Wealth Distribution Effect of Natural Catastrophe Risk and Insurance System Design

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Abstract:

Natural catastrophe risk has more destructive economic influence than common natural disasters and could impact not only the development of the aggregate economy but also the behaviors of micro-units and further wealth distribtution. The paper aims at probing the impact of natural catastrophe risk on wealth distribution from perspectives of wealth reduction, labor income variation, asset allocation and risk preference. Based on the theoretical analysis the paper will make empirical test on the short wealth distribution effect with data on flood disaster in specified areas in China and further propose the corresponding suggestions on the designing of catastrophe insurance system from both social and commercial perspectives.

1. Introduction

Natural catastrophe risk has more destructive economic influence than common natural disasters and could impact not only the development of the aggregate economy but also the behaviors of micro-units, market operation and further wealth distribution.

The impact on wealth distribution, i.e. wealth distribution effect of natural catastrophe risk, refers to the wealth disparity across people incurred by passive wealth adjustment, income variation and subjective asset allocation. In China the impact mechanism of natural catastrophe risk works as well while demonstrating the distinctive features with different economic and institutional background. For example, when natural catastrophe shocks the labor market after the event, will the segregation of labor market impede the labor demand recovery during reconstruction period and enhance the cross-group wealth disparity? When natural catastrophe insurance is scare in the market, will the catastrophic losses frustrate the household to hold physical asset which may result in higher systemic risk of the portfolio and lager wealth disparity after catastrophe? And in the long run, will the expectation towards

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natural catastrophe risk alter the risk preference of household and lead to differentiated portfolio choice and further enhance the wealth disparity in the risk-prone areas? If all this happens, managing natural catastrophe risk with efficient insurance system to weaken the adverse effect on wealth distribution will have very important welfare implication.

The purpose of the paper is to seek answers to these questions through probing the impact of natural catastrophe risk on wealth distribution from perspectives of wealth reduction, labor income variation, asset allocation and risk preference. Based on the theoretical analysis the paper will make empirical test on the wealth distribution effect of natural catastrophe risk with data from specified areas in China and further propose the corresponding suggestions on the designing of catastrophe insurance system from both social and commercial perspectives.

2. Literature Review[3]

Traditionally the scholars observe the economic impact of natural disasters including catastrophe risk from the perspective of aggregate economy and gradually turned attention to the impact of natural disasters on the micro-units and social welfare indexes while the risk evolved and the diversity of research methods strengthened. Leiter et al. (2009) examined the impact of flood on capital reservation and productivity with the data from European enterprises. Guimaraes et al. (1993) probed the wealth and income effects of natural disasters with hurricane Hugo as the example. Masozera et al. (2007) and Shaughnessy et al. (2010) discussed the change of income distribution before and after hurricane Katrina and the distribution of impacts of natural disasters across income groups.

There are also researches on how to manage the negative effect of natural disaster and catastrophe risk with financial instruments and government resources. Kunreuther (1996), Cummins（2004）, Lakdawalla（2006）, Borensztein (2009), Kunreuther et al. (2009), Masahiro Shoji(2010) discussed the feasibility of utilizing insurance, micro finance and capital market to handle catastrophic risk for public sectors. Jaffee and Russell (2013) explored the labor division and cooperation between private and public sectors in the field of catastrophe risk management with methods of welfare economics. Charpentier and Maux (2014) developed a theoretical framework for analyzing the decision to provide or buy insurance against the risk of natural catastrophes and shows that government-provided insurance will be more attractive in terms of expected utility,

There are also researches probing the catastrophe risk problems in China. Sun et al. (2004), Lu and Cui (2007), Liu (2008) and Zhang (2010) studied the catastrophe risk

[3] Reference is given at the end of the paper.

appraisal, impact mechanism, management strategies and public policy experiences in China. And the research focus has been turned to wealth and production problem in recent years. Zhao (2011) and Li (2013) discussed the losses to national wealth incurred by natural disasters and resulting loss distribution and equity adjustment. Xu (2011) took Wenchuan earthquake in Sichuan Province as the case and examined the distribution of wealth distribution and flowing mechanism after the event. Feng Kong, Lili Lü, Jian Fang (2016) reviewed the risk assessment theories and methods about agricultural catastrophe and the study was based on the loss of agricultural production.

