance in China, and proposes key focus points for the meteorological department to participate in climate catastrophe insurance. Finally, this paper proposes measures to enhance climate catastrophe insurance in China in future from the development of international catastrophe insurance and China's climate catastrophe pilot work. Firstly, consider the whole process of comprehensive disaster prevention and mitigation concept and play the role of the government and the market and other multi-body, to explore the construction of the catastrophe insurance system. Secondly, establish a special or comprehensive catastrophe insurance fund. Thirdly, promote the formation of public–private partnership sharing mechanism. Fourthly, the government should provide appropriate legal and policy support. Fifthly, use the market mechanisms to reduce government pressure on public finances in catastrophe insurance.

Keywords Climate change risk · Climate catastrophe · Catastrophe insurance · Insurance mechanism · Chinese practice of climate catastrophe insurance · International practice of catastrophe insurance

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1 Introduction

The average global surface temperature has risen by 0.85 °C since 1880, with two-thirds of that increase occurring since 1975 (IPCC Climate Change 2014, 2021; IPCC Srex 2012). Along with rising temperatures, global sea levels have risen by 19 cm and polar ice reserves have declined at an accelerated rate, averaging 362 billion tons per year over the past five years (IPCC Climate Change 2021). With the further development of global warming, human society is facing increasingly severe climate catastrophe risks (World Economic Forum 2021; United Nations International Strategy for Disaster Reduction 2013, 2015, 2019).

In recent years, the frequency, breadth and depth of climate catastrophes have been increasing in many regions of the world (Kong et al. 2018; Meng et al. 2015; Alexander 2006), and the hazards and impacts on socioeconomic systems have further increased (World Trade Organization 2012; Shi et al. 2016). At the same time, the cross-regional nature of climate catastrophes is becoming increasingly evident (Kong and Sun 2021; Shi et al. 2013), the multi-causal and complex nature of catastrophes is intensifying, and the uncertainty and randomness of their occurrence are increasing (Cummins 2006; Amendola 2013; Chen and Guo 2019). As a result, climate catastrophe risk wreaks havoc on natural ecosystems and socioeconomic systems (Shi 2019). In particular, climate catastrophes have had many significant impacts on key areas such as regional water resources, food production, habitat, ecology, human health and major projects (Wisner et al. 2013). If humans do not succeed in controlling the global average temperature rise to 1.5 ℃, it will bring catastrophic consequences, such as habitat loss, coral extinction, ice cap melting, sea level rise, etc. (IPCC Srex 2012; Li 2016; Kong 2020a, b). Climate catastrophes will also increase further dramatically, which will seriously threaten human survival and development, and will also bring more damage to global economic development (Eisenack et al. 2012; Fleming et al. 2018). According to a report released by the World Bank in 2015, 100 million people will fall back into poverty by 2030 due to climate impacts if no measures are taken to address climate change (IPCC Climate Change 2014). When faced with climate catastrophes, disaster preparedness, infrastructure, and adaptive capacity vary greatly from country to country (IPCC Climate Change 2014; Shi 2019). The poorest developing countries and the poor are the biggest victims of climate change and climate catastrophe risk (United Nations International Strategy for Disaster Reduction 2019), which is also related to the global sustainable development issues of fighting hunger, poverty and maintaining social stability, and therefore the success or failure of climate catastrophe risk prevention is significant (Michael 2007; Nam 2017).

The most significant feature of global warming is the increase of extreme weather and climate events (IPCC Climate Change 2014), which seriously affect people's lives and property safety, and the resulting increase of economic losses, especially the losses caused by climate catastrophes account for a particularly prominent proportion of climate disaster losses (IPCC Srex 2012), and have a direct or indirect impact on the lifeline of national economic development (Meng et al. 2015). In the past 40 years, major global natural disasters have developed rapidly and most of them are closely related to climate change or climate factors (World Economic Forum 2021; Shi et al. 2013; Nam 2017). The global frequency of major natural disaster events has increased from 249 in 1980 to 820 in 2019 (World Economic Forum 2021). The frequency and situation of major natural disasters worldwide are showing a rapid increase, and the situation of climate catastrophes or disasters closely related to climate factors is more severe (Xu 2014, 2019). In particular, disaster-related

deaths are larger in less economically developed Asia and Africa, and disaster-related economic losses and disaster-related insurance losses are larger in Asia and North America (IPCC AR6 WGIII 2022a, IPCC AR6 WGII 2022b).

Statistics from the World Metrological Organization show that global climate and hydrological events accounted for about 90% of all disasters during 1992–2001, resulting in 622,000 deaths, affecting more than 2 billion people and causing an estimated economic loss of $450 billion, or about 65% of all natural disaster losses (Shi 2019). The top 10 climatic hazards caused only 0.1% of the total number of climatic hazards, resulting in 70% of the deaths, while the top 10 climatic hazards caused 19% of the total direct economic losses. The top 10 climatic hazards in terms of direct economic losses accounted for 19% of the total losses, while storm-like events such as typhoons and floods accounted for 79% of the total climatic hazards, and the proportion of human deaths and economic losses caused by these two hazards were 56% and 85% of the climatic hazards, respectively (Li 2016).

According to the Global Risks Report 2021 released by the World Economic Forum on January 9, 2021, environmental risks remain the top issue in terms of the probability of occurrence and potential impact of risks over the next decade (World Economic Forum 2021). The top five risks in terms of likelihood are: extreme weather events (e.g., floods, storms, etc.), climate change mitigation and response failure, man-made environmental damage and disasters, infectious diseases, major biodiversity loss, and ecosystem collapse. The top five risks in terms of severity of impact are: infectious diseases, climate change mitigation and response failure, weapons of mass destruction, significant biodiversity loss and ecosystem collapse, and natural resource crises. In 2007–2020, the risk factors of extreme weather and climate events, natural disasters, and climate change preparedness and adaptation failure are rising in the global risk pattern consisting of likelihood and impact, far surpassing other risk factors to become the most important risk factor affecting human society. In the context of globalization, which is mainly characterized by interconnectedness, the exchange of people, materials and information between various regions of the world has been intensified, giving rise to various types of contact networks represented by production chains and supply chains, thus leading to an amplification effect of the impact of catastrophes beyond the disaster area itself. For example, the global, systemic, complex, and coupled nature of risks resulting from climate catastrophes and climate change response failures is increasing due to widening economic disparities between regions and frequent global governance failures. Especially in urban areas around the world, disaster losses due to secondary disasters continue to rise due to the accumulation of economic assets in areas facing extreme weather and climate events. In 2018, the total global insured losses amounted to $219 billion, of which economic losses caused by secondary disasters with climate change accounted for more than 50% (International Monetary Fund 2020a). It is evident that climate catastrophe risk has become one of the most important threat factors for global and regional sustainable development (International Monetary Fund 2020b, c).

