A Simple Assessment of Flood Risk from Insurance Perspective: Based on Historical Data in Japan

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Abstract: Flood risk is widely deemed increasing in recent years, but few evidence has proved it empirically. Current literatures mostly proved from meteorological aspects that global warming has increased flood risk in general but serious changes are still decades away. One of the difficulties to prove the existence of increase in flood risk is flood risk assessment. Most studies concerning flood risk assessment use hydrological methods, which are generally computationally demanding and subject to substantial uncertainties. This article tries to provide a simple flood risk assessment method from an insurance perspective using statistical method with open accessed historical data. With historical loss data, this article first estimates flood hazard based on the statistic scale of municipalities (shi-ku-chou-son), then introduces vulnerability variables to assess flood risk in Japan. Distribution of flood risk and affecting factors are analyzed detailed in assessment. This article finds that demographic distribution, socio-economic development and location of properties are main factors attributing to the increase of flood risk. From a public good perspective, this article suggests that insurance companies and the government should adjust their insurance supply strategies based on risk classification results of each municipality, and public policies should also be adjusted according to the risk characteristics of each municipality. Therefore, this article shed some light on the importance of public-private partnership in flood risk insurance market under current circumstances.

Keywords: Flood risk; Risk measure; Factor analysis; Cluster method

1. Introduction

1.1 Natural background

In recent years, Japan has been suffering from several severe natural disasters as a result of its special geographical conditions and climate change. Of which, flood caused by Baiu (rainy season) front or typhoon is recognized as one of the most devastating disasters, especially when lots of people have been settled down in floodplain areas(1). In 2018, flood disasters caused annual direct economic losses of 536 billion yen (4.95 billion dollar)(2), while property insurance industry paid 172 billion yen (1.59 billion dollar)(3). As shown in Table 1, amongst the 10 most severe flood disasters happen in the past 10 years, around 50% were caused by typhoons, and the other half were caused by Baiu front. Damage intensity every year is about 0.13% to 0.92%. This number is not too big for the general insurers to provide flood insurance products, while in some cases, e.g. the U.S., the damage intensity is about 3.06% of GDP(4), which is considered as one of the reasons that insurers in the U.S. are reluctant to provide flood insurance products.

Table 1 Most severe flood disasters in 2006-2018

	Time	Flood causes	Damage	Claims paid(5)
2018	6.26-7.9	Baiu front	1,158,000.00(6)	195,595.14
2011	8.30-9.7	Typhoon Talas	319,124.89	
2015	9.6-27	Typhoon Etau	294,084.45	52,381.90
2016	8.28-31	Typhoon Lionrock	282,415.64	21,528.22
2006	6.30-7.25	Baiu front	198,058.56	
2017	7.5-13	Baiu front	190,352.58	8,225.98
2011	7.24-8.1	Cloudburst	160,045.55	
2013	9.14-17	Typhoon Man-yi	155,247.56	38,349.64
2012	7.10-23	Baiu front	151,684.36	
2017	10.19-24	Typhoon Lan	149,931.63	121,667.50

Source: e-Stat, https://www.e-stat.go.jp/, damage and claims are calculated in 1 million Yen.

1.2 Current status of flood insurance market

Although the private market is still providing flood insurance products, the penetration rate is not sanguine. According to a public opinion poll conducted by the cabinet(7), only

(1) The General Insurance Association of Japan. (2016). Insurance for Wind and Flood damages: Promotion for Preparation against Wind and Flood damages. *Monthly Fescue,* 2016 No.8, 418: 35-39.

(2) MLIT. (2020, March 25). Survey of Flood Damage. Retrieved from: https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00600590

(3) The General Insurance Association of Japan, (2020, May 15). Claims Paid due to Wind and Flood in Recent Years. Retrieved from: http://www.sonpo.or.jp/news/statistics/disaster/weather/index.html#2017

(4) Youbaraj Paudel. (2012). a Comparative Study of Public—Private Catastrophe Insurance Systems: Lessons from Current Practices. The Geneva Papers on Risk and Insurance Issues and Practice, 37(2), 257–285.

(5) SONPO, https://www.sonpo.or.jp/report/statistics/disaster/weather.html

(6) Predicted number, retrieved from https://www.mlit.go.jp/report/press/mizukokudo03_hh_000985.html

31.1% of the respondents had flood insurance for either buildings or contents. The main reason of take-up rate of flood insurance being so low is that there is not enough propagate education. According to the same survey, 52.2% of the respondents believed that they will never suffer from any flood in 10 years. When they were asked "why don't you buy any flood insurance?" 43.4% of the respondents believed that their properties will never suffer from any flood; and 14.1% did not know there was any flood insurance. Compare to earthquake insurance, another insurance program that Japanese government has concentrated for a relatively long time, the main reason of people not buying it is that the premiums are too expensive.

