Ann Oper Res (2019) 283:795–810
https://doi.org/10.1007/s10479-017-2589-x

Analysis and exploration of damage-reduction measures for flood disasters in China

Malin Song[1] · **Qianqian Du**[1]

Published online: 27 July 2017

Abstract With the changing global climate, natural disasters occur frequently, greatly affecting many aspects of our lives. This study objectively discusses the major flood disasters that occurred in China from 1950 to 2014, and makes an explicit demonstration of the disasters, affected areas, and economic losses caused by floods. To study damage-reduction measures, based on Chinese insurance companies' disaster-related operations, statistics and recommendations along with the status of the Chinese insurance industry are presented. In terms of policy-guided agricultural insurance, a thriving and popular business, governments and insurance companies should continue to strengthen cooperation and expand coverage, striving for policy and model innovation to benefit more farmers. Considering the low number of residents with housing insurance in China, it is proposed that residents in disaster areas should implement pre-disaster defense measures. Considering the costs and benefits, both tangible and intangible, the author holds that residents who live in or wish to move to areas with high incidences of disasters are more willing to undertake pre-disaster precautions, and the government can rely on these residents to implement pre-disaster defense measures. Furthermore, this research suggests that early encouragement by the government could increase residents' enthusiasm to implement pre-disaster defense measures.

Keywords Flood disaster · Humanitarian operations · Agricultural insurance · Housing reinforcement · Intangible benefit

1 Introduction

For nearly half a century, owing to accelerating global development, remarkable progress has been made by industrialization and rapid economic growth worldwide, which also brings about global climate changes. Natural disasters occur more frequently, leading to huge eco-

✉ Malin Song
songmartin@163.com

[1] Research Center of Statistics for Management, Anhui University of Finance and Economics, Bengbu 233030, People's Republic of China

nomic and social losses. Natural disasters are characterized by their extensiveness, high frequency, severity, and uncertainty. Disasters may occur anywhere in the world, whether on land or at sea. Every moment, a region in the world may be suffering from a disaster. As for their uncertainty, the time, place, and degree of catastrophe can vary dramatically. Thus, using historical data modeling to predict disasters is not effective, and it is difficult to accurately predict a catastrophe. For example, existing scientific and technological methods could not predict earthquakes until recently, and these methods could only help us detect the earthquake time, epicenter, and magnitude after the fact. The severity of disasters ensues from their uncertainty, as people cannot move their property, resulting in serious losses. Losses are not limited to the economic aspect; the loss of the residents' lives in disaster areas is another visible aspect. After a disaster, locals cannot engage in productive activities for a long time, and the indirect economic losses are huge (Gunasekaran 2014). These characteristics are reflected in recent catastrophic events worldwide.

In the 1990s, economic losses caused by floods in China were about 1.2 trillion yuan. The Yangtze River Basin floods in 1998 were the most severe floods experienced in the whole basin in 150 years. The number of people affected by the floods was as high as 233 million, and the losses were more than 160 billion yuan.[1] In 2004, the Indian Ocean earthquake and tsunami, which measured 9.3 on the Richter scale and resulted in 226,000 deaths, was the most serious tsunami disaster in nearly 200 years and affected several countries including Indonesia, Sri Lanka, India, and Thailand, with the global aid totaling more than 3 billion US dollars.[2] Hurricane Katrina, in August 2005, was the largest hurricane in the history of the United States, which caused catastrophic damage to Louisiana and Mississippi, resulting in economic losses of approximately 75 billion US dollars. The US government signed more than 60 billion US dollars in disbursement grant bills before and after the disaster.[3] In January 2010, an earthquake measuring 7.3 on the Richter scale occurred in Haiti, collapsing 250,000 houses, killing 300,000 people, and displacing 48 million people. The number of victims reached 3.7 million, and international organizations donated 5 billion US dollars to Haiti for post-disaster reconstruction and disaster relief.[4] In 2016, the severe drought in Southeast Asia resulted in 50% of arable land being salinized, which seriously affected the growth of rice; Vietnam, as the world's second largest exporter of rice, suffered from its worst drought in 100 years, and rice exports were greatly reduced.[5]

From the above global disaster data, it is clear that the impact of unpredictable disasters on a region, or even a country, is huge, and could cause heavy losses. It is difficult for victims to undertake post-disaster reconstruction by themselves. Generally, governments of affected countries allocate funds to help people in the affected areas rebuild their homes and resume production. In developed countries, compared with their gross domestic production, the amount of funding is insignificant; however, for developing countries, especially small island countries, disaster relief funding is not a small expense (Opschoor 2011). For example, the share of losses in the 2004 tsunami disaster in the Bahamas, Grenada, and Cayman Islands accounted for 10, 212 and 183% respectively (Hoeppe and Gurenko 2006), and economic losses exceeded their annual GDP, which these countries could not bear by themselves. International aid, a drop in the bucket, cannot really solve the problem, and small countries are

[1] Data from the weather network, www.weather.com.cn, 1998 floods documentary.

[2] Data from Reuters, www.cnn.com, 10 years since India Ocean tsunami, Dec 26, 2014.

[3] Data from the US Cable News Network.

[4] Data from the US Cable News, www.cnn.com, Haidi donations: $1.3billion, July 9, 2010.