Disaster insurance in developed countries can cover more than 30% of losses after a natural disaster, while in developing countries like China, the average coverage of disaster insurance is only 1% (Li 2016).The global average of insured losses to total losses from natural disasters was 43.6% during 2009–2014, which means that 43.6% of natural disaster losses can be covered by insurance (Kong 2020b). North America, Europe, and Asia are the regions with the most severe natural disaster losses due to the long-term effects of earthquakes, hurricanes, floods, and strong convective storms (Xu 2014, 2019). Of these, North America is the region with the highest losses and insurance recoveries, with a very high percentage of losses covered by insurance, averaging 62.6% and reaching a high of

74.7% between 2009 and 2014 (Shi et al. 2016). Asia was the region with the second highest losses from natural disasters, but with a very low percentage of insurance recoveries, averaging 11.2%, with the highest being 18.9% in 2011, mainly due to the East Japan earthquake. Europe ranked third in terms of disaster losses with an average of 35.6% and a high of 49.8% (Kong and Sun 2021). Oceania had an average insurance payout of 50.6% and a maximum of 68.7% (Kong et al. 2018). In general, the insurance market in developed countries is more developed and the percentage of compensation for natural disaster losses is much larger than that in developing countries.

At present, the development of disaster insurance in China still cannot meet the needs of rapid social and economic development (Xu 2014, 2019). The direct economic losses caused by the ice and snow rains in several provinces in southern China during the Spring Festival in 2008, the Wenchuan earthquake on May 12, 2008, and the Yushu earthquake on April 14, 2010, were RMB 151.7 billion, RMB 845.1 billion and RMB 64 billion, respectively, and the insurance compensation amount was RMB 5.0 billion, RMB 1.66 billion, and RMB 800,000, respectively, accounting for 3.3%, 0.2%, and 0.01% of the direct economic loss, respectively (Li 2016). In contrast, the direct economic losses caused by Hurricane Katrina in late August 2005 and Hurricane Ike in early September 2008 in the USA were US$125 billion and US$38.3 billion, respectively, and the insurance payouts were US$62.2 billion and US$18.5 billion, respectively, accounting for 49.8% and 48.3% of the direct economic losses (Shi 2019). It is noteworthy that catastrophe insurance losses in China are mainly paid to large factories, commercial companies and wealthy households, with only a small portion being used to spread the losses of ordinary individuals, especially poor households, mainly because poor households cannot afford insurance products (Li 2016).

How to understand the current situation of climate catastrophe loss and climate catastrophe insurance and effectively plan its future development path under the current socioeconomic situation, climate background conditions and climate observation and forecasting development level, and accurately position the depth of meteorological department's participation and service mode, has become an important issue to be solved in China's climate catastrophe risk prevention (Gloor et al. 2020; He 2016; Crichton 2002). In order to answer the above questions, the analysis is carried out according to the following logical framework (Fig. 1).

2 Understanding the definition of catastrophe and climate catastrophe in China

As for the definition of catastrophe, scholars in different fields have different understanding and awareness of catastrophe, and there is no unified classification standard, and more consideration is given to sudden-onset catastrophes (e.g., earthquakes, floods, etc.), while less consideration is given to the classification standard of gradual-onset catastrophes (e.g., droughts, snowstorms, etc.) (Meng et al. 2015; Shi et al. 2013). According to existing research, a catastrophe is a huge natural disaster caused by a strong hazard with many casualties, large property damage, wide impact and high relief needs, and once it occurs, the affected area is unable to cope with itself and must rely on external forces to deal with it (Kong et al. 2018; Cummins 2006; Shi and Li 2014; Cutter 2016).

Catastrophes have the following three main characteristics. Firstly, the intensity of the disaster is high. A catastrophe is usually composed of a specific hazard or a disaster

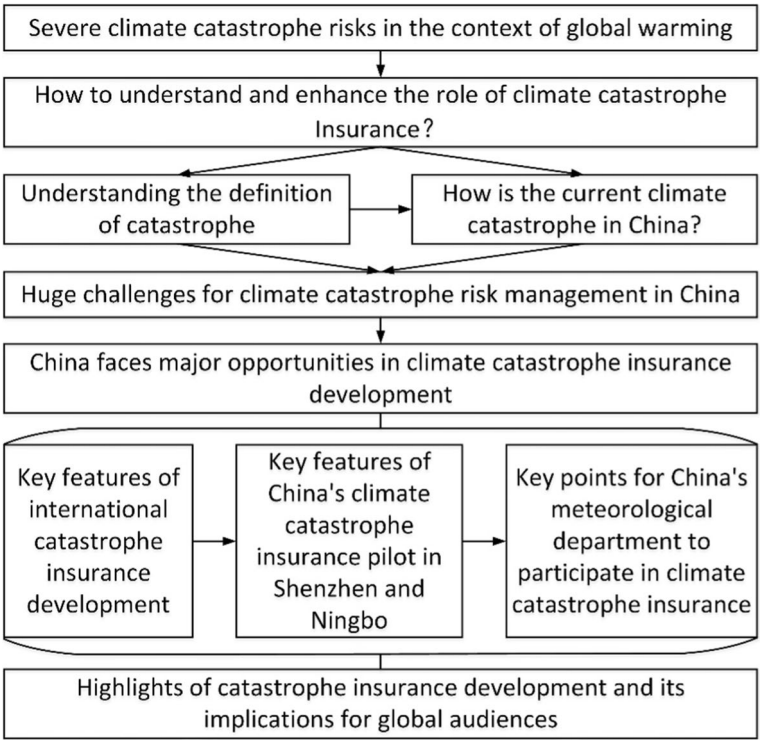

Fig. 1 The logical framework of this paper

chain formed by a heavy or specific hazard and a series of secondary hazards triggered by it; or a multi-hazard superposition formed by the coexistence or concurrency of multiple hazards in a specific area and at a specific time. Secondly, disaster losses are heavy. Catastrophes usually result in a large number of casualties, huge property losses, and severe economic, social, and natural environmental impacts, creating a widespread disaster area. Thirdly, the demand for relief is high. The emergency relief and rehabilitation of catastrophes usually require support and assistance at a larger regional or even national level, and sometimes international assistance is indispensable (Gloor et al. 2020; Lewis and Nickerson 1989).

In the case of China, climate disaster statistics from 1949 to 2013 show a significant downward trend in the number of people killed by disasters (1950s: > 10,000/a; after 2000s: < 1000/a) and mortality rates; the absolute value of direct economic losses (1950s: < 100 billion yuan RMB per year; since 2000s: > 300 billion yuan RMB per year) has shown a significant upward trend; the proportion of deaths and direct economic losses to all natural disasters is 55% and 87%, respectively (Li 2016). The absolute value of direct economic losses (1950s: < 100 billion yuan RMB per year; since 2000s: > 300 billion yuan RMB per year) has shown a significant upward trend; the proportions of deaths and direct economic losses in all natural disasters are 55% and 87%, respectively, on average over the years (Li 2016). During the period of 2004–2008, about 2600 people died and 400 million people were affected by climate disasters in China each year, with an average of 41 million hectares of crops affected, an average of

4.6 million hectares of crop failure, and an average of 236 billion yuan RMB in direct economic losses, which accounted for about 1% to 3% of the gross national product (Kong et al. 2018).