The literature above provides foundation and also space for further study on this issue. For example, few researches distinguished the short-term and long-term impact of natural catastrophe on wealth distribution and combine the static wealth variation effect with dynamic asset allocation effect. The empirical research on accurate impact of China natural catastrophe and the theoretical research on the details of insurance system design are also scarce. All this deserves more efforts in this field.

3. The Impact of Natural Catastrophe Risk on Wealth Distribution

There are several assumptions before the analysis: (1) Assume the households in the same area exposed to the same natural catastrophe risk can be divided into two groups in terms of wealth level, financially strong and weak ones, denoted by Gs and Gw. (2) Assume the insurance and other marketized loss-mitigation mechanisms are absent before and after the catastrophe, which is usually true in the underdeveloped areas. (3) Assume household wealth is composed of initial wealth, volatile labor income and return form asset portfolio.

3.1 Property Loss and Initial Wealth Variation

From short-term perspective, when the natural catastrophe occurs, both groups will be impacted while Gw will possibly suffer from larger proportional losses over wealth because their wealth accumulation is usually inadequate for the natural catastrophe shock. The stronger wealth variation of Gw will lead to the larger difference in wealth level between the two groups and brings adverse effect to disparity.

From long-term perspective, things may be different. Usually there is after-disaster economic assistance from governments and the resources will be allocated to the people suffering natural losses averagely instead of being based on the absolute loss in the catastrophe. Obviously Gw will obtain more adequate compensation than Gs and this will possibly frustrate Gs in accumulating wealth in long-term, decrease the difference and bring the positive influence to the wealth distribution.

3.2 Crowding Out Employment and Labor Income

Gw is more vulnerable than Gs not only in terms of initial wealth but also dynamic labor income while the losses incurred by natural catastrophe could impede the process of economic development. Nevertheless, Gs could create more employment opportunities for Gw in the field of real estate construction and social service etc. while recovering from catastrophe losses. In the areas where self-operated business takes dominant shares, this is especially expectable.

Then, even if the natural catastrophe could crowd out employment capacity in general, there is the chance of the production of the new employment. And when the new employment is transferred from Gs to Gw, the income gap between the two groups can be narrowed.

3.3 Risk Preference and Restructured Portfolio

Gs and Gw usually holds different asset portfolio and rely on the asset return to different degree due to different risk preference. Usually the more wealth one has, the more risk averse he will be. While the existence of natural catastrophe risk could possibly further widen the wealth gap between the groups, their risk preference can be changed in the long term. For example, Gs could hold riskier portfolio under risky scenario compared with the one under secure scenario, and Gw could hold more conservative portfolio under risky scenario and rely more on stable asset return.

Riskier portfolio brings more volatile asset return. When the financial environment is optimistic, the asset return difference between Gs portfolio and Gw portfolio could be larger than the asset return difference in the pessimistic environment. Correspondingly, whether the change of risk preference will produce adverse selection is decided by the actual financial market performance.

4. Empirical Analysis of the Wealth Distribution Effect of Natural Catastrophe Risk

Based on the theoretical analysis, we will select the specific period and sample areas to make empirical analysis of wealth distribution effect of specific natural catastrophe risk. There are various types of natural catastrophe risks in China and one of the most distinctive risks is the flood risk which has the extensive impact on almost all the areas.

According to Nannan Zhang (2010), the disaster can be regarded as natural catastrophe if the direct economics losses incurred by the single disaster divided by GDP in the specific area is larger than 0.2 percent. The following table gives the landscape of flood risk facing the whole country: 24 areas suffered from such grave economic losses incurred by flood during year 2002 to 2012 and some of the losses reached about ￥50 billion which is the very hard hit to the economy of one single area.[4] The analysis of wealth distribution effect of flood in these areas will be very representative and of practical importance.