[5] Data from People's Network www.people.com.cn, Vietnam encountered the most serious drought in a 100 years, Mar 17, 2016.

less likely to have access to international loans because of their weak economies. Insufficient funds will not only make relief work impossible, but will also lead to social unrest and political instability due to unpacified victims. These consequences suggest that disaster risk research must be conducted, and preventive measures must be undertaken before disasters occur to help cope with the resulting difficulties.

China has always encouraged cooperation among countries, especially after forming part of the BRICS (Brazil, Russia, India, China, and South Africa) association. Using the BRICS platform and its emerging economy, China has cooperated with other countries in multiple fields, including but not limited to economic trades, politics, humanitarianism, climate change, and global governance. According to the Global Competitiveness Report 2016–2017, published by the World Economic Forum 2016, China's global competitiveness ranks 28th worldwide,[6] slightly higher than other BRICS countries, making the nation one of the best emerging economies. China occupies a major position among the BRICS countries due to its strong competitiveness and favorable development status. It is not only an excellent partner but also the leader in implementing cooperative endeavors. Regarding flood disasters, India and Brazil are frequently affected and it is necessary for India to find appropriate ways to counter flood disasters since it is an important producer of food crops in the world. Comparatively, China has stronger comprehensive national strength and better living conditions. Hence, developing proper measures to counter flood disasters and extending them to other developing countries through flood disaster research in China will result in greater cooperation among BRICS countries and sustainable development in newly-developing countries.

This study focuses on floods that occurred after the founding of the People's Republic of China, that is, after 1949, and conducts in-depth research regarding insurance development in China. The remainder of this paper is structured as follows: Sect. 2 summarizes and expounds the success of international disaster research at this stage; Sect. 3 provides descriptive statistics regarding floods in China from 1950 to 2014; Sect. 4 explores the development of disaster-related insurance in China, based on which agricultural insurance and disaster mitigation measures will be discussed in detail; finally, Sect. 5 presents the final summary and future prospects of this study.

2 Literature review

Due to the frequency and severity of disasters, many scholars have turned their attention to this field. Disaster management research is characterized by the following (1) disaster management functions, including decision-making, disaster prevention and relief, humanitarian logistics, casualties management, and disaster area restoration and rebuilding; (2) time, mainly pre-, peri-, and post-disaster; (3) disaster type, mainly accidents, earthquakes, floods, hurricanes, landslides, and terrorism; (4) data type, including on-site and file data, actual data, and assumed data; (5) data analysis techniques, including bidding model, decision-making analysis, fuzzy analysis system, game theory, network logistics, heuristic method, mathematical programming, queuing theory, simulation, and statistical analysis (Gupta et al. 2016). For flood disasters, researchers mainly focused on the causes of these disasters, their impacts, and relief measures. However, due to the uncertain nature of disasters, disaster prevention research is insufficient. This study focuses on the impacts of disasters and measures to reduce resulting losses. Hoeppe and Gurenko (2006) used World Bank data to study the number and magnitude of natural disasters occurring globally, between 1950 and 2005, and

[6] Data from Global Competitiveness Report 2016–2017.

compared the number of disasters, resulting losses, economic impact, insurance development, and international aid, including international loans, between high-income countries and low- and middle-income countries. They concluded that, although the number of disasters was slightly less than that of high-income countries, the economic and social impacts of disasters on low- and middle-income countries were more deadly, and international aid was insufficient to help affected areas to weather the storm. Sodhi (2016) explored the influences of frequent disasters from the feedback perspective and found that the fragility of a population could transform external disasters into national disasters and worsen their negative effects on national economic development, which was a vicious cycle that increased the effects of disasters exponentially. They used data from 179 countries spanning 50 years to verify their model and put forward recommendations to improve disaster management and national development. Similarly, Jha et al. (2010) also researched the relationship between disasters and national development, focusing on the link between disaster and poverty, stating that countries with financial difficulties were more affected in the event of a disaster. For developing countries, the GDP growth rate is slow and it is hard to improve living standards. Of course, economic recovery by governments would inevitably take a long time; thus, taking advantage of government policy to encourage residents to purchase insurance for pre-disaster defense, and reducing losses after disasters became the focus of research. All these researchers emphasized the connection between the economy and disasters and revealed the severity of disasters, but did not specifically explain how low-income countries could reduce disaster-related damage.