3 Major issues and challenges of climate catastrophe risk management in China

3.1 Increased risk of climate catastrophes in the context of global warming

In the context of global climate change, the occurrence of extreme climate disasters faces increased uncertainty (IPCC Climate Change 2014, 2021; IPCC Srex 2012). The IPCC's Fifth Assessment Report states that 1983–2012 may be the warmest 30 years of the last 1400 years (IPCC Climate Change 2014). During the period 1880–2012, the global average land and sea surface temperature increased by 0.85 °C. The global mean sea level rise rate averaged 1.7 mm per year during 1901–2010, 2.0 mm per year during 1971–2010, and 3.2 mm per year during 1993–2010, with a significant acceleration in the rate of sea level rise. Global warming has changed the circulation of the atmosphere and oceans, and strong tropical cyclone activity is likely to increase, which may cause an increase in more extreme climate disasters and an expansion of the impact area (IPCC Climate Change 2014). According to the Sigma report of the Swiss Re Institute, the global insured losses due to disasters in 2017 were approximately US$136 billion, much higher than the average of the previous 10 years (US$58 billion) (Kong 2021). China is a sensitive area and a significant impact area of global climate change, and the warming rate is significantly higher than the global average during the same period. 1951–2020, the annual average surface temperature in China shows a significant increasing trend, with a warming rate of 0.26 ℃/10 years (Kong and Sun 2021). The last 20 years is the warmest period since the beginning of the twentieth century, and of the 10 warmest years since 1901, all but 1998 occurred in the twenty-first century. 1961–2020, extreme heavy precipitation events in China show an increasing trend, extreme low temperature events decrease, and extreme high temperature events increase significantly since the mid-1990s; landfall in China since the late 1990s From 1961 to 2020, China's climate risk index tends to increase; from 1991 to 2020, the average value of China's climate risk index (6.8) increased by 58% compared with the average value of 1961–1990 (4.3) (Kong and Sun 2021). This shows that the possibility of extreme climate disasters in China cannot be ignored (Kong and Sun 2021). Climate catastrophe insurance has become and will become a hot, difficult and key issue in the development of disaster insurance for a long time to come (Li 2016; International Monetary Fund 2020b; Gloor et al. 2020; He 2016).

3.2 China's climate catastrophe insurance payout ratio still leaves a gap

Insurance is an effective means of mitigating economic losses from natural disasters, and there is still a gap between China's catastrophe insurance payout ratio and that of developed countries (Li 2016). In the global statistics on disaster loss compensation, compensation from insurance companies accounts for more than 36% of total disaster losses, and this indicator is even as high as more than 80% in developed countries (Kong 2020a), while in China, the share of many natural disasters covered by insurance companies is even less than 1% (Li 2016; Kong 2021). According to relevant data, the frozen rain and snow disaster in

southern China, which caused a direct economic loss of 151.65 billion yuan in early 2008, only received about 3% of the compensation from the insurance industry (Shi 2019). This shows that the risk diversification and economic compensation function of China's climate disaster insurance is far from being given full play, and the development of such insurance business still has huge room for improvement (Kong and Sun 2021; Shi 2019; Li 2016).

3.3 Catastrophe risk management urgently requires the capture of extreme climate events

Advances in meteorological data observation tools and forecast and prediction technologies, and the enhanced ability to capture extreme climate data, have important implications for the outcome of climate catastrophe insurance risk predictions and the development of the weather insurance industry (Li 2016; Xu 2019; Gloor et al. 2020; He 2016). In climate disaster risk assessment, the actuarial calculation of insurance rates and reserves is often based on historical meteorological records, and the temporal and spatial accuracy of the recorded volume of historical meteorological events will seriously restrict the estimation accuracy of the probability distribution of the causal factors, which in turn will have a greater impact on the reliability and stability of the risk assessment results (Porrini and Schwarze 2014; Wang et al. 2014). In particular, the results of the recurrence period of the assessment of extreme climate disaster events that occur less frequently but have a huge impact tend to be more unstable, leading to increased risk uncertainty in the assessment (Shi et al. 2013; Fleming et al. 2018). For example, Hurricane Andrew, which struck Florida in 1992, caused 11 insurance companies to fail due to unpayable claims. Hurricane Katrina in 2005 caused storm surge and flooding in the New Orleans area, and the addition of water records from this extreme event reduced the return period for the same water level from 1200 to 397 years, forcing some insurance companies to stop insuring the area or increase premiums to address the risk. Some insurers had to stop insuring the area or raise premiums to address the risk (Shi et al. 2013; Li 2016).

3.4 A single way to engage the meteorological department in climate catastrophe risk governance

The Chinese meteorological department has been involved in the implementation of climate disaster insurance in a rather superficial and homogeneous way (Kong and Sun 2021). Although climate disaster insurance has been implemented in China for many years, the Chinese insurance industry does not have a deep understanding of climate disasters, especially in the more specialized property insurance (e.g., agricultural insurance and auto insurance), the climate service approach is still mostly superficial in terms of direct provision of data support for climate hazards, lack of in-depth integration between the meteorological department and insurance companies on the design of insurance products, and lack of dynamic integration of pre-disaster warning, damage determination and post-disaster verification (Kong and Sun 2021; Figueiredo and Martina 2016; Florence et al. 2016). The role of the meteorological department in the future climate catastrophe insurance is positioned, and it is of great practical importance to explore the way of deep involvement of the meteorological department in the climate catastrophe insurance service in terms of data support, product design, and operation mechanism (Valente et al. 2019; Mills 2009; Surminski 2014).

4 Major opportunities for the development of climate catastrophe insurance in China

4.1 Opportunity 1: the overall national security concept and the practice of a comprehensive national strategy for disaster prevention and mitigation