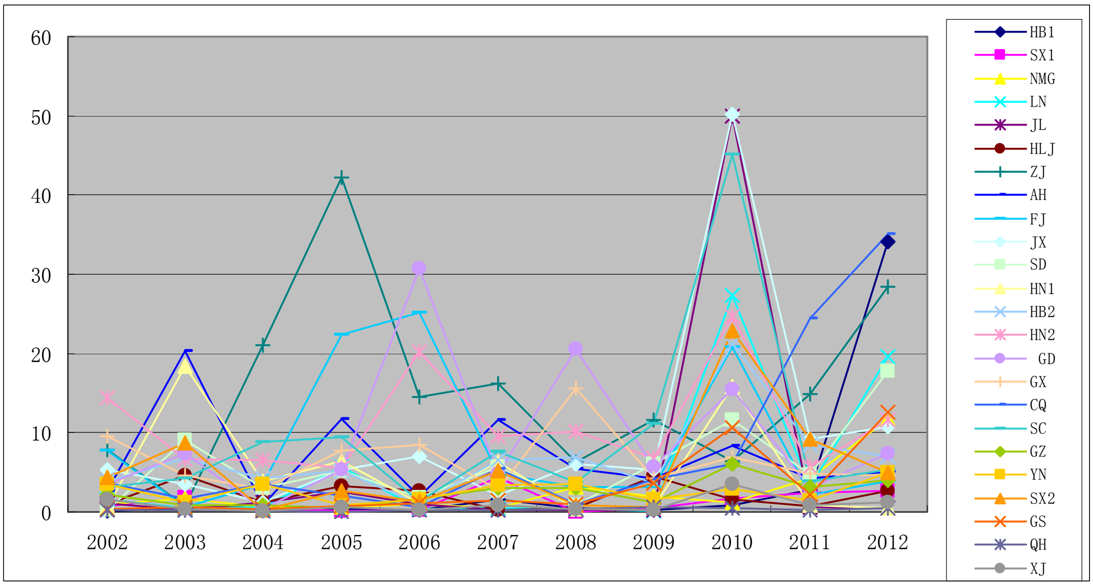

Figure1 The Direct Economic Losses of 24 Areas Incurred by Flood (Unit: ￥bl)[5]

4.1 Variable Construction

4.1.1 Dependent and Independent Variables

(1) Pure Income Per Capita of Rural Households/Disposable Income Per Capita of Urban Households

As discussed above, we need to specify the wealth disparity indicator as dependent variable to demonstrate the difference of the two groups, Gs and Gw with different wealth level. When there are not direct data on this for sample areas and there is the significant income gap between urban and rural households in China, the paper selects Pure Income Per Capita of Rural Households/Disposable Income Per Capita of Urban Households, Y, to denote the wealth disparity between Gw and Gs. Since the number of this is usually a fractional number, the larger value of the variable (especially closer to 1) will mean less disparity.

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4 Average direct economics losses incurred by flood / Average GDP during 2002-2012 for each area >0.2%.

5 The data are from *Bulletin of Flood and Drought Disasters in China (2010-2012)*, *Yearbook of China Water Resources (2003-2013)* and *Almanac of China Statistics* (2003-2016), http://www.mwr.gov.cn, www.stats.gov.cn.
The abridged titles for the 24 areas in Figure 1 refers to Hebei, Shanxi, Neimenggu, Liaoning, Jilin, Heilongjiang, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Chongqing, Sichuan, Guizhou, Yunan, Shaanxi, Gansu, Qinghai and Xinjiang from top to down.

(2) Direct Economic Losses Incurred by Flood/GDP

The direct impact of flood on wealth of the two groups can be denoted as Direct Economic Losses Incurred by Flood/GDP, X_1. The ratio helps to minimize the huge difference of the absolute values of flood losses in various areas and make the data more comparable. The higher the ratio, the more serious the flood risk is.

(3) Pure Operating Income Per Capita of Urban Households/Pure Operating Income Per Capita of Rural Households

Pure Operating Income Per Capita of Urban Households/ Pure Operating Income Per Capita of Rural Households, X_3, is used to denote the difference of labor income of Gs and Gw. Although the data on the change of labor income before and after flood are scarce, this ratio could elaborate to some degree that the more operation income urban households obtain, the more employment capacity after flood could be transferred from Gs to Gw and reduce inequality.

(4) Property Income Per Capita of Urban Households/ Property Income Per Capita of Rural Households

Many factors together lead to the change of household's risk preference, while we can't separate the impact of flood from others and use Property Income Per Capita of Urban Households/ Property Income Per Capita of Rural Households, X_4, to roughly demonstrate the long-term risk preference of Gs and Gw. As the variable turns larger, that means Gs is inclined to hold more speculative assets with more volatile return in the portfolio and probably produce complex impact on disparity.

(5) Transfer Income Per Capita of Rural Households/Transfer Income Per Capita of Urban Households

Aside from losses incurred by flood, the transfer income or economic assistance after disaster will also impact the wealth of different groups. Transfer Income Per Capita of Rural Households/Transfer Income Per Capita of Urban Households, X_5, denotes the protection from governments. Although the transfer income is not exclusively for flood risk, we can deduct that the larger the ratio, the less inequality in wealth between Gs and Gw.

