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Impact Analysis of Climate-related Risks on Residential Mortgage Portfolios in Japan

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Abstract

In recent years, climate-related risks in the financial sector have been increasing as a result of frequent and severe natural disasters. Yet, the impact analysis of retail portfolios is often limited to simple analysis. The impact of climate-related risks on residential mortgage portfolios is not small, considering Japan's geographical features and the share of residential mortgage loans in financial institutions' total loans outstanding.

Previous research has shown that energy-efficient housing reduces default risk. Although the practices of Japanese financial institutions do not explicitly incorporate climate-related risks in mortgage screening and monitoring, it was suggested that climate-related risks are reflected through changes in housing prices. In addition, regarding the method of quantitative impact analysis, we attempt to reflect climate-related risks using existing models for estimating the probability of default (PD). We also discuss the role of fire insurance in reducing risks related to residential mortgage portfolios and their sustainability amid the increasing frequency and severity of natural disasters. Finally, we clarify challenges in addressing climate-related risks associated with residential mortgage portfolios.

Keywords: Residential mortgage loan, climate-related risk.

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1. Research Background

In this paper, we consider the impact of climate-related risks on residential mortgage portfolios of Japanese financial institutions, taking into account previous studies and actual risk management practices. We would like to express our sincere appreciation to all organizations and individuals who have cooperated with us in writing this paper.

Climate change may result in physical and transition risks that could affect the safety and soundness of individual banking institutions and have broader financial stability implications for the banking system (BCBS 2022). In 2015, the Financial Stability Board (FSB) established the Task Force on Climate-related Financial Disclosures (TCFD) at the request of G20 Leaders. In Japan, the Financial Services Agency (JFSA) proposed issues to be considered for enhancing disclosures from the perspective of sustainable finance (JFSA 2021).

Under these circumstances, in December 2017, financial supervisory authorities established the Network for Greening the Financial System (NGFS). The NGFS published its first comprehensive report in 2019 titled “A call for action: Climate change as a source of financial risk” (NGFS 2019). Since impacts of climate-related risks are likely to manifest over many decades, we need to have in mind long-term time horizon and consider the spillover effects of risk factors interacting with each other in order to estimate the impacts. Therefore, scenario analysis is used to assess the impacts of climate-related risks, which can comprehensively cover various risk factors, in the same manner as stress testing.

The NGFS published scenarios to examine the impacts of climate-related risks on financial institutions. The first version was published in June 2020 (NGFS 2020), the second in June 2021 (NGFS 2021), and the third in September 2022 (NGFS 2022). In Japan, based on the recommendations of the Report by the Expert Panel on Sustainable Finance “Building A Financial System that Supports a Sustainable Society,” the JFSA and the Bank of Japan published in August 2022 “Pilot Scenario Analysis Exercise on Climate-Related Risks Based on Common Scenarios” (JFSA and BOJ 2022) using the second version of NGFS scenarios.

Assessment of the impacts of climate-related risks through scenario analysis is considered to be still in its infancy, given the need to set long time horizons and to consider the spillover effects of risk factors interacting with each other. In particular, impact assessments of retail exposures[1] are often limited to pool-by-pool basis, where claims are bundled into a single pool in accordance with pool management,[2] because the value of individual loans is much smaller for retail borrowers than for corporate borrowers. As a result,

[1] Retail exposures are defined in Article 1 (v) of the Notice of Capital Adequacy Regulations (standards for judging whether a bank’s capital is sufficient in light of their assets, based on the provisions of Article 14-2 of the Banking Act (Financial Services Agency Notification No. 19 of 2006)), and collectively refer to residential property exposures, eligible revolving retail exposures, and other retail exposures.

[2] Pooled management is a method used for managing receivables when the value of individual receivables is small and there are many receivables with similar risk profiles. By collecting a large number of bonds with similar risk characteristics, the law of large numbers will work and it will be easier to control the default rate and loss rate every year. Because the value of individual loans is small, individual loans are not managed separately but in pools, from a cost perspective.

the impact assessment of retail exposures is often limited to a simple assessment. However, residential mortgage loans (hereinafter referred to as "mortgage loans") account for a fairly large proportion of financial institutions' total loan portfolios. In addition, given the increase in physical damage caused by natural disasters such as storms and floods in recent years, the impact of housing loans on the soundness of financial institutions is increasing. Furthermore, given the promotion of energy-efficient housing and housing-related policies to address natural disasters, there are concerns about the impact on the housing market, such as a fall in the price of non-energy-efficient housing, caused by changes in people's behavior. When housing prices fall, the value of collateral declines, thereby increasing risks for financial institutions.