Currently, general insurance companies provide flood insurance through additional clauses of fire insurance. Normally fire insurance (home insurance in Japan) covers fire, lightning, explosion, windstorm, snowstorm, theft etc. Floods and earthquakes are excluded risks. According to GIROJ (General Insurance Rating Organization of Japan), only 69.1% of fire insurance policies include flood coverage, which explains why claims paid for typhoons are usually more than Baiu front (shown in Table 1). Limit of indemnity of flood insurance in Japan is 70% of total insured value (based on rebuild cost).(8) Every general insurance companies calculate their own premiums based on GIROJ's reference loss cost rates, which is calculated through simulating loss cost rates of one disaster in the future based on historical data. However, the premiums of flood insurance are only partially risk-based. The premiums show no differences in the geographical location of a house (whether it is on a mountain or near a river), nor the property's inundation history. But the premiums do differ in two aspects: (1) construction of the property, i.e. concrete construction (M), steel construction(T), and other construction (H, e.g. wooden construction), generally, H has the highest premiums, while M is the lowest; (2) administrative region, as the possibility of natural disasters varies in different prefectures. Current premium rate of flood insurance is about 0.015% ～ 0.045%(9). With claims paid caused by windstorm and flooding increasing in

(7) Cabinet Office (2017, January). Poll of Preparing for Floods. Retrieved from: https://survey.gov-online.go.jp/tokubetu/h27/h27-suigaig.pdf

(8) Damage over 30% of total insured vale will be indemnified by: insured amount × total loss/ insured value; damage between 15% ～ 30% of total insured vale will be indemnified by 10% of insured amount; and only 5% of insured amount will indemnify if the damage is less than 15% of insured value.

(9) According to the General Insurance Association of Japan, for a house built in year 2000 with insured value 200 million yen, the premium gap between fire insurance with and without flood coverage is about 3 ～ 9 thousand yen per year.

recent years, there has been a discussion that reference loss cost rate should be furtherly raised and premiums should be rated based on risk within every prefecture. Therefore, the importance of risk assessment and pricing has been magnified since then.

2. Literature review

To date, a plethora of literatures concerning flood risk management can be observed across the globe. According to Klijn (2012), flood risk management can range from engineering science perspectives such as inundation modelling and hazard mapping, to social science perspectives such as economic vulnerability/resilience and policy instruments.

For example, Kobayashi (2016) developed a large-scale, high-resolution distributed rainfall–runoff /flood inundation simulation model (DRR/FI) to simulate inland inundation processes. The model was applied to Yodogawa River catchment to check the validation with data from 1997 and 2009 flood events. As the flood hazard maps of Japanese municipalities are prepared with the same resolution (250m), the inundation model also contributes to hazard mapping in Japan. According to Rodríguez (2012), flood risk maps usually perform the form of probability flood maps, which provide forecast probability of future floods events based on measured precipitation, with incorporation of numerical weather prediction models, on a geographical map with a certain resolution.

Considering the complexity of ensemble prediction systems, it is quite difficult to ensure the accuracy of flood risk maps. Therefore the researches about hazard mapping has been focused on reducing the uncertainties from both internal and external variability. For example, Mizuta (2017) performed an unprecedentedly large ensemble of climate simulations with a 60-km atmospheric general circulation model and dynamical downscaling with a 20-km regional climate model. Considering the fact that uncertainties rises with smaller scale systems, this research simulated global hydrological system for 5000 years, under three different scenarios. The control variables of these three scenarios focused more on the uncertainties caused by greenhouse gases to help better understand human influences on past changes in extreme events. It is worth mentioning that the simulation results are freely available as a database named "Database for Policy Decision Making for Future Climate Change" (d4PDF).