4.1.2 Control Variables

There are some control variables impacting the disparity ratio as follows:

(1) Incremental Value of Finance Sector/GDP

When the financial industry takes more market shares and makes more contribution to economy, that could optimize the resource allocation and reduce economic difference between Gs and Gw. Incremental Value of Finance Sector/GDP, X2, is selected to be the positive factor to impacting wealth distribution.

(2) Incremental Value of Primary Sector/ Incremental Value of Second Sector

The primary and second sector refers to agriculture and industry respectively. Usually the lower the ratio, the more industrialized the area is and less disparity will exist among various groups. This variable, X_6, is selected to be the negative factor impacting wealth distribution.

4.1.3 Summary

The following table gives the summary of all the variables and their definitions.

Table 1 Variables, Expected Signs and their definitions

Variables	Expected Signs	Variable Definition
Y		Pure Income Per Capita of Rural Households/Disposable Income Per Capita of Urban Households
X_1	+/-	Direct Economic Losses Incurred by Flood/GDP
X_2	+	Incremental Value of Finance Sector/GDP
X_3	+	Pure Operating Income Per Capita of Urban Households/ Pure Operating Income Per Capita of Rural Households
X_4	+/-	Property Income Per Capita of Urban Households/ Property Income Per Capita of Rural Households
X_5	+	Transfer Income Per Capita of Rural Households/Transfer Income Per Capita of Urban Households
X_6	-	Incremental Value of Primary Sector/ Incremental Value of Second Sector

4.2 Data and Sample

As shown in Figure 1, we will select the 24 areas suffering from serious flood risk as sample areas and collect the original data on flood losses, GDP, Pure Income per capita etc. to compute the required ratios. [6]We also select the observation period 2002-2015 to study the impact and the data for dependent variable will be from 2005 to 2015 and data for other variables will be from 2002 to 2012 with consideration of

[6] The data are from *Bulletin of Flood and Drought Disasters in China (2010-2012)*, *Yearbook of China Water Resources (2003-2013)* and *Almanac of China Statistics (2003-2016)*, http://www.mwr.gov.cn, www.stats.gov.cn.
Since the value of the variables is mostly proportional based on the comparison between the same type of indicators, the inflation factor could be ignored.

lagging effect of flood.

Table 2 Sample Descriptive Statistics

	Y	X_1	X_2	X_3	X_4	X_5	X_6
Mean	0.342264	0.006973	0.034986	0.428188	3.827897	0.078393	0.294063
Median	0.345755	0.004101	0.032634	0.384847	2.474892	0.074676	0.278470
Maximum	0.484454	0.057669	0.084480	1.404427	171.2500	0.244998	0.710824
Minimum	0.217691	2.32E-05	0.006353	0.089673	0.244770	0.013220	0.073916
Std. Dev.	0.059219	0.008838	0.013359	0.214301	10.73450	0.037096	0.129553
Skewness	-0.013042	2.767023	1.098063	1.400497	14.49084	1.146498	0.576458
Kurtosis	2.547459	12.57639	4.930273	5.954920	225.9029	5.385378	2.884708
Jarque-Bera	2.260208	1345.663	94.03814	182.3484	555782.0	120.4264	14.76757
Probability	0.323000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000621

Table 3 Correlation Coefficients of Independent Variables

	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.000000	-0.051512	-0.056097	0.029767	-0.080900	0.226819
X_2	-0.051512	1.000000	0.514335	0.008171	0.235039	-0.359454
X_3	-0.056097	0.514335	1.000000	-0.001013	0.397759	-0.364518
X_4	0.029767	0.008171	-0.001013	1.000000	-0.141166	0.180338
X_5	-0.080900	0.235039	0.397759	-0.141166	1.000000	-0.460697
X_6	0.226819	-0.359454	-0.364518	0.180338	-0.460697	1.000000

Table 2 gives sample descriptive statistics and table 3 gives correlation coefficients of independent variables. As shown here, most of variables are flexible within the narrow range of value, the standard deviation and the correlation coefficients between variables are fairly small. That means the sample data are stable and multi-collinearity doesn't exist. Together with the result from unit root test, the data are proved to be fit for panel data regression.

4.3 Estimation Method

4.3.1 Panel data Regression

In this part Panel data Regression will be performed. Due to too many areas pooled together, the flexible-intercept models including fixed-effects model and random-effects model is adopted to estimate equation. The Hausman test shows p-value is equal to 0.132, so the original hypothesis is accepted and the random-effects model is selected.