In 2014, Chinese government policymakers put forward "the overall national security concept", which requires attaching importance to both traditional security and non-traditional security, attaching importance to both development and security issues, insisting that development is a guarantee for security and security is a prerequisite for development, adhering to a people-oriented and people-oriented approach, insisting that national security is all for the people and all relies on the people, and truly consolidating the mass foundation of national security (Shi and Li 2014). Since July 2016, Chinese government policymakers have made several important instructions and speeches on disaster prevention, mitigation, and relief (Kong 2021). On July 28, 2016, Chinese government policymakers visited Tangshan and delivered an important speech, proposing a new concept of disaster prevention, mitigation and relief with "two insistences" and "three changes", i.e., insisting on prevention as the main focus, combining prevention, resistance and relief, unifying normal disaster reduction and extraordinary disaster relief, striving to realize the change from focusing on post-disaster relief to pre-disaster prevention, from dealing with a single type of disaster to comprehensive disaster reduction, from reducing disaster losses to mitigating disaster risks, and comprehensively enhancing the comprehensive prevention capacity of the whole society to resist natural disasters (Shi 2019). This concept provides the basic guidelines for China's disaster prevention, mitigation, relief and emergency management efforts. On December 29, 2016, the General Office of the State Council of China issued the "National Comprehensive Disaster Prevention and Mitigation Plan (2016–2020)" (Shi 2019). In this context, a national comprehensive disaster prevention and mitigation strategy was born and is imperative, and catastrophe insurance is an important tool for climate disaster risk management. The Chinese government will play the role of insurance and other market mechanisms, improve the financial support system for coping with disasters, expand the coverage of residential housing disaster insurance and agricultural insurance, and accelerate the establishment of a catastrophe insurance system (Kong and Sun 2021). At the same time, the Chinese government will actively introduce market forces to participate in disaster governance, cultivate and improve the ability of market players to participate in disaster governance, encourage regions to explore market-based sharing models for catastrophe risks, and improve disaster governance (Kong 2020a, b).

4.2 Opportunity 2: the construction of emergency management system with Chinese characteristics enters a new stage

In March 2018, the State Council of China newly formed the Ministry of Emergency Management in accordance with the Program for Deepening the Reform of the Communist Party of China and State Institutions adopted by the Chinese government and the State Council Institutional Reform Program considered and approved at the first meeting of the 13th National People's Congress. The Ministry of Emergency Management has integrated the original 11 departments, including production safety, fire management, geological disaster prevention and control, earthquake emergency relief, including 13 emergency rescue

responsibilities (Kong and Sun 2021). The establishment of the Ministry of Emergency Management marks a new and substantial stage in the construction of a "unified command, specialized and permanent, responsive, up-and-down, and integrated emergency management system with Chinese characteristics". The establishment of the Ministry of Emergency Management fully reflects the new trend of modern governance combining emergency management and normal management. The construction of an emergency management system with Chinese characteristics has entered a new phase, providing new opportunities to strengthen cooperation between climate disaster prevention and the insurance industry, integrate social emergency industry resources, and provide new opportunities for the meteorological department to fully participate in natural disaster response.

4.3 Opportunity 3: continuous improvement of catastrophe compensation mechanism

The systematization of catastrophe insurance system is one of the important tasks of the government service and financial institutionalization reform proposed by the Chinese government in November 2013 (Li 2016). In August 2014, the State Council issued "Certain Opinions on Accelerating the Development of Modern Insurance Services Industry", announcing the incorporation of insurance into the disaster prevention and relief system, and further proposing the establishment of a catastrophe insurance system based on system construction, commercial insurance as a platform, and multi-level risk sharing as a guarantee; study the establishment of catastrophe insurance fund, catastrophe reinsurance and other systems to gradually form a multi-level catastrophe risk dispersion mechanism with financial support; encourage localities to explore effective protection models for typhoons, earthquakes, landslides, mudslides, floods, forest fires and other disasters according to risk characteristics; develop catastrophe insurance regulations; establish a reserve fund system for nuclear insurance catastrophe liability; and establish a catastrophe risk management database (Shi and Li 2014). The establishment of a catastrophe insurance system will open up a new and broad space for the development of catastrophe insurance in China and provide a solid guarantee for the comprehensive risk management of catastrophes. The first Sigma study released by Swiss Re in 2019 concluded that emerging markets in Asia will lead emerging market premium growth in the next 10 years, with China becoming the largest insurance market in 15 years; as the center of economic gravity continues to shift from the West to the East, emerging markets will provide growth drivers for the global economy, with the seven largest emerging markets contributing up to 42% of global growth, of which China alone will contribute 27%. China's contribution alone will be 27% (Kong and Sun 2021). Therefore, it is incumbent upon the meteorological sector to fully integrate the establishment and practice of climate catastrophe insurance systems.

4.4 Opportunity 4: high quality implementation of several national development strategies calls for climate catastrophe insurance

In the context of global climate change and rapid urbanization, the frequent occurrence of extreme weather and climate disaster events has put forward higher requirements for the development of comprehensive meteorological disaster prevention and mitigation. Inadequate disaster monitoring and forecasting capabilities, inadequate multi-sectoral coordination mechanisms, and inadequate public awareness of self-help have become the shortcomings of China's comprehensive meteorological disaster prevention and mitigation efforts

(Shi et al. 2016). Since 2012, the release and implementation of the Chinese government's strategies and plans on Belt and Road Initiative, Beijing-Tianjin-Hebei Cooperative Development, Yangtze River Economic Belt, Xiong'an New Area and Guangdong-Hong Kong-Macao Bay Area have brought both challenges and rare opportunities for the development of climate catastrophe insurance (Shi 2019; Li 2016). The implementation of the aforementioned national strategies faces the impact of climate catastrophe risks, especially in the construction of critical infrastructure (Kong and Sun 2021). The pressure to let government public finance alone bear the potential loss of climate catastrophe risk is huge (Li 2016). Therefore, it becomes an issue of contemporary value and an opportunity of the times for the development of climate catastrophe insurance to play a role in catastrophe risk prevention by leveraging the financial advantages of the market.

5 Key features of typical international catastrophe insurance developments

Generally, the ways of compensation for catastrophe risk losses mainly include government compensation, commercial insurance compensation, social donation and self-compensation (Li 2016). Due to the special nature of catastrophe risk, a complete catastrophe risk management system must be established for effective management of catastrophe risk, and one of the three aspects of government public finance, catastrophe insurance, and social assistance is indispensable (Kong 2020a). Among them, catastrophe insurance is inseparable from the catastrophe insurance system, which refers to a market-based mechanism system for risk diversification and financial compensation for property losses and personal injuries caused by catastrophe risks through insurance, a risk-sharing mechanism based on the law of large numbers.

Many countries and regions around the world have developed their catastrophe insurance systems earlier (Stahel 2009; Cremades et al. 2018; Loh 2005), so their experience in the operation of catastrophe insurance has important implications for the trial implementation and further exploration of catastrophe insurance in China at this stage (Shi 2019; Li 2016; Kong 2021). Some of the more typical foreign catastrophe insurance systems are Japan earthquake insurance, California earthquake insurance, Turkey earthquake insurance, New Zealand earthquake insurance, Florida hurricane insurance, US national flood insurance, UK flood insurance, France natural disaster insurance, Japan agricultural disaster insurance, and Caribbean catastrophe insurance co-insurance agency, which include 6 earthquake catastrophe insurances, 1 typhoon catastrophe insurance, 2 flood catastrophe insurances, and three comprehensive catastrophe insurance. With the evolution of insurance, New Zealand earthquake insurance and UK flood insurance coverage has also been extended to cover multiple catastrophes (Cummins 2006; Li 2016; Fleming et al. 2018; Nam 2017; Florence et al. 2016).