Notwithstanding, even with more advanced hydrological methods, Samuels (2012) hold that absolute protection from flooding cannot be achieved and the societal goal is for the management of flood risks at an "acceptable" level. The problem rises that how to improve economic resilience against floods to an acceptable level with *ex ante* and *ex post* methods. *Ex ante* measurements include using flood resilient building materials, comprehensive community resilience system building and etc. *Ex post* measurements are mostly about *ex post* compensation for the victims. Of which flood insurance is one of the most important tool of financial compensation along with government relief. Although the insurance industry still provides flood insurances under current circumstances, as stated in the first chapter, there are also problems to be solved. One possible solution is through public policy instruments, for example public provision of flood insurance scheme or Public-Private Partnership (PPP) system building. Zhuo (2012) regarded natural disaster insurance as quasi-public goods. Government-provided natural disaster insurance can address the insufficient supply issue through its positive externality property. Compared to private markets, public provisioning can (1) lower the price due to economies of scale, (2) guarantee impartiality for low-income group, and (3) make the system more economically sustainable. Paudel (2012) compared PPP flood insurance systems with fully private and fully public systems in three aspects: general characteristic, funding and mitigation measurements. The analysis was based on 20 indicators such as damage coverage and premium level. The results supported that PPP systems have a better performance regarding integration of incentives and risk reduction policies.

For insurers or other public flood risk taking entities, the assessment of flood risk is of great importance. Especially for countries like Japan with low penetration rate, risk assessment can help with accurate premium pricing, risk mapping and underwriting strategies. As Neuhold (2012) elucidated, flood risk assessment combines engineering science perspectives (hazard assessment) and social science perspectives (vulnerability assessment). Mourato (2012) defined hazard assessment as the probability of occurrence of flood events based on their main physical characteristics such as flood depth and flow velocity) modeled by hydrological and hydraulic methods; while vulnerability as the potential losses because of the flood event and the recovery capacity.

Started from 1950s[10] with more than 50 years' history, food risk assessment methods can be divided into three categories: historical-flood-hazard-based assessment method, index-system-based assessment method and simulation-based assessment method (Li, 2013). Based on the digital topographical map and the data of 10 heavy floods since 1870 in the Yangtze River basin, Qin (2005) used historical-flood-hazard-based method to conduct an assessment of flood risk and primary zoning in the middle and lower reaches of the Yangtze

(10) See Richards BD (1955) Flood estimation and control. Chapma, London.

River. Mourato (2012) adopted index-system-based method to assess flood risk of city block in Vila Nova de Gaia. Index of hazard and vulnerability were built separately, and the product of vulnerability index multiplied by hazard index became the total risk. The hazard index used data of hazard map to classify in Low, Medium and High Hazard. While the vulnerability index was created using principal components analysis. Chie (2018) on the other hand used Monte Carlo method to simulate long-term synthetic rainfall events based on a stochastic rainfall event model, and then adopted simulation data to evaluate flood risk in terms of probabilistic distribution of flood damages.

However, as stated by H de Moel (2012), flood risk assessments might be complicated because (1) complicated components of meteorological calculation (e.g. flood frequency analysis, determination of hydraulic boundary conditions, depth-damage relationships, etc.), (2) high computational costs of modelling, and (3) high requirement of data availability and data accuracy, which depend the reliability of flood risk assessment. Hill (2012) added another reason that vulnerability functions vary from country to country. Neuhold (2012) also hold that standardized flood risk assessment approaches usually underestimate the high variability in most relevant processes (hydrology, hydrodynamics) or the processes themselves. Therefore, an increase in data availability and accuracy enables a more robust calculation of both hazard and vulnerability.

As reviewed from the literatures above, there is a wide range of current research on flood risk management. Progress concerning modelling efficiently and accurately have been achieved during the past decades. However, research on flood risk assessment has mainly focused on meteorological methods. Given the inherent uncertainty of current flood risk assessment processes, many literatures agree that the accuracy of results could be doubtful, and there is few hope of solving this issue in the near future considering the fact that the global meteorological system itself is a chaotic system. For insurers, it might be more challenging to assess flood risk by themselves because of the lack of data and relevant expertise. As revealed by the literatures above, from insurers' perspective, flood risk assessment is useful for mainly premium differentiation and underwriting strategies. Therefore, the comparison between risk of different areas (or assessment of relative risk) is more important. It will be more practical for insurers to assess flood risk with accessible data and low calculation cost. Thus this paper will try to provide a flood risk assessment method from an insurance perspective using statistical method with open accessed historical data. First, the concept of flood, flood risk and flood risk assessment will be introduced in the next chapter. Then the assessment model will be built and explained. After introducing historical data, this article will assess the flood risk situation of each municipality based on the above model and analyze the affecting factors of flood risk in Japan.

3. Flood, flood risk and assessment model

3.1 Flood

According to Wisner (2012), generally, flooding is a natural part of the hydrological cycle and the life of rivers. It can be perceived as a physical and/or social process. The simplest definition of floods is "too much rain; too little time" (physical). On the other hand, from social perspective, floods occurred in intensively developed urban areas can be understood as rain water that exceeds the capacity for storm water management.