Disaster relief management is a complex task that includes all actions taken before, during, and after disasters. Besides post-disaster relief, disaster prevention, reduction, and preparation are also important. The efficient coordination of the three stages of disaster management could improve the effectiveness of disaster management in a range from 7.5 to 24% (He and Zhuang 2016; Edrissi et al. 2013; Sushil 2017). Considering target and multi-agent interest limits, Ermolieva and Sergienko (2008), using the stochastic optimization model, proposed robust suggestions regarding disaster risk management. Additionally, they emphasized the need for comprehensive precautionary measures and post-disaster remedies, considering the case of the Hungarian Tisza River floods. Moreover, they meticulously developed a disaster policy, focusing on three levels, namely the international, regional, and domestic levels. Faturechi et al. (2016) focused on the design of building shelters and exits in high-risk areas, and stressed the importance of aisles and evacuation paths to minimize evacuation risks post disaster. After a disaster occurs, people will evacuate and self-rescue while government and humanitarian groups organize rescues. Logistic paths for multiple-stage disaster relief operations, selection of distribution centers for relief goods, and logistic limitations all strongly affect the efficiency of relief operations (Duhamel et al. 2016; Burkart et al. 2016). Further, the type and quantity of donations during the relief process directly determine whether humanitarian operations will succeed (Ülkü et al. 2015). Although governments have sufficiently focused on disaster risk, introducing various precautionary measures and disaster relief measures for natural disasters, the real effect of these measures has not received enough attention. To solve the problem of under-utilization of disaster prevention tools, despite increased insurance coverage in Mexico, Saldana-Zorrilla (2015) recommended that the federal government grant subsidies to administrative agencies that have insufficient capacity, to assist them in disaster prevention and loss compensation.

Apart from government and humanitarian groups' actions, the most critical subjects in disaster risk management are insurance companies. Regarding the role of insurance, some scholars believe that insurance only protects the interests of institutional investors, and increases the economic burden of residents, and are unable to make up for the loss of victims

(Young 2008). However, the role of insurance in compensating for the loss resulting from natural disasters is still positive, based on the majority of research results (Cottle 2007; Collier 2014). Cottle (2007) focused his research on commercial forest fire disasters and pointed out that insurance is more economically valuable than pre-disaster protection measures, and insurance companies can help facilitate sustainable forest risk management. He stated that insurance advantages mainly benefit insurance companies themselves and cannot play a significant role in the external environment. Cordella and Yeyati (2015) suggested that disaster insurance could not only compensate for the loss caused by natural disasters but could also be a powerful catalyst for external financing. By reducing the impact of disasters, vulnerable low- and middle-income countries can more easily obtain international capital assistance.

Several studies proved that while the role of insurance companies in disaster compensation was indispensable, insurance companies were inactive in providing disaster insurance, and residents showed little interest in purchasing disaster insurance. Based on data regarding the US Hurricane Andrew and the 1993 Mississippi River flood disaster, along with previous surveys (Kunreuther 1996; Palm et al. 1990; Palm 1995), Kunreuther et al. (1978) analyzed the reason why residents in risky areas had a negative attitude toward disaster insurance. He pointed out that insurance companies were inactive in the catastrophe business due to their uncertainty regarding the occurrence of disasters, and the possibility of their finance suffering negatively after disasters. To encourage residents to purchase insurance, Marshall (1974) recommended that insurance companies avail of the design of a special participatory contract to attract farmers to buy disaster insurance. He also recommended that insurance companies return some premium when the insured did not make a claim, or when the company made profits. Doherty and Schlesinger (2002) used theoretical models to demonstrate that participatory insurance policies could be used as risk management tools to expand disaster coverage and to prove that participation in insurance could address the insured's personal risks and increase the insured's wealth. This model was widely applied in health insurance, but had not yet been applied in agricultural insurance. Enjolras and Kast (2012) discussed whether this type of policy could be applied to agricultural insurance, particularly to grain and cereal insurance. They believed that insurance companies were supposed to design the best policy to attract policyholders with the aim of maximizing farmers' wealth, while reducing risk. Although the question of how to realize interest of insured was considered, the risk of the company remains. When insurance companies adjust their policy model to attract clients, they should also be concerned about the company's financial risks. Hochrainer et al. (2009) presented the case of food microinsurance in Malawi, an African country, where insurance companies and banks collaborated to offer funds and insurance to farmers, using climate variability models and disaster insurance models to assess climate change, and realize insurance pricing and policy adjustment. They focused on analyzing the bankruptcy risk of insurance companies, concluding that insurance companies should make timely changes to ensure that the reserve capital was sufficient to cope with the disaster risks caused by climate change. Regarding the interests and risks of insurance companies, some scholars considered the implementation and promotion of disaster-risk securitization products in recent years. Scholars at home and abroad (Lee et al. 2007; Froot 2008) clarified the principles of securitization, and designed the securitization model and products, in an attempt to combine the capital market with the insurance market. Borensztein et al. (2017) used a stochastic optimization model to estimate the benefits of a catastrophe bond issued by a small open economy when suffering from a natural disaster. They benchmarked the model with reference to natural disasters such as earthquakes, floods, and storms in developing countries. Additionally, for these countries, it was feasible to take catastrophe bonds to reduce losses because the cost of issuing bonds was small. These innovative securitized financial products required strong theoretical research to

identify appropriate securitization products. Conversely, it was important to enjoy a relatively complete capital market environment. However, there are not many regions where these factors exist simultaneously; consequently, numerous difficulties still exist in the popularization of these products.

Scholars from different countries have different opinions about the impact of disaster and loss reduction. They have pointed out the severity of disasters and the feasibility and importance of insurance. However, for China's flood disasters, the research on such mitigation measures is limited, and does not consider the development of China's disaster insurance industry. Some flood disaster insurance schemes mentioned above have not yet been implemented in China. Since China's insurance industry is underdeveloped, pre-disaster defense is an important method for reducing damage and as well the highlight of this study. Moreover, this study incorporates intangible benefits into the revenue, and comprehensively explores the important factors that affect residents' pre-disaster defense.