Compared with government public finance and social donation, the market-based compensation method of catastrophe insurance system has the following advantages. Firstly, the leverage of insurance will enlarge the government's financial input, share the pressure of government financial expenditure, and form a multi-level catastrophe risk-sharing mechanism (Li 2016). Secondly, stabilizing and smoothing fiscal expenditures with relatively fixed premium expenditures contributes to the planning and continuity of the fiscal budget, which in turn maintains national financial security and stability (International Monetary Fund 2020c). Thirdly, the advantages of insurance mechanisms

to play a rapid recovery of production and life after the disaster, and risk prevention and management before the disaster. Fourthly, gather social power to form a catastrophe loss compensation fund for long-term accumulation to improve the compensation capacity. Fifthly, through the introduction of insurance mechanism to promote the improvement of government management and functional transformation. On the one hand, the professional services provided by commercial insurance companies, such as urban disaster risk assessment, data platform and analysis model, disaster prevention and mitigation advice, will promote the improvement of the government's catastrophe risk management; on the other hand, the government can focus more on macro-policy formulation, public facility construction, public service provision, and disaster response knowledge dissemination for catastrophe risk management (Wang et al. 2014).

However, the risk of insurance operations must meet the conditions of insurable risk (Li 2016). In short, this can be summarized in two points: firstly, that enough people buy insurance so that the risk is sufficiently diversified; and secondly, that a sufficiently large pool of capital can be created for financial compensation (Kong and Sun 2021). Due to the characteristics of catastrophe risk, catastrophe risk is very difficult to manage with insurance in both aspects. The limitations in the application of the law of large numbers and probability theory make it difficult to set catastrophe risk rates. If the rate is too high, the public cannot afford it, and if the rate is too low, the insurance company cannot afford to pay (Cummins 2006). Therefore, in addition to their own capital and general reserve accumulation, commercial insurance companies must resort to other effective financing mechanisms to perform their financial compensation functions. Moreover, the number of insured people is a problem. Due to the low probability of catastrophe risk, the number of insured persons is also very low, making risk diversification difficult. In short, it is difficult to operate a catastrophe insurance system relying solely on commercial insurance.

At the same time, the characteristics of catastrophe risk also show that catastrophe insurance is a quasi-public good with double positive externalities. By paying premiums for catastrophe insurance, residents can not only guarantee their income stability, but also ensure smooth social reproduction and stabilize their lives. By the same token, insurance institutions provide catastrophe insurance to earn profits while playing a macro role as an economic booster and social stabilizer. Therefore, the supply of catastrophe insurance is inseparable from the support of the body that holds and controls public resources, i.e., the government.

Throughout the world, catastrophe insurance systems that are well implemented have effectively utilized the advantages of government and market mechanisms to mobilize resources from all sectors of society to cope with catastrophe risks. These systems not only play an effective role in responding to major natural disasters, but also prevent catastrophes from having a major impact on economic and social development. These systems can be broadly classified into the following three models.

The first model is government-led catastrophe insurance. The government compels residents to purchase insurance by enacting laws, or encourages or semi-compels the purchase of catastrophe insurance by means of rate subsidies and other forms linked to benefits, and the government also fully assumes the reinsurance of catastrophe insurance. The main representative is the USA (Li 2016).

The second model is market-led catastrophe insurance. Commercial insurers act as the main body of coverage and rely on actuarial results to set rates and deductibles, and rely on reinsurance and capital markets to transfer and diversify risks, but the government must provide the necessary disaster protection measures as a prerequisite for underwriting by

commercial insurers, such as building dykes. Major representatives include the UK (Shi et al. 2013).

The third model is the government-market collaboration type of catastrophe insurance. Commercial insurance companies operate catastrophe insurance in the market according to the principle of operating commercial insurance, and the government only regulates catastrophe insurance through legislation and provides certain policy support and institutional protection to commercial insurance companies, and finally shares the risk of huge disasters. The main representatives are countries such as New Zealand, Turkey, and Japan (Kong and Sun 2021; Li 2016).

6 Key features of China's climate catastrophe insurance pilot

6.1 The development process of China's climate catastrophe insurance pilot

In 2014, the Chinese government issued "Several Opinions of the State Council on Accelerating the Development of Modern Insurance Services", which clearly proposed to establish a catastrophe insurance system and encouraged localities to explore effective protection models for typhoons, earthquakes and other disasters based on risk characteristics (Li 2016). In January 2017, the Chinese government issued the "Opinions of the State Council on Promoting Reforms of the Institutional Mechanism for Disaster Prevention, Mitigation and Relief", which proposed that "localities are encouraged to explore effective protection models for catastrophe risks by combining the characteristics of disaster risks (Shi 2019). With the policy support, catastrophe insurance pilots covering climate catastrophes have been launched one after another. In July 2014, Shenzhen was the first to start a catastrophe insurance pilot, and since then Ningbo, Yunnan, Sichuan, Guangdong and Heilongjiang have launched catastrophe insurance pilots one after another. China's catastrophe insurance pilots are unique; for example, the Shenzhen catastrophe insurance, launched in 2014, provides insurance coverage of up to 100,000 yuan RMB per person for 15 types of disasters, including typhoons, and the resulting risk of nuclear accidents (Shi 2019). The pilot catastrophe insurance in Guangdong Province was launched in 2016, the first time China used commercial insurance to provide insurance coverage for local finances (Kong 2021). The catastrophe insurance pilot project uses index insurance in the form of wind speed, rainfall, and other parameters as the basis for claims, and the insurance payout is paid to the local treasury for government relief and reconstruction in the public sector, providing more than 2 billion yuan RMB of insurance coverage for the 10 pilot cities in Guangdong Province (Shi 2019). Heilongjiang Province launched agricultural catastrophe insurance in 2016, specifically to protect the agricultural sector against catastrophes and contribute to precise poverty alleviation by the insurance industry. The development of China's catastrophe insurance pilot has produced experiences such as the "Ningbo Model" (Wudaokou 2021; General Office of Ningbo Municipal People's Government 2021–2023), and many problems and shortcomings have been identified in the system design and insurance products, which need to be further improved and perfected. This paper examines the catastrophe insurance pilot situation in Shenzhen and Ningbo, which covered climate disasters at the beginning of the catastrophe insurance pilot, and compares the basic situation, product design, government participation methods, and characteristic points from the perspective of learning from them and exploring the path (Shi 2019).

6.2 Shenzhen catastrophe relief insurance

In terms of the basic situation, Shenzhen catastrophe insurance has been piloted since May 2014, when the Shenzhen Civil Affairs Bureau and PICC in Shenzhen officially signed the "Shenzhen Catastrophe Relief Insurance Agreement", with the municipal government fully funding 36 million yuan RMB to purchase catastrophe insurance services from commercial insurance companies, making it the first catastrophe landing pilot project in China (Kong 2020a). In the pilot process, Shenzhen urban catastrophe insurance has been continuously adjusted and improved, introducing the catastrophe co-insurers model, improving the policy design, increasing the coverage standard, expanding the coverage, and taking the lead in China in terms of coverage.