Due to different causes of flooding, the understanding of flood also varies among countries. In the United Kingdom, the Environment Agency divides flood risk into three categories according to different water systems: rivers or the sea, surface water, ground water and reservoirs,(11) which can furtherly divided into: (1) heavy rainfall and thunderstorms over a short period (e.g. 2007 United Kingdom floods), (2) prolonged, extensive rainfall, and (3) high tide combined with stormy conditions (e.g. North Sea Flood of 1953).(12) In the United States, heavy precipitation is also the most common cause of flooding, but different with the U.K., the precipitation is usually along with hurricanes. Much of the severe flooding in America has occurred around the Mississippi River and in Texas, as well as along the Gulf Coast and Florida, mainly because of their vulnerability to hurricanes.(13) While floods in Japan shows a feature of combination of the U.K. and the U.S. According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), floods in Japan are categorized into 7 different groups: typhoon, torrential rain, Baiu front, storm, landslide, snow melt, and wave. Of which, typhoon, torrential rain and Baiu front take about 97% of all flood losses.(14)

3.2 Flood risk

The concept of flood risk differs among researches. Wei (2002) defined flood risk as the

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(11) Environment Agency, https://flood-warning-information.service.gov.uk/long-term-flood-risk/risk-types

(12) Law & your environment, http://www.environmentlaw.org.uk/rte.asp?id=99

(13) U.S. Geological Survey, https://waterwatch.usgs.gov/index.php?id=flood&sid=w__gmap&r=us

(14) Ministry of Land, Infrastructure, Transport and Tourism, https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00600590

occurrence frequency of floods of different intensity and the corresponding water depth distribution. Li (2013) applied the risk triangle concept proposed by the European insurance industry, which defined flood risk as the product of the following three factors: the flood hazard, the exposure and the vulnerability of disaster bearing body. Morita (2012) defined flood risk as the product of potential flood damages and the probability of flood occurrence. Mourato (2012) referred flood risk to the interaction between the hazard and the vulnerability. Hazard is defined as the probability of occurrence flood events. While vulnerability is related to the potential losses due to the flood events and recovery capacity. Dassanayake (2012) also calculated flood risk based on the combination of probability of a flood event and expected damages associated with this flood event. In this article, the definition of flood risk will also be referred as the product of probability of flood hazard and its expected damages (vulnerability of society). Flood damages on the other hand, can be classified by many standards. Neuhold (2012) divided flood damages into individual damages, economic damages and environmental damages. While this article will categorize flood damages into tangible and intangible damages based on Velasco (2012). According to the same study, both tangible and intangible losses can be fatherly distinguished by direct and indirect damages. This article will focus on the direct tangible damages, which, in general, are estimated by the flood depth.

3.3 Flood risk assessment model

As stated in section 2 above, food risk assessment models can be currently divided into 3 types: historical-flood-hazard-based assessment model, index-system-based assessment model and simulation-based assessment model. Index-system-based model transfer flood hazard and social vulnerability into indexation systems. For example, one can adopt per capita fixed assets and population density to value social vulnerability; and use annual maximum daily rainfall and water area ratio to measure flood hazard. The indexation system could be designed complicatedly, thus the assessment system could be very comprehensive. Yet the selection of index is very subjective and also highly work-loaded. Simulation-based assessment model is based on clear hydrological and hydraulic theories, which can fully simulate the whole process of floods. Although this model is supposed to be the most legitimate and accurate way to predict flood and flood risk, there is a high requirement of availability and accuracy of original data set. As pointed in section 2, the algorithm and calculation are also deemed complicated with possibility of leading to unrobust results. Historical-flood-hazard-based assessment model assess flood risk based on historical flood events and corresponding loss data. Although there are considerable errors in the description of flood risk at present and in the future because of uncertainties in climate system and the change of social-economic environment, it is the most convenient and practical method to conduct. Since the purpose of this article is to provide a more feasible method from an insurance perspective, historical-flood-hazard-based assessment model will be applied with open accessed historical data.

Historical data on meteorological disaster losses are taken from *Survey of Flood Damage* conducted by MLIT (the Ministry of Land, Infrastructure, Transport and Tourism). Online data is available since 2006[2]. Noted that flood damage is highly related to the geographic location of insured property, but the dataset is collected based on administrative divisions. Therefore, for the sake of accuracy, this article chooses the smallest municipality in the survey, namely shi-ku-chou-son, as our statistic scale of both loss and risk. The data of number of flooded houses (categorized by inundation depth) will be used in this article.

Based on the definition of flood risk in sub-section 3.2, this article will also assess flood risk from two aspects: flood hazard and vulnerability of society. For the sake of convenience, this article only considers direct economic damages of residential houses, and assume that insurance companies only assure residential house buildings.