3 Descriptive statistics

There are two large rivers, Yangtze River and Yellow River, flowing through mainland China, of which the Yangtze River is the world's third largest river and is the only river to run within one country. Some provinces that at least two large rivers run through include Qinghai, Gansu, Tibet, Sichuan, Yunnan, Shanxi, Shaanxi, Hubei and other provinces, and the drainage basin also covers several important cities, such as Wuhan, Chongqing etc. In the rainy season, or during too much rainfall, the river level is bound to rise. If prevention and control measures are not in place, floods will submerge everything, bringing huge losses to the government and the people.

Figure 1 presents the general situation of floods in China from 1950 to 2014 it can observed that there were five more severe floods in the mid-1950s, early 1960s, 1990s, and the turn of the century. The most notorious floods were the Yangtze River floods in 1954 and the 1990s. Due to the previous flood season, the 1950s flood featured heavy rain, long duration,

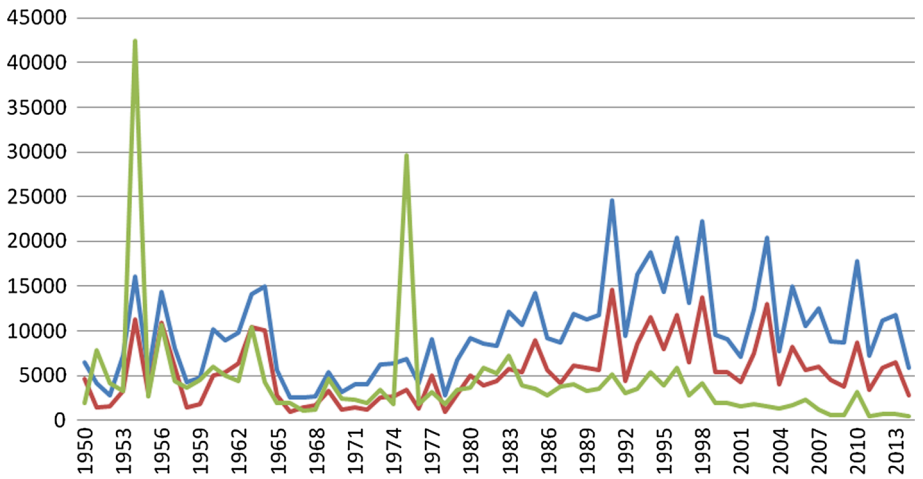

Fig. 1 Damage caused by floods from 1950 to 2014 in China. The *blue* and *red solid lines* represent disaster-affected areas and inundated areas, respectively; the unit is 1000 ha; the *green solid line* represents death toll. *Source*: China flood and drought disaster bulletin, 2014. (Color figure online)

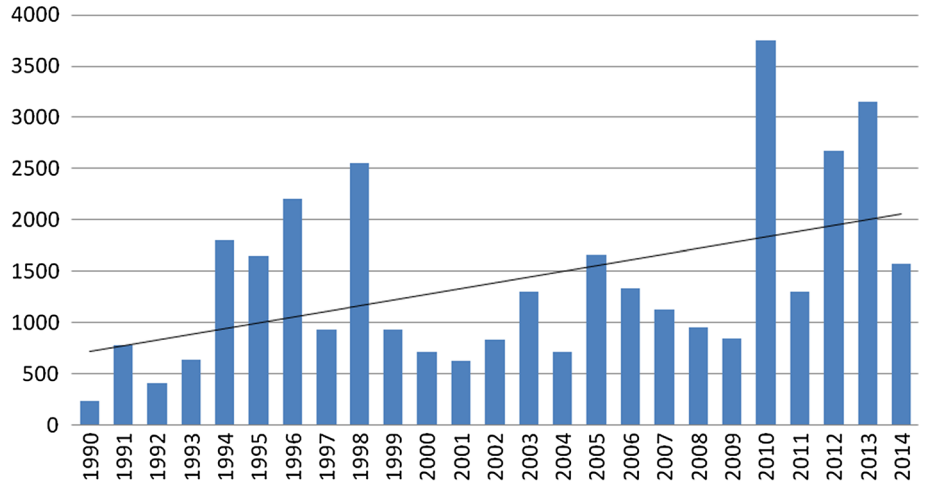

Fig. 2 Direct economic losses of floods in China since 1990. The unit of direct economic loss caused by floods is billion yuan; the *black solid line* represents the linear trend of flood direct economic losses. *Source*: China flood and drought disaster bulletin, 2014

covering a wide area, so that the water level within the basin hit a new record. Moreover, since the People's Republic of China was newly founded, and the renovation of the river dam was incomplete, the disaster was particularly catastrophic once it happened. There was no doubt that the number of disaster-affected areas and affected people increased dramatically, and the affected population in this flood reached its apex between 1950 and 2014. As for the 1990s floods, the flood storage, regulation capacity, and flood diversion capacity were the main reasons, besides precipitation, that led to the disaster. From 1990 to 2000, floods occurred fairly frequently; thus, China had been busily fighting the floods during the whole of the 1990s. Of course, many areas were influenced by the 1950 disaster, and it still holds the record of causing the most damage. However, compared with the 1990s, the difference between the stricken areas and inundated areas was small in the 1950s, which means that in the disaster-affected areas, where the vast majority of the plant harvest reduced by more than three percent, the impact of disasters was huge on the regional agricultural economy. While more areas were hit by flood disasters in the 1990s, it was obvious that the disasters were effectively controlled and the numbers of stricken areas and inundated areas were fewer than those in the 1950s.