In this paper, we examine how climate-related risks in Japan affect mortgage portfolios of financial institutions by reviewing the current status of their responses to climate-related risks in their mortgage portfolios. We then consider impact assessment method and discuss challenges in addressing climate-related risks.

2. Prior Research

Impact assessment of climate-related risks associated with mortgage loans is often conducted for pools of loans rather than individual loans, in accordance with the pool management of mortgage portfolios, which is the standard practice. There are good reasons for the practice of pool management. The basic idea of pool management is to apply the law of large numbers by aggregating a large number of loans with similar risk profiles and equalizing the risk profiles of the portfolios. Through this approach, we can expect the probability of default (PD)[3] and the loss given default (LGD)[4] of the loan pools to remain within a certain level for each accounting period. If we can expect PD and LGD to be within a certain level for each accounting period, we can estimate the value of expected loss[5] for each period with high accuracy, which in turn facilitates the profit management of mortgage portfolios. Specifically, if the expected loss for any mortgage portfolio is within a certain level for every accounting period, earnings from the portfolio can be secured with high probability by making operating revenue that exceeds the expected loss. In addition, pool management has the advantage of reducing the cost of monitoring throughout the term of loans because it does not require close monitoring of individual loans. It is a reality that these benefits enable the continued provision of housing loans. Under these circumstances, for example, stress tests to assess the adequacy of capital requirements for housing loans and other retail exposures are often conducted against pooled loans. Therefore, the methodology for impact assessment of climate-related risks on individual mortgage loans is still under development.

[3] Probability of default (PD) means the likelihood of default occurring. For example, if there are 1,000 loans in a pool and three of them default, PD is 0.3%.

[4] Loss given default means, for a given claim, an estimate of the economic loss rate on the exposure at the time of default. For example, if the exposure amount at the time of default is JPY 10 billion and the amount that can be recovered is JPY 7 billion, the LGD is calculated as (JPY 10 billion - JPY 7 billion) / JPY 10 billion = 30%.

[5] The amount of expected loss can be calculated for a given portfolio as "PD×LGD× the value of portfolio."

2.1 Prior research from a quantitative perspective

Benjamin Guin and Perttu Korhonen (2020) show that mortgage loans for energy-efficient housing have a lower default risk than mortgage loans for non-energy-efficient housing. The lower default risk for energy-efficient housing is not affected by the income level of lenders at the time loan was made. Furthermore, even when loan-to-value (LTV), which is considered to be closely related to default risk, as well as borrower age and total household income are put in as explanatory variables, the relationship that energy-efficient housing lowers default risk seems robust. However, differences in borrowers' financial literacy, risk avoidance behavior, and time preferences may affect their propensity to buy energy-efficient housing, so further research is needed to conclude about the relationship that energy-efficient housing lowers default risk. Nevertheless, this result suggests that energy-efficient housing can be taken into account as an explanatory variable for credit risk modelling conducted by financial institutions.

According to Duc Duy Nguyen (2022), residential properties exposed to Sea Level Rise (SLR) risk carry high interest rate spreads in the United States. The presence of high interest rate spreads is well recognized, even after taking into account location, property characteristics, borrower creditworthiness, and flood insurance. The SLR premiums are notable in long-term mortgages, and are not influenced by short-term flood events or borrower creditworthiness at the time of borrowing. This suggests that lenders view SLR risk as a long-term climate change risk. An evaluation of the increase in implicit default probabilities due to SLR premiums shows that they are moderate compared to levels reported in recent studies. This suggests that not all lenders reflect SLR risk equally. In particular, SLR premiums are significantly lower in regions where exposure to climate-related events and news is low and where local residents do not believe in climate change. Regarding spreads, interest rate on mortgage loans are approximately 7.5 basis points higher in regions exposed to SLR risk than in regions not exposed to SLR risk, according to an analysis of 30-year U.S. mortgage loans.