In terms of catastrophe insurance product design and improvement, according to the characteristics of natural disasters, geographical and geological conditions, population size and structure and nuclear safety risks in Shenzhen, the coverage includes 15 kinds of disasters (storm, rainstorm, cliff avalanche, lightning strike, flood, tornado, squall line, typhoon, tsunami, mudslide, landslide, subsidence, hailstorm, inundation, earthquake of main quake magnitude 4.5 and above) and their secondary disasters. Compensation for personal injury, housing damage, etc. The coverage is for all people who are within the administrative area of Shenzhen when a disaster occurs, including the resident population and those who come to Shenzhen temporarily for business, tourism, work, rescue and disaster relief and courage. The insurance liability includes the following three areas (Kong 2020a).

(1) Personal injury and death assistance costs: The liability limit for personal injury or death caused by earthquakes, tsunamis, and secondary disasters of mainshock magnitude 4.5 or above is 250,000 yuan RMB per person per disaster, and the total limit for each disaster is 2 billion yuan RMB; the liability limit for personal injury or death caused by other disasters and secondary disasters is 250,000 yuan RMB per person per disaster, and the total limit for each disaster is 100 million yuan RMB (Kong 2020a).
(2) Cost of relocation of victims: Nuclear emergency relief costs are limited to 2,500 yuan RMB per person per disaster, with a total limit of 500 million yuan RMB per disaster; other emergency relocation costs are limited to 300 yuan RMB per person per disaster, with a daily limit of 20 yuan RMB per person, with a total limit of 10 million yuan RMB per disaster (Kong 2020a).
(3) Post-disaster relief costs: Post-disaster personnel relief costs, including the standard of transitional living relief for disaster victims is 2250 yuan RMB per person per disaster liability limit and 25 yuan RMB per person per day, and the resettlement cost of the families of the victims is 20,000 yuan RMB per victim, and the total limit of the above two items is 2 million yuan RMB per disaster; the compensation cost of housing damage for residents is 20,000 yuan RMB per household per disaster liability limit, and the total limit of 200 million yuan RMB per disaster. The total limit of each disaster is 200 million yuan RMB (Kong 2020a).

In terms of government participation, the Shenzhen government fully funds the purchase of insurance, which is docked by the Shenzhen Civil Affairs Bureau and assigned to the Shenzhen Emergency Management Bureau after the Chinese government's institutional reform of government departments in 2018.

In terms of catastrophe co-insurers, the catastrophe insurance pilot process introduces a "co-insurance" underwriting model, in which one lead insurance underwriter is the primary

underwriter, supplemented by multiple insurance underwriters, to jointly underwrite the policy. In terms of government procurement methods, catastrophe insurance was changed from single-source procurement to open bidding to the community. In 2016, the Shenzhen Civil Affairs Bureau won the bid through an open tender on the online platform of Shenzhen Government Procurement Center, and the co-insurers consisting of National Life General Insurance Shenzhen, Pacific General Insurance Shenzhen and Huatai Property and Casualty Insurance Shenzhen. In 2019, Shenzhen catastrophe insurance co-insurers consist of five insurance companies: PICC Property & Casualty Insurance, Pacific Property & Casualty Insurance, Taiping Property & Casualty Insurance, National Life Property & Casualty Insurance and Ping An Property & Casualty Insurance, of which PICC Property & Casualty Insurance is the chief insurer.

6.3 Ningbo public catastrophe insurance

In terms of the basic situation, in March 2014, Ningbo City formally proposed to China Insurance Regulatory Commission to carry out catastrophe insurance pilot, and was approved (Kong 2020a). In November of the same year, following the principles of "broad coverage, basic protection, market-oriented operation and gradual progress", Ningbo issued the "Opinions of the General Office of Ningbo Municipal Government on the Implementation of Catastrophe Insurance Pilot Work", in which the government funded 38 million yuan RMB to purchase catastrophe insurance services from commercial insurance companies, providing 600 million yuan RMB of risk protection. Ningbo public catastrophe insurance officially entered the implementation stage in 2018 (Kong 2020a). The implementation plan of Public catastrophe insurance in Ningbo city (2021–2023) will be officially released in 2021. The main content is to give full play to the positive role of catastrophe insurance in disaster prevention, mitigation and relief, and continuously promote the healthy and orderly development of catastrophe insurance (Wudaokou 2021; General Office of Ningbo Municipal People's Government 2021–2023). Ningbo public catastrophe insurance has formed a disaster relief network with close collaboration among the government, grassroots organizations and insurance institutions, improving social cooperation in disaster prevention and mitigation, and becoming an innovative case of the government applying modern financial and insurance means to improve its ability to cope with major natural disaster risks (Wudaokou 2021).

In terms of catastrophe insurance product design and improvement, The coverage of catastrophic insurance is to provide relief for personal injury and death and household property damage caused by secondary disasters such as typhoons, tornadoes, strong tropical storms, heavy rains, floods and lightning strikes and the sudden landslides, mudslides, dam failures of reservoirs, power leaks and explosions, and leaks of chemical installations that the local area is prone to. The protection objects are all the people who are within the administrative area of Ningbo at the time of the disaster (including the resident population and the mobile population who come to Ningbo for business, tourism and work) for personal injury and death, as well as the household property damage relief for the permanent residents within the administrative area of Ningbo (those who have the household registration of Ningbo or hold the residence permit). The maximum limit is specified in the insurance liability. In the event of personal injury or death caused by a catastrophe, the insurance agency will pay out up to 100,000 yuan RMB per person; in the event of property damage to the housing actually occupied by the residents, the relief amount will be up to 2,000 yuan RMB per household; in the event of death or disability caused by the

residents' courageous acts during the catastrophe, the insurance agency will pay out up to 100,000 yuan RMB per person for the additional compassionate expenses for courageous acts (Shi 2019). Through years of piloting, based on the summary of the pilot experience, in December 2017, Ningbo Municipal Government issued the "Implementation Opinions on Deepening Catastrophe Insurance Work", in terms of coverage and liability, the coverage of natural disaster insurance has increased to include blizzard liability insurance, lightning strike insurance liability has been expanded to include residential household property damage relief, and the compassionate and resettlement expenses for personal injuries and deaths caused by major sudden public safety accidents have also been included in the coverage (Kong 2020a).

In terms of government participation, The Ningbo Municipal Government fully funds the insurance, which is docked by the Ningbo Civil Affairs Bureau, and is sponsored by the Ningbo Emergency Management Bureau after the Chinese government's institutional reform in 2018. Ningbo Municipal Government injected funds to establish a catastrophe fund. The Ningbo Municipal Government separately arranges 10.2 million yuan RMB per year to establish a catastrophe risk reserve fund, which can be used to make up for insurance losses when catastrophe insurance operates at a loss in a year, so as to smooth out the fluctuations of catastrophe insurance operations (Shi 2019). The Ningbo Municipal Government is responsible for overseeing the operation of catastrophe insurance and continuously adjusting and improving the pilot.