In terms of the direct economic losses caused by floods, Fig. 2 showed that the direct economic losses of floods had been increasing from 1990 to 2014. The floods in 2010 brought about the largest losses, reaching 374.543 billion yuan, followed by 2012, 2013 and 1998. In 2010, severe flooding occurred in the Yangtze River and Song-Liao River basin, and the average of mountain flood disasters was much higher than the average since 2000, resulting in great economic losses. In 2013, the typhoon disaster in Guangdong led to heavy direct economic loss, and the economic losses caused by the typhoons "Yout" and "Tianyu" accounted for one-third of the total loss caused by floods in the country. Since 2000, the annual number of typhoons could reach 7.5. Every year typhoons collapsed 123,600 houses and affected nearly 34.06 million people, with direct economic losses reaching an average of 42.6 billion yuan.[7] It is worthwhile to note that the Guangdong and Fujian provinces are prone to suffer

[7] Data from Bulletin 2014: Flood and Drought Disasters in China.

from typhoons, since they lie in the path of typhoons. More than one typhoon lands every summer in these provinces, which undoubtedly affects the local economy and negatively impacts people's lives.

4 Compensatory measures for losses in disasters

4.1 Natural disaster insurance in the Chinese mainland

Whether a flood or a typhoon, the impacts of natural disasters are significant and destructive. Regarding the issue of disaster loss reduction and post-disaster reconstruction, Hoeppe and Gurenko (2006) suggests that the government's sole support is more than enough, and the most effective approach is the implementation of disaster insurance. Availing of insurance lowers risks, prevents disaster-related losses, and provides corresponding financial compensation. Thus, disaster insurance would help pull disaster-hit residents out of trouble and reduce the burden of the government. So far, China has not yet officially implemented the above-mentioned coverage. Several insurance companies only provide the businesses of agricultural insurance and building insurance, listing some natural disasters as insurable risks. To examine resident property protection in agricultural and building insurance, we analyze the businesses of five representative insurance companies. Table 1 presents their relative index with respect to building and agricultural insurance. Companies whose comprehensive scale and premium income are in the top five ranking are considered. It is based on the business ranking of China's insurance companies (property insurance) in January 2016.

The conclusions that can be drawn from Table 1 are as follows:

(1) Building insurance is provided by all five insurance companies and is classified under housing insurance. The range of insurance coverage is primarily the house; the scope of cover includes rainstorms, floods, mud avalanches, landslides, lightning, hail disaster, typhoons, fire disaster, explosions, etc., a list that explicitly excludes earthquakes and tsunamis, which implies that losses such as house damage and collapse caused by the latter cannot be claimed for insurance indemnity. Moreover, the current insurance industry in China has no products that cover earthquake disasters. Usually the house damage caused by earthquakes is disaster-ridden: cracks would emerge after a small earthquake, and large earthquake could destroy houses. Houses are the most important fixed asset for residents, and reconstruction would cost large amounts of material resources and money, which places a great burden on them. Thus, this would influence residents' lives for the next 10 years. Generally, the government gives economic aid for residential housing and regional infrastructure damage caused by earthquakes, but large amounts of financial appropriation is definitely not an efficient solution.

Although all large insurance companies provide property insurance, the coverage ratio is quite low, with an average level of less than 10%,[8] greatly lagging behind developed countries' 70–80%. Additionally, car insurance comprises the largest part of property insurance, while building insurance accounts for little. The number of households that insure their houses is small, whether in large cities like Beijing and Shanghai, or in small towns. By analyzing the operating statistics on the CPIC and PAIC annual report, we found that car insurance accounts for a majority in the property insurance business, with 77 and 80% respectively. In

[8] Source: from www.zhongmin.cn.

Table 1 Five property insurance companies' business operations. *Source*: The Insurance Association of China, www.iachina.cn

Insurance company	Agricultural insurance	Range of insured objects	Scope of cover	Exemption from liability	Building insurance	Scope of cover	Exemption from liability
People's Insurance Company (Group) of China	√	Corn, rice, wheat, rapeseed, soybean, cotton, peanut, forest, etc.	Drought, fire, hail, flood, wind damage	Politics, war	√	Rainstorm, flood, mud avalanche, landslide, lightning, hail, etc.	Earthquake and related disaster; tsunami
Ping An Insurance (Group) Company of China	√	Forest	Fire	Explosion, lightning strike, nuclear radiation, etc.	√	Same as above	Same as above
China Pacific Property Insurance Company	√	Forest	Fire, flood, wind damage, snow and ice disaster	Politics, war	√	Same as above	Same as above
China Life Insurance (Group) Company	×	–	–	–	√	Same as above	Same as above
China United Property Insurance Company	√	Corn, soybean, rapeseed, tobacco, grape, etc.	Rainstorm, flood, wind damage, hail, snow and ice disaster	Politics, war	√	Same as above	Same as above

contrast, housing insurance accounts for less than 2%.[9] Considering the current situation, it is essential to strengthen pre-disaster defense.