In a study examining the Italian housing market, Monica Billio et al. (2022) found that energy-efficient housing has a lower default risk. This result dose hold even after taking into account fixed effects of region and year, in addition to explanatory variables such as dwellings, households, mortgages, and markets. Furthermore, in an analysis using receiver operating characteristic (ROC)[6] curve, the accuracy of prediction has improved by using energy efficiency as an explanatory variable in models predicting creditworthiness.

Koide et al. (2022) demonstrated the impact of flood risk on land prices using the hedonic approach and local projection method. As a result, the presence of flood risk that is objective as indicated by hazard maps pushes down land prices, and when flood risk increases, land prices decrease. However, there is a time lag before updated hazard maps are reflected in land prices, which suggests there is some kind of information friction. They also point out that information about how many times large-scale flood damages

[6] ROC takes figures between 0 and 1, and a model's accuracy of prediction is higher when the figure is closer to 1.

occurred in the past also affects land prices, and that such information has more explanatory power than objective data on flood risk depending on the type of flood risks and the use and type of land. For example, even if the objective assessment of flood risk indicated by hazard maps is equal, in areas where flood damage occurred frequently in the past, risks are more likely to be reflected in land prices. On the other hand, in such areas, even if the objective assessment of flood risk changes, the impact on the level of land prices is limited because it has already been incorporated into the level of land prices to some extent. Furthermore, they point out that objective assessment of flood risks may not be factored into land prices sufficiently depending on the type of flood risks or the use and type of land, suggesting that subjective views about risks have strong influence on land prices.

Markus Baldauf et al. (2020) show that differences in beliefs about climate change are reflected in housing prices. Specifically, all other things being equal, housing in areas that "deny" climate change will sell for about 7% more than those in areas that "believe" climate change. These results are also robust when considering factors such as changes in recognition of climate change over time, the significance of flood risk, and the effect of housing supply. Thus, they conclude that heterogeneity in beliefs about long-run climate change risks significantly affects the U.S. real estate market.

Magyar Nemzeti Bank (2019) found an inverse correlation between mortgage energy efficiency and PD in the case of Belgium and the Netherlands. For example, in the case of Belgium, a logistic regression analysis using energy efficiency (dummy variable; high energy efficiency = 0, low = 1), loan-to-value (LTV) ratio, debt service coverage ratio (DSCR), and borrowing period as explanatory variables showed that PD of mortgage loans for low-energy efficiency housing was 2.8 times higher than mortgage loans for high-energy efficiency housing. Similarly, in the case of the Netherlands, a logistic regression analysis using energy efficiency (dummy variable; high energy efficiency = 0, low = 1), LTV ratio, DSCR, and borrowing period as explanatory variables showed that PD of mortgage loans for low-energy efficiency housing was 5.39 times higher than mortgage loans for high-energy efficiency housing.

2.2 Prior research from a qualitative perspective

Sandra Batten et al. (2016) point out that sharp tightening of carbon emissions to contain climate-related risks could trigger re-pricing of the value of carbon-intensive assets, and this could have significant impacts on markets. For example, a sharp fall in prices of carbon-intensive assets could lead to a deterioration in the performance of firms associated with carbon-intensive assets. This could also have a negative impact on the economy if the effect spreads to other firms. As a result, weaker demand for housing by those affected could lead to lower housing prices.

Amine Ouazad and Matthew E. Kahn (2019) found that strict securitization rules by government sponsored enterprises (GSEs)[7] make it easier for financial institutions to provide mortgage loans in the

[7] In the U.S. residential mortgage markets, GSEs provide loans and loan guarantees.

aftermath of natural disasters, thereby transferring climate risk to GSEs. However, they noted that the lack of comprehensive flood insurance coverage for housings creates market incompleteness. The lack of flood risk-related premium charge in GSEs' mortgage securitization is a significant mispricing in the market. Such mispricing suggests that the two securitization providers—Fannie Mae and Freddie Mac—may bear a significant portion of the increasing climate-related risks. These mispricing mechanisms are not limited to risks of storm surge due to hurricanes, but also apply to wildfires. Kahn's research has also been referred to in the conference report of the Bank of Japan (2021).