In terms of catastrophe funds, Ningbo established a catastrophe fund in 2019, with the government's public coffers investing an initial 5 million yuan in start-up funds, mainly to cover payouts above the government's catastrophe insurance payout limit, and to fully mobilize all parties and widely absorb social donation funds to form a public platform for coping with catastrophe risks with the participation of the whole society. Ningbo Catastrophe Insurance Foundation selects the winning bank to open a basic deposit account and a special deposit account through a bidding process.

In terms of the effectiveness of catastrophe insurance, the catastrophe insurance coinsurer has achieved certain results in improving the quality of claims service, awareness of catastrophe insurance, disaster prevention and mitigation publicity, training and exercises, and disaster research, providing an insurance service model for disaster prevention and mitigation and disaster relief in cities.

7 Key points for China's meteorological department to participate in climate catastrophe insurance

7.1 Strengthening climate change monitoring and prediction

The increased rate of greenhouse gas emissions since the industrial revolution has made global warming a consensus. The Intergovernmental Panel on Climate Change introduced the concept of tipping points 20 years ago, when it was thought that these tipping points in the climate system could only be reached if global warming exceeded 5 °C above pre-industrial levels, and more than half of the climate tipping points identified 10 years ago are or have been activated (IPCC Climate Change 2021; Kong et al. 2018). How to measure climate catastrophe risk under global climate change conditions is a pressing concern for China's meteorological department in the coming period (Shi et al. 2016).

The prediction of exceeding probability of extreme weather and climate events under climate change conditions will play a decisive role in the planning and design of national catastrophe reimbursement system, insurance products and even the layout of the insurance industry. Historically, many catastrophe financing program shortfalls have been caused by underestimates of future risk, such as the $7 billion maximum loss estimate for individual hurricane losses prior to the devastating Hurricane Andrew in 1992, which caused $26 billion in losses ($15.5 billion of which were insurable losses), thereby causing many insurers, reinsurers, and others to struggle financially (Kong 2020a). Therefore, the meteorological department, as the key department of climate change monitoring and prediction, should use the effective technical means of climate monitoring and medium and long-term prediction to provide scientific, accurate and objective directional suggestions and technical support for long-term catastrophe risk control of the government, public and insurance sectors in a timely and effective manner.

7.2 Participate in the top-level design of cross-regional catastrophe insurance

At the national level, the release and implementation of the Chinese government's strategies and plans on Belt and Road Initiative, Beijing-Tianjin-Hebei Cooperative Development, Yangtze River Economic Belt, Xiong'an New Area, and Guangdong-Hong Kong-Macao Bay Area have brought both challenges and rare opportunities to the meteorological department (Shi 2019). The international community is expecting China to play a greater role in disaster prevention, mitigation and relief. Climate change risk assessment is one of the first key scientific issues faced in the implementation of strategic planning (Kong and Sun 2021). The Chinese meteorological department have global monitoring, global forecasting and global service capabilities, as well as an emphasis on building comprehensive disaster risk prevention capabilities for multi-hazards and disaster chains, providing support for the realization of major strategic projects at home and abroad.

At the local level, according to the first catastrophe insurance pilots in Shenzhen and Ningbo, the catastrophe insurance in Ningbo has a very high insurance payout ratio, and years of hard work still cannot withstand the impact of one catastrophe; if added to the various taxes and fees of the insurance business, the insurer may have a loss in the catastrophe insurance business. In contrast, not all risks can be dealt with by insurance mechanism in traditional insurance, but several pre-conditions must be met. Firstly, the probability of loss of each risk unit is predictable; secondly, each risk unit is independent of each other; thirdly, the risk is to be largely homogeneous; fourthly, a large number of homogeneous risks. Only when the above conditions are met can the law of large numbers be met, and the occurrence of a catastrophe often causes serious damage to property in the affected area within a short period of time, and a large number of risk targets suffer losses at the same time, making the independence of risk targets required for catastrophe insurance weak or even lost, which in turn leads to insurance companies facing extremely high payout rates in catastrophes. Coupled with the frequent occurrence of extreme weather and climate events, catastrophe insurance business is facing greater challenges. Although the premiums are borne by local governments, it is not conducive to the promotion of catastrophe insurance and public awareness of disaster prevention.

Climate catastrophes, especially typhoons, droughts, rain and snow freeze disasters, are cross-regional, wide-ranging, with large losses and homogeneous samples of the impact range of disasters (Kong and Sun 2021). Therefore, the meteorological department can

actively play its professional strengths and seize the opportunity to actively participate in the top-level design of cross-regional catastrophe insurance.

7.3 Actively leading the development of climate catastrophe models

For many years, catastrophe models in China are mostly at the research stage, and there is a lack of commercial models. Even though insurers and reinsurers have their own internal models, they still rely on three global modeling companies, AIR (Applied Insurance Research), RMS (Risk Management Solutions), and EQE, as several selected models are commonly used in the insurance industry.

The independent research and development capability of China's catastrophe models is improving in recent years. China Insurance Regulatory Commission has promoted the exploration and research of earthquake insurance system for household property in China since 2003 (Shi et al. 2013), while useful exploration has been made in the area of agricultural weather catastrophe insurance system. In May 2018, China Reinsurance Group officially released China's first commercially available earthquake catastrophe model with independent intellectual property rights, which is a milestone in systematically improving China's quantitative earthquake catastrophe risk management capability (Shi 2019). Following the earthquake catastrophe model, the development of other natural disaster catastrophe models that meet our national conditions is included in the planning.

The Chinese meteorological department needs to seize the opportunity, learn from the mature experience of earthquake catastrophe model development, combine with its own reality, actively work together with emergency management departments and relevant departments of the insurance industry, and actively promote the application practice and commercialization of scientific and technological professional innovation in climate catastrophe risk management, in order to achieve the maximum mitigation of climate catastrophe risk.

7.4 Innovation to establish a sound climate catastrophe insurance service system

In August 2014, the Chinese government issued "Several Opinions on Accelerating the Development of Modern Insurance Service Industry", announcing the inclusion of insurance into the disaster accident prevention and relief system. The opinion proposes to establish a catastrophe insurance system based on system construction, commercial insurance as a platform, and multi-level risk sharing as a guarantee; study the establishment of a catastrophe insurance fund, catastrophe reinsurance and other systems, and gradually form a multi-level catastrophe risk dispersion mechanism with financial support.