(2) Among the top five insurance companies, only GPIC has not issued agricultural insurance products. However, there are differences among the agricultural insurance products offered by the other four companies, mainly in their scope of cover. For example, CPIC's and PAIC's products only cover forests, for which fire disaster is the major risk covered by insurance, and the PAIC's scope of cover is larger, including floods, wind damage, snow, and ice disasters. Besides forests, the PICC includes common agricultural products into scope of cover, such as rice, corn, wheat, and cotton, while the CPIC's classification is more specific, offering insurance products for rapeseed, tobacco, and grape, in addition to common agricultural products. For the above-mentioned agricultural products, insurance companies' scope of coverage includes common natural disasters, excluding earthquakes or tsunamis.

The development of agricultural insurance can be divided into two phases: from the 1930s to 2004, and from 2004 to the present. Before 2004, commercial insurance companies mainly conducted the business of agricultural insurance. However, due to the characteristics of agricultural production and farmers' low income, agricultural insurance was declining: scale shrunk, premium income and coverage types decreased, and commercial insurance companies increasingly withdrew from this field, which negatively affected agricultural development. Considering this situation, the Chinese government implemented experimental policy-based agricultural insurance in 15 provinces and regions in 2004 and 2005, successively. Under this policy, the government provided financial funds as subsidies to farmers' premium. Agricultural insurance developed rapidly due to the joint support of the central and local governments. The model of policy-based agricultural insurance is implemented as follows: the government and farmers pay for the premium together, the major share being paid by the former, and a small share by the latter. For example, in the Shandong province, the central and provincial government budgeted burden is 50%, and the local government and farmers' burdens are 30 and 20% respectively. Consequently, up to 2014, agricultural insurance's accumulated premium income reached 32.58 billion, the number of farmers insured is 250 million, and risk security offered is 1.6 trillion. Insurance compensation and areas of insured crops have made new breakthroughs, in which the risk security of corn and rice exceeded 68%, and wheat reached 49%.[10] At this point, China's policy-based agricultural insurance system had formally formed. With the development of agricultural insurance, farmers' grain is insured in of the event of a flood disaster.

4.2 Study on residents' pre-disaster defense measurement

Compared with the success of agricultural insurance products, housing insurance is less developed and has a lower rate of subscribers. Under such conditions, it is necessary to focus on pre-disaster defense measures to reduce losses in the event of a disaster. This study analyzes the perspective of residents, selecting the cost-benefit method to determine the conditions under which residents are willing to perform pre-disaster defense measures, and to convert intangible benefits into earnings.

In China, a house's tenure of use is 50 years, after which, the house's condition will be appraised if the house owner wants to keep the house. The house could be retained if it

[9] Source: 2015 Annual Report China Pacific Insurance (Group) Co., Ltd., and 2015 Annual Report Ping An Insurance (Group) Company Of China, Ltd.

[10] Source: 2014 Bulletin of Insurance Market.

is identified as up to standards. Assuming that the recurrence interval of flood disasters in some areas in China is n = 50 and 75 years, then the probability of occurrence is $\lambda = 0.02$ and 0.013, respectively. Assuming that reinforced houses could avoid the damage caused by disasters, when a disaster happens, house loss "L" is 20,000 RMB (this estimation is based on China's building materials market and housing costs), then the expected revenue for the house is $R = 0.02 \times 20{,}000 = 400$ RMB. The benefits of reinforcement are mostly tangible; however, there are also intangible benefits. For instance, the sense of security gained by implementing this measure is valuable, which is an intangible benefit. Thus, this study considered two types of conditions: one considering tangible benefits only, and the other considering both tangible and intangible benefits as an integral part.

4.2.1 Tangible benefits

Since the coverage rate of building insurance (housing insurance) is quite low, we suggest that residents should check their houses periodically to see if the house is aging. If it is, the owner should perform timely repair to prevent potential damage by disasters. For storied and roofed houses, cement plaster can be applied for reinforcement. For protruding parts of buildings, vertical braces can be set using appropriate measurements. These pre-earthquake defense measures shave protective effects, but are expensive, so residents will certainly weigh the benefits and costs of these measures before they take action. Only when residents consider that the benefit will be larger than cost for a certain period, would they willingly start implement these measures. Regarding the benefit-to-cost ratio (B/C), the cost is determined by the current market price of cement plaster that is used to maintain the house, while the benefit is the sum of discounted expected revenue each year since the house has been maintained. According to the above-mentioned basic conditions of housing and disaster risk, and assuming the discount rates to be 10 and 15% respectively, B/C can be calculated. When $B/C > 1$, the benefit is larger than the cost for residents, which means it is cost-effective and reasonable to maintain and reinforce the house. Figure 3 shows the B/C ratio of each year when the recurrence interval is 75% and discount rates are 10 and 15% respectively. Figure 4 shows the B/C ratio under different recurrence intervals, when the discount rate is 10%.

The major factors influencing residents' decision can be summarized from the above two graphs, that is, disaster recurrence interval, discount rate and tenure of use. Combined with residents' expected length of residence-to-benefit ratio, it can be inferred whether residents would maintain and invest in the house or not.