2.3 Preferential treatment in financial administration

Hungary has incentive measures in place in financial administration to contain climate change (Magyar Nemzeti Bank, the central bank of Hungary, 2019). Such measures have been implemented in the capital adequacy framework with a four-year transition period. Specifically, mortgage loans related to renovation, construction and purchase rated as energy efficiency standard "BB" can have a 5% discount on the amount of required capital. For mortgage loans related to construction and purchase with energy efficiency standard "AA" rating, a 7% reduction in the amount of required capital is permitted. There is a ceiling to how much capital reserve can be reduced by these incentive measures, and that is 1% of the total lending (total exposures). Mortgage loans subject to these incentives are eligible for a 0.3 percentage point reduction in loan interest rate, provided that data are provided to Magyar Nemzeti Bank on a voluntary basis.

3. Responses to Climate-related Risks in Japan

In order to understand how financial institutions in Japan are addressing climate-related risks, we conducted a survey on their holdings of mortgage exposures, their risk management approach to fire insurance, the impact of climate-related risks on parameter estimates (PD, LGD), and their current status of addressing climate-related risks in mortgage portfolios.

3.1 Holdings of mortgage exposures

Figure 1 shows the ratio of mortgage loans to total loans outstanding of Japanese financial institutions. The ratio rose sharply toward the end of March 2006, peaked at the end of March 2014, and has since remained at around 25 percent.

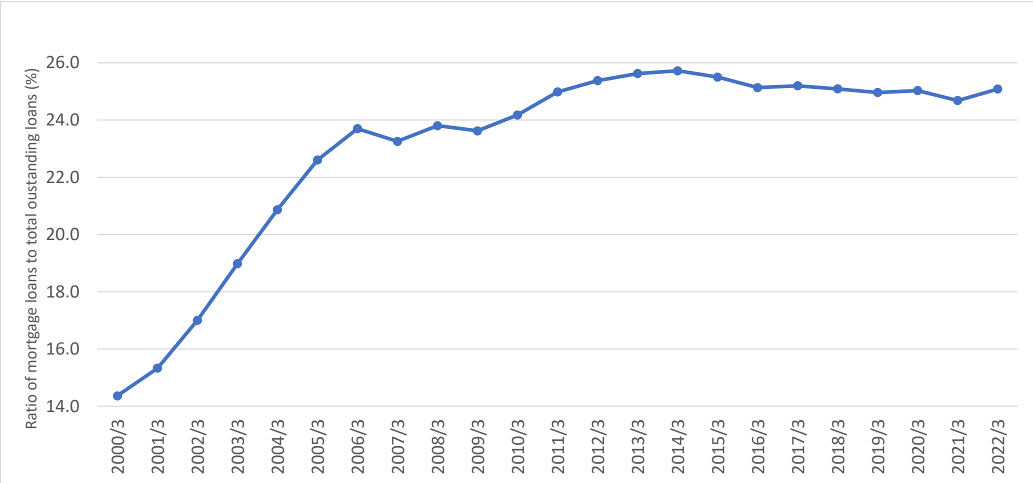

Figure 1: Ratio of mortgage loans to total outstanding loans

Source: Bank of Japan website for time-series statistical data (housing funds/outstanding balance/loans to individuals/banking account/domestic banks; and total loans/outstanding balance/banking account/domestic banks).

3.2 Receivables management

As described in 1. above, in the case of mortgage loans, because the value of individual loans are relatively small, they are often bundled into and managed as pools of loans, rather than managing individual claims one by one in detail. Furthermore, as described in 2. above, the basic idea of pool management is equalizing the risk characteristics of loan pools by collecting a large number of claims with similar risk characteristics and make the law of large numbers work. In this way, financial institutions can expect that the actual default rate and actual loss rate at default for the pool will remain within a certain level stably every period. If the actual default rate and actual loss rate at default for each period remain within the range of prediction, the amount of expected loss for each period can be estimated fairly accurately, and the profitability of the pool can be managed easily.