4.3.2 Regression Results

We make pooled least squares regression and find that the results basically support our initial assumption that natural catastrophe risk will impact the wealth distribution through passive wealth adjustment, varying labor income and risk preference and thus active asset allocation and portfolio construction.

Table 4 Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.294045	0.015352	19.15344	0.0000
X_1	0.183615	0.144711	1.268837	0.2056
X_2	1.081526 ***	0.200609	5.391205	0.0000
X_3	0.036857 ***	0.011007	3.348534	0.0009
X_4	-1.02E-05	0.000114	-0.088826	0.9293
X_5	0.266563 ***	0.050896	5.237429	0.0000
X_6	-0.093648 ***	0.023062	-4.060698	0.0001
R-squared	0.623457	Mean dependent var		0.036298
Adjusted R-squared	0.614666	S.D. dependent var		0.029477
F-statistic	70.92082	Durbin-Watson stat		0.696667
Prob(F-statistic)	0.000000			

Note: *** denotes the coefficient is statistically significant at the 1 percent level; ** statistically significant at the 5 percent level; * statistically significant at the 10 percent level; N=264.

As table 4 shows, the equation is statistically significant and the coefficients for X_2, X_3, X_5, and X_6 are 1.081526, 0.036857, 0.266563 and -0.093648, which are statistically significant at the 1 percent level. The positive signs of coefficients for X_2, X_3 and X_5 demonstrates that the more developed the finance sector is, the more operating income urban households obtain and the more transfer income rural households obtain, the less inequality in income will be observed. The negative sign of coefficients for X_6 demonstrates Incremental Value Ratio (Primary Sector/Second Sector) is negatively correlated with Pure Income Per Capita Ratio (Rural/urban), which means the more industrialized the area is, the less inequality in income will be observed. The coefficients for X_1 and X_6 are positive and negative while they are not statistically significant, which means the wealth variation and portfolio restructuring effects incurred by flood are two-sided. The relationship between the two variables and income inequality is decided by which side takes dominance.

5. Insurance System Design

To mitigate the negative wealth distribution effect and enhance the positive impact of the natural catastrophe risk, how to design relative insurance system turns more important. Both policy arrangements and labor division between public sector and insurance industry need to be studied. Corresponding to the analysis above, the insurance system includes, but not limited to, the following options concerning natural catastrophe risk: the comprehensive catastrophe-linked insurance programs, the differentiated subsidy mechanism for catastrophe insurance, and the high-level risk diversification mechanism. Still with flood as example, the corresponding insurance system could consist of the following ones.

5.1 Comprehensive Catastrophe-linked Insurance Programs

As shown in the empirical analysis, the more developed the financial sector in one area is, the less wealth inequality there will be. From this perspective, the more comprehensive financial system including catastrophe-linked insurance and finance programs needs to be established. In terms of catastrophe-linked insurance programs, there are several feasible options to be considered:

5.1.1 Expand the Coverage of Property Insurance

China market has no independent flood insurance program when most of flood insurance coverage is contained in the property insurance products. Among the products, agriculture insurance and farmhouse insurance occupying small market shares are policy-oriented insurance and cover the most of losses incurred by flood, while commercial homeowner's policy excludes the losses to property located in flood storage zone, flood flowing zone， shore side of rivers, lowland area and outside levee but below warning water level all year around. All this means that high risk areas are less probable to be covered by flood insurance and it's necessary to expand the coverage of existing property insurance or build the independent flood insurance to cover catastrophic losses.

5.1.2 Design Embedded Insurance to Promote Credit and Employment Arrangements

To adjust the wealth inequality, the other important way is to enhance the self-adjustment between groups. Finance especially credit arrangement could help realize this. In the past insurance was almost independent from other sectors, however the coordination between them could improve the efficiency of financial market and labor market nowadays.

For example, insurers could attempt to design contingent contracts embedded in credit arrangement. When flood happens and the losses incurred by flood exceed specified level, the loan of the households can be exempted by the banks and insurance repay part of debt. In such a way, credit sector will not be endangered by flood risk and more loan or relative financial products will be offered for households to recover from losses and continue the production. On the other hand, insurers could provide the catastrophe-linked coverage for employment and small business to support emergency labor market. The function of this type of insurance can be as above.