(1) If the recurrence interval is "n," the disaster occurrence probability of each year is $\lambda = 1/n$. The probability and thus the expected revenue for reinforced houses $E = \lambda L$

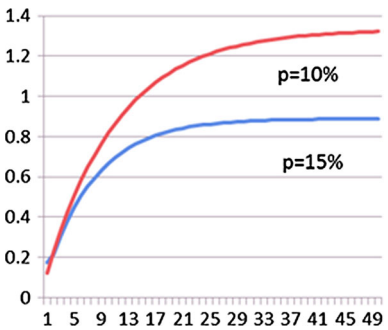

Fig. 3 B/C under different discount rates. The x-axis is the year and the y-axis is the B/C ratio

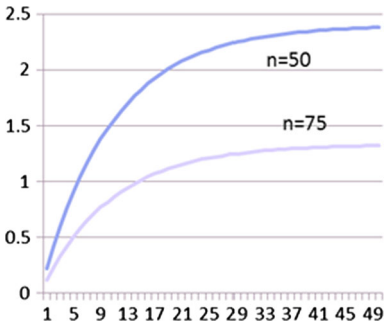

Fig. 4 B/C under different recurrence intervals. The x-axis is the year and the y-axis is the B/C ratio

becomes smaller as the recurrence interval increases. Thus, for regions with different recurrence intervals, the residents' expected revenue is different. Residents in regions with smaller recurrence intervals and higher annual disaster probability are more willing to undertake defense measures.

(2) Discount rate (p) can reflect the investors' expectation of revenue and their risk preference. Expected revenue being the same, with lower discount rate and larger present value, residents are more willing to invest in reinforcing their houses. As shown in Fig. 3, when discount rate is 10%, the B/C will not exceed 1 until the fifteenth year; when discount rate is 15%, B/C has never exceeded 1 within 50 years' of use, which means that both revenue and discounting have not surpassed cost for 50 years. Therefore, even with high discount rates, residents would not undertake disaster defense actions.

(3) Expected length of residence: For some residents, their house does not function only to service people, but is also an important investment, and they seek profits from house property rights transference. For these investors, the estimated time of residence is short, so they would deliberate on their "extra" investment. Figure 3 reflected that with a 10% discount rate, when investors' expected house holding time is less than 8 years, the total expected revenue is less than the cost within the holding period. Under such conditions, investors, as rational persons, usually would not maintain and reinforce the house. Hence, the key is to find out the critical number of years when B/C is 1. When length of residence is higher than the critical number of years, it is worth reinforcing the house; otherwise, it is more beneficial not to maintain the house.

Overall, there are various factors influencing whether residents would implement pre-disaster defense measures. Residents would undertake these actions when they realize the probability of disaster occurrence is quite high and they wish to reside in their houses permanently. When the discount rate is rather low, the risk compensation residents require for reinforcing their houses is lower; thus, residents who are not risk-averse are more willing to implement pre-disaster defense measures. Therefore, it will be efficient to call on these residents to take actions. Moreover, considering the cost-benefit method, residents would be more likely to invest when cost is lower. Therefore, government and humanitarian groups could offer subsidies to families that reinforce their houses to reduce the residents' cost and further encourage them to participate.

4.2.2 Comprehensive benefit

Benefits gained from any investment should not only include tangible benefits but also intangible benefits, such as sense of honor, sense of security, and happiness. Since it is difficult

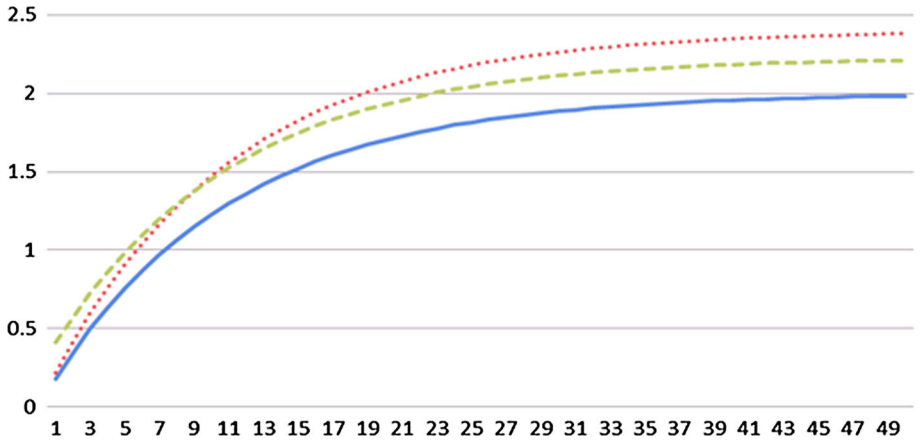

Fig. 5 B/C considering intangible benefits. The x-axis is the year and the y-axis is B/C ratio. The *solid curve* represents the tangible B/C, and the *squired* and *dotted ones* represent the B/C considering the intangible benefits of security and honor, respectively