Climate-related risks could be addressed by, for example, adopting a risk driver[8] related to climate-related risks in the criteria for classifying a given mortgage loan pool. In such a case, when allocating a given mortgage claim to a given mortgage pool, an attribute information such as "a house located in a disaster risk zone" can be adopted as one of the risk drivers. At present, however, no Japanese financial institutions have adopted risk drivers related to climate-related risks.

3.3 Loan Examination

A checklist for loan examination of mortgage loans are as shown in Table 1. The focus is generally on borrowers' repayment capacity. The assessment of climate-related risks is currently either not used or very rare.

[8] Risk drivers represent the attributes of the claims making up a given pool.

Table 1: Checklist used by more than 90% of financial institutions

#	Check points	Perspectives on creditworthiness evaluation
1	Age at the time loan is repaid	Repayment capacity
2	Health status	Repayment capacity
3	Age at the time of borrowing	Repayment capacity
4	Collateral valuation	Collateral margin
5	Years of service	Repayment capacity
6	Joint and several guarantee	Repayment capacity
7	Repayment burden ratio	Repayment capacity
8	Annual income	Repayment capacity
9	Financial institutions' business areas	Repayment capacity

Source: Fiscal 2022 Housing Loan Survey Report (Ministry of Land, Infrastructure, Transport and Tourism). Table is compiled by the author.

In order to prepare this paper, we conducted interviews with several financial institutions about their practice in mortgage loan business. We did not find any case where financial institutions raised loan interest rates as a result of consideration for climate-related risks when screening housing loans.[9] Many of them commented that it would be difficult to raise loan interest rates from competitive concern to win customers.

3.4 Role of fire insurance in risk management

In recent years, the number of natural disasters has been on the increase in Japan (Figure 2). In particular, there is a marked increase since 2011.

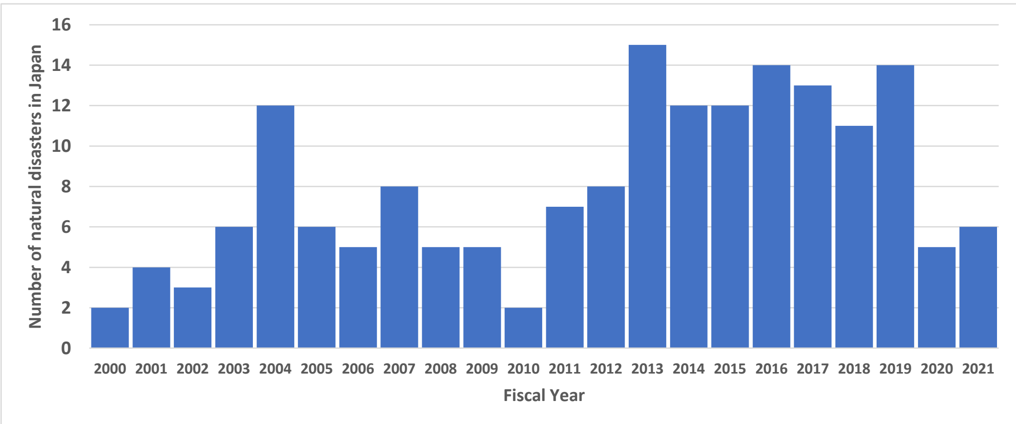

Figure 2: Number of natural disasters in Japan

Source: Website of Cabinet Office Disaster Prevention Information (https://www.bousai.go.jp/updates/index.html). Graph created by the author.

[9] We did find cases where favorable loan rates were provided for mortgage loans for energy-efficient housing.

It has also been pointed out that natural disasters have become increasingly severe recently. Figure 3 shows annual insurance claim payments due to major hurricanes and floods exceeded JPY 1 trillion for fiscal years 2018 and 2019. Insurance claim payments for fiscal 2020 and fiscal 2021 were low, but this could be because actual payments are not yet fully reflected. Therefore, it is necessary to pay attention to future trends in claims payments.