(1) Flood hazard

For flood hazard, this article takes the possibility of a house in a specific municipality suffering from floods in one year to be the proxy variable. As shown in equation (1), P_m stands for the probability of a house got destroyed by floods in one year in municipality m, h_m is the number of houses that are destroyed by floods in one year in municipality m, H_m is the total number of house buildings in municipality m. If P_m equals to 0.005, that means floods destroyed 0.5% of house buildings in municipality m in that year, and the probability of a house got destroyed by floods in municipality m is 0.005.

$$P_m = h_m \div H_m \tag{1}$$

It should be noted that h_m is highly related with inundation depth. For example, if a residential house is flooded with inundation depth of 100cm, and economic loss or money to recover is about 30% of the current value of the house, then it can be deemed that 0.3 of the house is destroyed. However, the depth-damage function is quite complicated, to simplify the model, this article adopts the function from the Cabinet Economic Research Bureau document[(15)]. As shown in Table 2, the inundation depth is divided into four groups: 1 ~

49cm, 50 ~ 99cm, 100 ~ 199cm and above 200cm (which divided into half demolished and fully demolished), which is complied with classification of the *Survey of Flood Damage.* The row of damage in Table 2 is based on average of historical damage data conducted by MLIT.

Table 2　Depth-damage function of floods

Inundation depth	Inundated above floor level (cm)				
	1 ~ 49	50 ~ 99	100 ~ 199	Above 200	
				Half demolished	Fully demolished
Damage	0.126	0.176	0.343	0.647	0.870

Source: MLIT. (2006). Economic Survey Manual of Flood Control (draft).
Retrieved from: https://www.mlit.go.jp/river/basic_info/seisaku_hyouka/gaiyou/hyouka/h1704/chisui.pdf

However, insurers in Japan do not pay exact loss to policyholders, claims are paid by stairs instead. For example[16], damage over 30% of total insured vale will be indemnified by: insured amount × (total loss)/(insured value) × 70% (with a 70% up limit); damage between 15% ~ 30% of total insured vale will be indemnified by 10% of insured amount; and only 5% of insured amount will indemnify if the damage is less than 15% of insured value. The depth-damage function then turns into Table 3 below.

Table 3　Depth-damage function for insurers

Inundation depth	Inundated above floor level (cm)				
	1 ~ 49	50 ~ 99	100 ~ 199	Above 200	
				Half demolished	Fully demolished
Damage	0.050	0.100	0.240	0.453	0.609

Source: MSIG. (2007). Comprehensive Catalog of House Insurance.
Retrieved from: https://www.ms-ins.com/pdf/personal/kasai/jyutaku-kasai.pdf

(2) Vulnerability

Vulnerability is reflected by annually monetary loss for flood inundation damages. From insurance perspective, this article includes two variables for vulnerability: take-up rate and value of the housing building. The product of these two variables can be interpreted as total insured value of the municipality. Take up rate in this article is defined as:

$$\text{tr} = \frac{\text{number of flood insurance policies}}{\text{family number}} \tag{2}$$

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(15) Tanaka, G. and Nitta, T. (2018). Assumption Methods of Disaster Economic Loss – Heavy Rain at 2018/07. Economic Research Bureau, CABINET OFFICE. Discussion Paper 2018(4). Retrieved from: https://www5.cao.go.jp/keizai3/discussion-paper/dp184.pdf

(16) This article chooses house insurance policy of MSIG as a representative.

Although numbers of flood insurance policies are not available, the General Insurance Association of Japan provides attendant rate of flood insurance (policy numbers of fire insurances that carry flood clauses / total policy number of fire insurance). Total policy number of fire insurance can be retrieved from earthquake insurance, since JER (Japan Earthquake Reinsurance Ltd.) provides take up rate of earthquake insurance and policy numbers of fire insurances that carry earthquake clauses. Value of the housing building in municipality m on the other hand is reflected by housing stock of municipality m. As shown in equation (3), $stock_m$ is the municipalities' housing stock, which is proportionally allocated national housing stock based on population and house price. $stock_N$ is national total housing stock, LP_m is average housing price in municipality m.

$$stock_m = stock_N \times \frac{H_m \times LP_m}{\sum_{i=i}^{n}\left(H_i \times LP_i\right)} \qquad (3)$$

Finally, the flood risk in municipality m can be expressed as:

$$FR = P_m \times stock_m \times tr_m \qquad (2)$$

Since data of the number of house buildings are not available, this article uses number of families as a proxy variable to number of house buildings. Family numbers are retrieved from *Residential Basic Book* published by MIC (Ministry of Internal Affairs and Communications). Housing price data are also not available, therefore land price data are used as a proxy variable. Land price data can be retrieved from *Land General Information System* operated by MLIT.