to calculate them accurately, this section focused on the influence that intangible benefits have on residents' decision to reinforce their houses; thus, it would be convenient to make a hypothesis regarding intangible benefits. Two types of intangible benefits are considered here: the first one is the sense of security obtained by reinforcing the house "M" and supposing $M = \delta C$. To be specific, M is related to the cost of reinforcing the house, and usually the more money residents invest in pre-disaster defense, the safer they consider their houses, and the greater their sense of security. Moreover, if they choose to maintain the house, they would receive the intangible benefit of a sense of security every year. Under the second condition, we suppose that the government circulated a notice of commendation for residents who reinforced their houses to encourage them to practice pre-disaster defense. Residents gain a sense of honor from this commendation, and we presume the intangible benefit of sense of honor "H" to exist during the first year. For the cost and benefit accounts of the two conditions, and supposing $\delta = 5\%$, and $H = 500$, the results are presented in Fig. 5. The solid curve represents the tangible B/C, and the squired and dotted curves represent the B/C that considers intangible benefits of security and honor, respectively.

As can be seen from Fig. 5, the three curves cross the horizontal line at which $B/C = 1$ at different points; the solid curve takes the longest time to reach the horizontal line. The tangible B/C is slightly smaller than that considering intangible benefits for each point of time, which implies a deviation when only tangible benefits are considered. Taking the conditions in Fig. 5 as examples, when in the sixth year, the B/C of tangible benefit is 0.8711, but the actual comprehensive benefit is higher than cost. Thus, in the sixth year, the sum of investment benefit exceeds costs, and this project steps begins receiving investment return. However, if only tangible benefit is considered, it would take another 2 years to gain investment returns.

Conversely, sense of security is perceived as a durable benefit, while sense of honor peaks and lasts only during the first year. Benefit gained in the early period is the key to driving residents to invest, so when residents feel an intense sense of honor, conditions will appear as in Fig. 5. Moreover, it takes less time for benefit to override cost, and makes this project more attractive. Therefore, to encourage residents to respond to the call of "reinforcing their houses," the government could circulate notices of commendation to residents, or select them as model pacesetters in the first year.

5 Conclusion

5.1 Summarization and significance

This study, which focused on flood disasters in China during the period 1950–2014, discussed flood-damaged areas, inundated areas, and direct economic losses in detail, objectively describing the negative impact of disasters on the economy and people's lives, and found that huge losses caused by disasters aggravated the government's financial burden. Regarding disaster-loss-reduction measures, this study conducted a statistical analysis of the development of agricultural and building insurance for the top five insurance companies in China, summarized their scope of coverage and exemptions from liability in contractual terms, and concluded that China's agricultural insurance was well-developed with an extensive scope of coverage; thus, the country has the capability to recover from flood-related losses. Regarding the influence of flood disasters on housing, the number of residents whose houses were insured is limited, despite the presence of big insurance companies providing disaster insurance, and residents lack the conscientiousness to protect their property through insurance. To resolve the issue of low building-insurance coverage rate, this study proposed that residents implement pre-disaster reinforcement measures by themselves, from the perspective of tangible and intangible benefits. This proposal would be more effective in high-incidence areas, especially where the residents wish to live permanently. Moreover, the government should further encourage residents in the first year to undertake pre-disaster defense actions.

Disaster relief and operation management is an act that covers the whole pre-, peri- and post-disaster processes. This study considers disaster prevention and reduction during the pre-disaster stage as the key research object to find factors that influence residents' participation in pre-disaster prevention and accordingly, utilizes governmental and humanitarian assistance to reduce residents' disaster prevention and relief costs, improve their enthusiasm for preventing disasters and implementing pre-disaster measures well to lay a favorable foundation for disaster management, and reduce the difficulties in providing follow-up assistance.

Research regarding China's flood disasters is not only meaningful to China's own disaster operation management but can also serve as a reference to other newly-developing countries with similar problems since governmental and international assistance are all the same regardless of country size and level of development. The methods mentioned in this paper to promote residents' enthusiasm for pre-disaster work, such as the use of subsidies and honor incentives, are also applicable to other countries to improve the sustainable development abilities of newly-developing countries.

5.2 Limitations and future prospects

Due to imperfect statistics and theories, this study has the following shortcomings: (1) Up-to-date descriptive statistics about each year's flood disasters cannot be obtained due to limited statistical data regarding flood and drought disasters, and the impacts of disasters are only approximates due to limited statistical indexes. (2) The measurement of invisible earnings in this study is not sufficiently accurate due to the lack of relevant theories. (3) There are many factors that can influence residents' decision-making and individual variation exists. However, this study only considers the perspective of cost benefits and points out influential factors. The residents' final decision is still unknown.

From the research regarding insurance in this study, it is evident that there is still room for improvement in the insurance coverage rate. The government's policy incentives and insurance companies' innovation concerning guarantee slips can both be the focus of further

research. In areas with high frequency of disasters, further attention should be given to the government's difficulties in increasing residents' awareness of disaster prevention and making them understand the importance of pre-disaster precautions. Finally, there is still no unified method to measure invisible earnings, which requires further research.

Acknowledgements The work was supported by the Program for Projects in Philosophy and Social Science Research of the Ministry of Education of China (Grant No. 14JZD031), the National Natural Science Foundation of China (Grant Nos. 71471001 and 71171001).

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