5.2 Differentiated Income Transfer Mechanism

Theoretical analysis shows that the losses incurred by flood could bring larger initial wealth variation to Gw than Gs and thus produce more inequality in wealth, however the empirical analysis doesn't establish the relationship probably because the transfer income partly offset the adverse effect. Based on this, differentiated subsidy or tax-advantage policies are very indispensible in developing catastrophe-linked insurance.

Subsidy is the direct income transfer arrangement. And as established in the empirical analysis, the more transfer income the rural households obtain, the less wealth inequality there will be. It will be favorable for governments to provide more premium subsidy to Gw to stimulate their property insurance demand.

Tax-advantage is the indirect income transfer arrangement. It's more suitable for the governments to adopt this to stimulate Gs to purchase catastrophe-linked coverage to cope with business interruption risk and thus assure the stable employment market.

In reality, not only purchasing power of households, but also flood insurance gap, and fiscal strength of local governments are core factors impacting the level of income transfer. Due to discrepancy in these aspects in various areas, the uniform standard for subsidy and tax advantage is not proper. Except the income transfer from central governments, it's suggested that local governments could decide what kind of policy framework they will take.

5.3 High-level Risk Diversification Mechanism

To develop flood-linked insurance, the problem of insurability of catastrophe has to be resolved. Traditionally the catastrophe risk when most of exposures are strongly positively correlated in specific area. Nevertheless more mutually independent risk units could be obtained if we expand the observed samples in a broader scope.

We compute the correlation coefficients of flood losses (2002-2012) between any of two areas around the country and the areas with at least one of the correlation coefficients larger than 0.80 are illustrated in table 5. It is optimistic that only Xinjiang, Shaanxi, Sichuan, Jiangxi, Hubei and Liaoning among 24 areas have strong positive correlation with neighboring areas, the rest of the areas are weakly correlated in terms of flood risk. That demonstrates flood risk is diversifiable in a wider platform.

Table 5 Correlation Coefficients of Cross-area Flood Losses

	HB2	JL	JX	LN	NMG	SC	SD	SX2	XJ
CQ	0.16	(0.07)	0.10	0.46	**0.892776**	(0.08)	0.66	0.17	0.16
GS	0.62	0.57	0.68	**0.91**	0.682184	0.57	**0.87**	0.55	0.63
GZ	**0.81**	0.71	0.80	0.79	0.38	0.64	0.48	0.74	**0.81**
HB1	0.04	(0.11)	0.03	0.51	**0.95**	(0.11)	0.76	(0.01)	0.09
HB2	1.00	**0.91**	**0.91**	**0.80**	0.06	**0.89**	0.49	0.93	**0.86**
JL		1.00	**0.98**	0.79	(0.14)	**0.97**	0.35	**0.87**	**0.89**
JX			1.00	**0.85**	0.03	**0.93**	0.43	**0.89**	**0.90**
LN				1.00	0.45	0.76	0.76	0.74	**0.83**
SC						1.00	0.39	**0.81**	**0.83**
SX2								1.00	**0.88**

Based on this rough estimation, we can design the high-level diversification mechanism which includes three levels of forms for loss sharing. The first level refers to commercial insurance market including primary insurance and reinsurance. The role of government in this level is to share part of expenses for primary insurers to purchase reinsurance. The second level refers to Cross-area Catastrophe Funds operated by governments. Due to low correlativity between most of river valleys, it could be feasible to establish cross-area catastrophe funds involving areas relatively independent from others to share the excess losses over insured losses. The third level, the highest level, is National Catastrophe Fund guaranteed by central government. When cross-area catastrophe fund is exhausted, this fund will provide the final compensation for substantial losses incurred by flood to stabilize insurance market.

6. Conclusion

The research focus on natural disaster risk including catastrophe risk has been shifting from macro-level analysis to micro-level and structural analysis in recent years. Wealth distribution effect incurred by natural catastrophe risk is such a structural issue and has strong negative externalities which influence not only the recovery and reconstruction of the disaster areas but the synergetic structural development of national economy.

The paper tries to figure out the concrete channels of natural catastrophe risk producing wealth distribution effect, provide robust evidence through empirical analysis of specific catastrophe in specific areas and endeavor to establish decision-making logic for insurance system design.

Based on the empirical results, the paper proposes some fundamental ways to improve insurance system, such as establishing the comprehensive catastrophe-linked insurance programs, the differentiated subsidy mechanism for catastrophe insurance, and the high-level risk diversification mechanism which will probably favor both policymakers and market participants to mitigate negative effects of catastrophe risk and improve social welfare.

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