Finally flood risk data are adjusted based on CPI index (2015 benchmark).

4. Flood risk assessment

With risk assessment models built in section 3, this article calculates flood risk of every municipality during year 2006-2018. According to the calculation result, there are totally 1360 municipalities flooded during these 13 years, about 80% of all municipalities.

Figure 1 shows the yearly tendency of flood hazard and flood risk during 2006 to 2018 (in order to weaken the influence of extreme events and make the tendency more explicit, right subgraph of Figure 1 shows the logarithm of flood risk and flood hazard). A markedly increase can be observed of flood risk, while trend of flood hazard is unclear. A unit root test (ADF test) is employed to confirm this observation. The results of p values are shown in Table 4, under 99% confidence interval, neither flood risk nor flood hazard is stationary.

However, the first order difference of flood hazard is stationary, yet not for flood risk. Flood risk and flood hazard are both stationary when first order difference of their logarithm are taken. This result implicates that both flood risk and flood hazard has an upward tendency. Flood hazard has a relatively stable growth rate since its first order difference is stationary, while flood risk has a growing deviation, which make it more volatile than flood hazard.

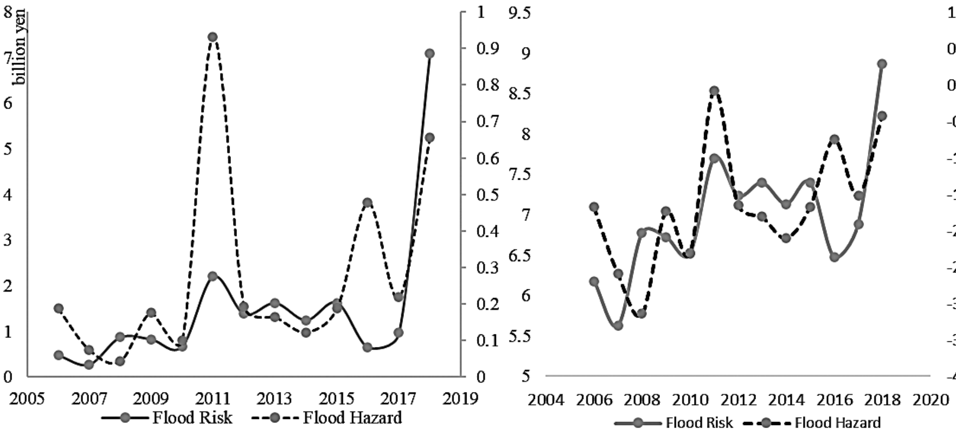

Figure 1　Flood risk change with year

Source: Author, based on calculation results in section 2.

Table 4　p value results of ADF test

	flood hazard	flood risk
raw data	0.1149	0.8024
first order difference of raw data ($X_t - X_{t-1}$)	0.0010	0.1814
first order difference of logarithm ($\ln(X_t) - \ln(X_{t-1})$)	0.0010	0.0046

Considering that flood hazard only reflects possibilities of house being destroyed in municipalities, the magnification effect observed of flood risk can only be explained that floods are more inclined to attack economically developed areas with larger population and higher land prices, or in other words, population are more concentrated in economically developed areas that are inherently vulnerable to flood and without enough mitigation against it. According to the calculation result, in year 2006, 16.84% of the 10% richest municipalities (housing stock wise) suffered from floods; in 2012, 23.68% of them suffered from floods; while in 2018, this number is 32.63%. On the contrary, as shown in Figure 2, frequency of floods during the same period does not show any sigh of increase, thus the influence of climate change to flood risk (especially for insurers) is not clear. As neither the population nor the economy of Japan increase in recent years, it can be concluded that population migration and property expansion are the main factors of risk increasing.

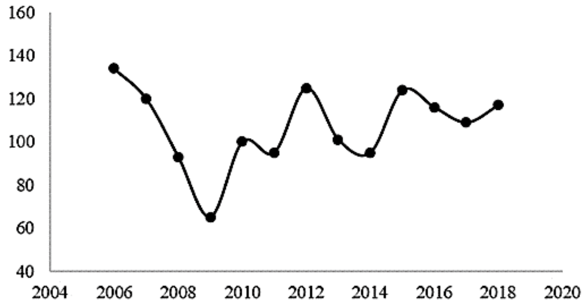

Figure 2　Frequency of floods during 2006-2018

Source: Author, based on calculation results in section 2.