The current global catastrophe risk derivative instruments are not fully utilized. In the USA, for example, since its establishment in 1992, the catastrophe insurance derivatives market has had various trading forms such as catastrophe futures, catastrophe options, catastrophe swaps, and catastrophe bonds. Compared with the USA, catastrophe insurance in China is still in the exploration stage, and the attempt and application of risk securitization and other related derivatives in China is still immature. Therefore, Chinese meteorological departments should consider multi-level participation in the exploration, research, and construction of catastrophe insurance sharing mechanisms, as well as the establishment of multiple innovative cooperative service models.

In the case of agricultural climate catastrophe insurance, which was developed earlier and contracted more actively, for example, its institutional mechanism is still quite

inadequate and lacks the vitality of institutional innovation. On the one hand, there is a need to strengthen the establishment of cooperation mechanisms between insurance and meteorological services at the national level. For example, the cooperation between China's meteorological department and China Banking Regulatory Commission and China Insurance Regulatory Commission can be strengthened to introduce relevant regulations and norms to promote the healthy and sustainable development of meteorological services in agriculture and other industries. On the other hand, there is a need to strengthen the establishment of an insurance industry sharing mechanism for weather service information, mainly including short-term weather forecasts, weather disaster risk warnings, agricultural weather intelligence, and medium- and long-term climate forecast information, so that insurance companies can do disaster risk warnings, business risk control and disaster pre-assessment in advance.

8 Highlights of catastrophe insurance development and its implications for global audiences

Based on the experience and lessons learned from international catastrophe insurance and China's catastrophe insurance pilot, combined with the current characteristics of China's climate catastrophe development and economic and social situation, the following insights are mainly for the Chinese and global audiences.

Firstly, establish a catastrophe insurance system in collaboration with multiple entities. Combined with the comprehensive disaster prevention and mitigation concept of pre-disaster prevention, emergency response and post-disaster relief, the government, together with the public, direct insurance and reinsurance companies, need to continuously explore the construction and improvement of a catastrophe insurance system. In response to various catastrophe events, Japan, the USA, the UK, France, New Zealand, and other countries with developed catastrophe insurance, the establishment of the catastrophe insurance system have experienced a long and even tortuous exploration and improvement of various catastrophe insurance systems, and the close integration of insurance and disaster mitigation, has been more reasonable to give full play to the insurance compensation function for disaster losses.

Secondly, establish a special or comprehensive catastrophe insurance fund. For example, the US Florida hurricane catastrophe fund only pays for losses caused by hurricane disasters, reflecting the idea of "special insurance fund for natural disasters", which is a catastrophe insurance fund for specific disasters in a specific region and can cope well with special catastrophe risks, avoiding cross-regional subsidies for catastrophe insurance, which also helps insurance companies to focus on specific catastrophe risks in their own regions and set reasonable insurance rates. Similarly, China has piloted a catastrophe fund in Ningbo, which can fully mobilize all parties to form a pool of funds for disaster relief. This experience can be extended to China at the provincial level or across regions, such as the establishment of a provincial typhoon catastrophe insurance fund along China's southeast coast, and a provincial earthquake catastrophe insurance fund in the earthquake-prone western provinces.

Thirdly, promote the formation of a catastrophe loss-sharing mechanism through public–private partnership. In the face of catastrophe risk, which is uninsurable in nature, the insurance industry alone cannot afford to pay for catastrophe losses. Therefore, it is necessary to combine the strengths of both commercial insurance and government to cope with

catastrophe losses. China should establish a similar catastrophe loss-sharing mechanism to form a catastrophe insurance system operated by policyholders, insurance companies, domestic reinsurers, international reinsurers, and capital markets. Rather than acting as the primary insurer or sole bearer of catastrophe losses, the government should position itself as a key reinsurer to support and stabilize the catastrophe insurance market.

Fourthly, the government should provide appropriate legal and policy support. For example, the Florida government's support is reflected in the establishment of a hurricane catastrophe fund through legal means, the provision of tax incentives for it, mandatory participation by insurance companies and the issuance of bonds. Its funding source relies mainly on the collection of premiums, investment income and the issuance of bonds, with no financial input from the Florida government to avoid a heavy financial burden on the government. In addition, the Florida government established the hurricane catastrophe fund not to replace private reinsurers, but to increase the supply of the reinsurance market and to support the efficient operation of the private insurance market. Drawing on its successful experience, the Chinese government could adopt similar policies and regulations to support China's catastrophe insurance fund, while avoiding the government's financial burden.

Fifthly, the government should gradually learn to let go from catastrophe insurance. In many catastrophe insurance pilots in China, catastrophe premiums are borne by the local government. On the one hand, there is a huge difference in economic levels between the east and west of China, and catastrophe premiums may cause some pressure on local finances, coupled with the conservative ideology of government officials in certain regions, there is bound to be greater resistance to the government purchase model in the process of implementation. On the other hand, "free" catastrophe insurance is provided to local residents as a quasi-public product, which is not conducive to the formation and improvement of local residents' risk awareness. Moreover, different users have different needs for catastrophe insurance, and universal low-density catastrophe insurance may not necessarily meet the needs of some users for personalized catastrophe insurance products.

9 Summary

Climate catastrophe preparedness is a major issue that needs to be a significant priority now and for a long time to come. Therefore, how to effectively respond to climate catastrophes is a common challenge for all of humanity. Insurance mechanism, as one of the relatively mature risk transfer tools, can effectively alleviate the loss pressure caused by climate catastrophes. Therefore, based on this core issue, this paper elaborates the current development status, problems faced, and future development path of climate catastrophe insurance with the example of China's practice. On the basis of understanding the definition of catastrophe, this paper describes the general characteristics of climate catastrophe faced by China and comprehensively analyzes the problems and challenges faced by climate catastrophe risk management in China, including the possible increase of climate catastrophe risk in the context of global warming, the payout ratio of climate catastrophe insurance still has a certain gap, the urgent need for catastrophe risk management to capture extreme climate events, and the single way of involvement of meteorological departments in catastrophe risk prevention. Then, this paper analyzes the opportunities facing the development of climate catastrophe insurance in China in terms of national development strategy needs, perfect emergency management system, perfect catastrophe compensation

mechanism, and rare opportunities brought by domestic and international climate disaster prevention, mitigation and relief tasks. On the basis of comparing the features of international catastrophe insurance development, this paper systematically analyzes the main features of climate catastrophe insurance pilot work in Shenzhen and Ningbo, and proposes the key points for the meteorological department to participate in climate catastrophe insurance. Finally, this paper combines the development features of domestic and international catastrophe insurance and proposes the main enhancement aspects for the future development and improvement of climate catastrophe insurance in China. This paper mainly answers the path of further improvement of climate catastrophe insurance in the context of frequent climate catastrophes caused by global warming through the above-mentioned settings. If the climate catastrophe insurance mechanism is reasonably formulated and climate catastrophe insurance products are scientifically designed, the future response to climate catastrophes will be assisted by insurance, which will link the government's financial pressure. In future, different regions of the world still need to actively explore market mechanisms for diversified disaster risk prevention, including climate catastrophe insurance, in order to guarantee global sustainable development.

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Declarations

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