Therefore, it is reasonable to divide municipalities into different groups as they have shown different appetite to flood risks. This article employs hierarchical clustering with Chebychev distance (since it has the best cophenetic correlation, 0.6616) to divide municipalities into different risk groups based on their annually average flood hazard and flood risk data. As shown in Figure 3, all municipalities are divided into 5 groups. Municipalities in group 1 have both high flood hazard and flood risk; group 2 also has high damage loss but the flood risk is relatively lower than group 1. Group 1 and group 2 are usually perceived as "high risk areas". Group 3 has relatively lower flood hazard, but with very high flood risk. Group 3 contains the most economically advanced areas in Japan. Although the natural risk of floods is not high, economic losses are usually gigantic because of population and assets

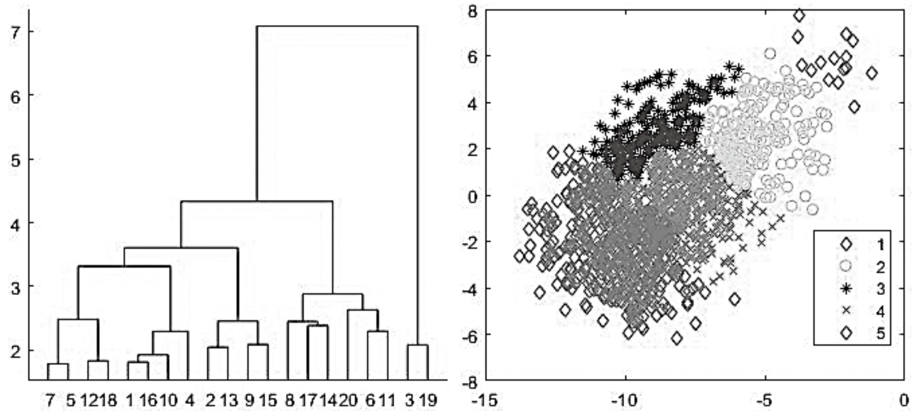

Figure 3　Dendrogram and scatter plot of hierarchical clustering result

being concentrated in these areas. Group 4 and 5 can be perceived as low risk areas, as neither the flood hazard nor flood risk are huge, even though sometimes severe floods may still attack these areas.

Group 4 and 5 are obviously attractive for general insurers' flood insurance business line, while group 1, 2, 3, especially group 3, are the main reasons for the deficit of flood insurance business line in recent years. However, we cannot leave this issue to be guided by market principles only – the government needs long-term vision in developing policies. For municipalities of group 1, since normally they are located in remote areas with few population and assets yet huge flood risk, government should migrate citizens there out to safer habitations. While for group 2, flood risk mitigation countermeasures should be government's first priority. For example, elevate the basement level of house building and structure strengthen the dikes. For group 3, since the natural flood risk is not very high, the best solution would be diversify the financial risk of floods though insurance and reinsurance schemes, some kind of public intervene might be necessary.

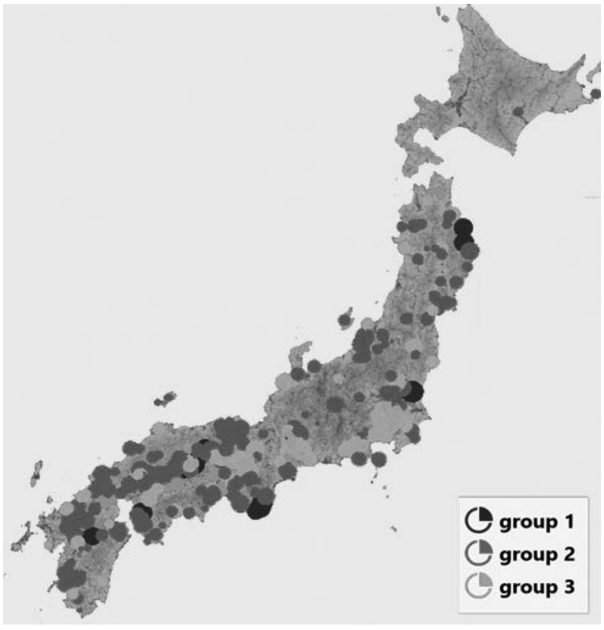

Figure 4 Location distribution of risk groups

Source: Author, based on clustering results above.

Another affecting factor that should not be neglected is the type of floods. According to the MLIT's data, floods are divided into 7 categories: typhoon, torrential rain, Baiu front, storm, landslide, snow melt, and wave, of which, typhoon, torrential rain and Baiu front take about 97% of all flood losses. It should be noted that flood riskes are more susceptible to extreme losses, which can explain the large percentage of typhoon and Baiu front (2018 Western Japan Floods). According to the calculation results above, different types of disasters are also showing different characteristics of geographic distribution. For example, 15.92% of torrential rain happened in group 2 municipalities, while 31.16% happened in group 3 municipalities, which implicates why flood risk of torrential rain has a bigger proportion than flood hazard as shown in figure 5.

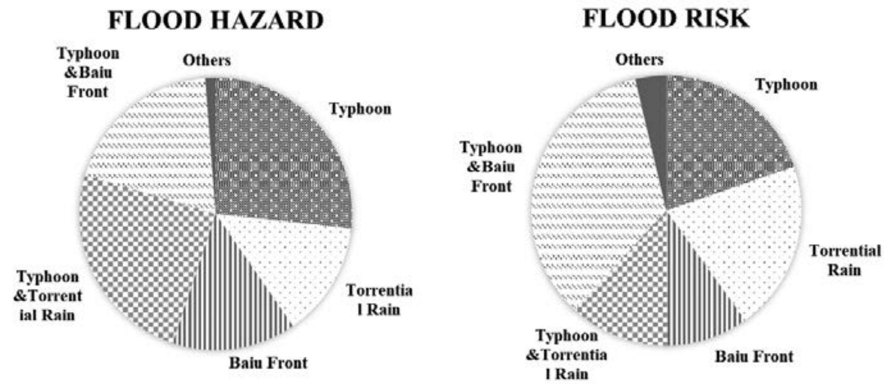

Figure 5 Flood risk change with year

Source: Author, based on calculation results in section 2.

5. Conclusions

This article studies the risk assessment problem of floods in Japan. Other than meteorological method, this article provides a simple model from an insurance perspective using statistical method with open accessed historical data. That is, using possibility of a house in a specific municipality suffering from floods in one year as the proxy variable of flood hazard, and using expectation of economic loss of a municipality to reflect flood risk. Although this article only provides a simplified assessment model, it contributes in this field as: (1) other hydrological methods may not provide more convincible results due to their inherent uncertainty and high requirement of data accuracy and calculation power; and (2) it provides fundamental basis for more advanced methods. Based on the risk assessment model, affecting factors are recognized and their importance are analyzed. Based on hierarchical clustering, this article managed to divide the whole nation into different risk appetite groups. The results show that:

(1) Empirical data proved that flood risk in Japan has been increasing and become more volatile.

(2) The increase is mainly caused by socio-economic factors such as population and asset concentration, while the influence of climate change seems unclear.

(3) Factors affecting flood risk level also include: demographic distribution, socio-economic development, location of properties and flood types.

This article provides a novel perspective of flood risk assessment. Based on the results, insurance providers can adjust their strategies according to the characteristic of the municipality. For example, 4 and 5 municipalities can be very appealing for private insurance companies, because it is easier to extend business line than other low risk areas since consumers' flood insurance purchasing decisions are highly correlated with the level of flood losses incurred during the prior year. High risk areas as groups 1, 2 and 3 seem to be less attractive, so insurance companies may stop providing flood insurance products in those areas. However, as insurance plays a very important role in compensating victims, it is necessary to protect the supply of flood insurance. Therefore, being consistent with mainstream opinion of insurance academic world, empirical results of this article make it more clear that: consideration regarding more efficient provision need to be addressed by insurers. However, there is a possibility that the private sector cannot resolve this issue alone. Some form of public intervenes might be an alternative (e.g. public-private partnership flood insurance program) under such circumstances, considering the characteristics of flood insurance as "public good" in those areas. For policy makers, risk mitigation measures should be conducted in flood-prone areas as group 2 municipalities, while people who live in group 1 municipalities might need to be resettled in other safer places.

However, it should be noted that municipalities with high flood risk are also with more premiums, considering that they are more populated and economically developed. Although this article considers penetration rate of different municipalities, the accuracy could be furtherly improved. Due to the lack of data, flood insurance premium of each municipality was not included in this article. Further research will take premiums into consideration: risk ratio (flood risk / flood insurance premium, based on the concept of loss ratio) might be adopted to assess flood risk of each municipality more accurately. In addition, due to the lack of data and specific knowledge, although risk might be heterogeneous for each municipality, this article cannot adopt meteorological methods as a proxy. Additionally, this article did not quantify each factor's contribution to the increase of flood risk. All these points will be addressed in posterior research.

Acknowledge: This paper is sponsored by China Scholarship Council under NO. 201806980008.

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