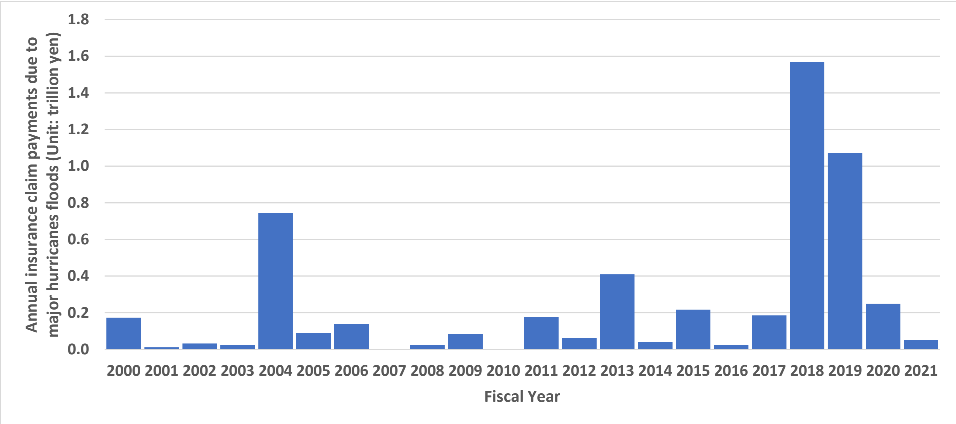

Figure 3: Annual insurance claim payments due to major hurricanes floods

Source: General Insurance Association of Japan. Graph created by the author.

Increased insurance payments due to hurricanes and floods can be considered as transfer of mortgage loan risk from the banking sector (in a broad sense),[10] which provides mortgage loans, to the non-life insurance sector. In other words, in the event of a natural disaster, fire insurance is used to rebuild the lives of disaster victims (debtors), and as a result, mortgage loans do not end up in default in a good number of cases.

In recent years, not only has the advisory rate for fire insurance been revised serially (Figure 4), but the contract terms for fire insurance have also been shortened (Table 2). Before October 2015, long-term fire insurance contracts of 35 years were available. From October 2015, contracts with terms beyond 10 years were abolished, and furthermore, contracts beyond 5 years were abolished in October 2022. The increase in the frequency and severity of natural disasters in recent years suggests that non-life insurance companies are no longer able to take on duration risk for natural disasters over a long time.

[10] In this paper, banking sector means all deposit-taking financial institutions that handle mortgage loans.

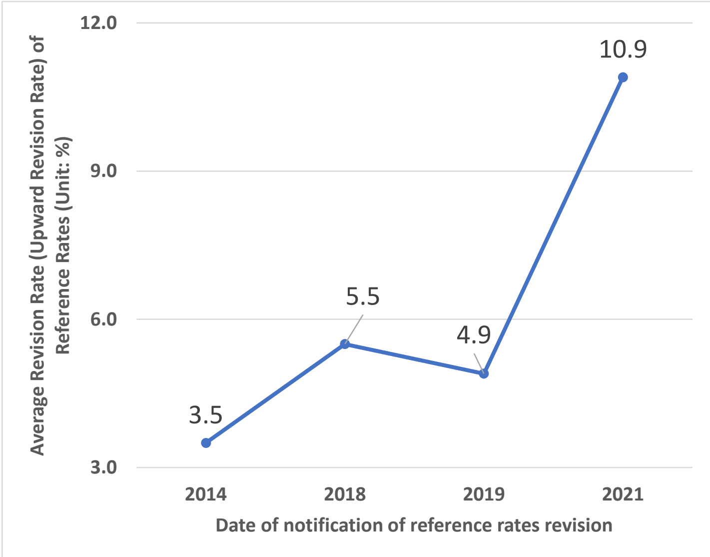

Figure 4: Average Revision Rate (Upward Revision Rate) of Advisory Rate

Source: "Overview of fire and earthquake insurance," General Insurance Rating Organization of Japan.

Table 2: Changes in Contract Periods of Fire Insurance

From October 2022	Contract period beyond 5 years abolished
From October 2015	Contract period beyond 10 years abolished

Source: "Overview of fire and earthquake insurance," General Insurance Rating Organization of Japan.

Under these circumstances, the "report by the advisory panel on fire insurance and flood insurance rates" (JFSA 2022) points out that flood insurance premiums for individuals do not reflect differences in the flood risk among policyholders, and proposes subdividing flood insurance premiums from the viewpoint of improving the fairness of insurance premiums. When subdividing premium rates, following points need careful consideration: (1) basic data used for subdivision; (2) premium rates comparison by subdivision; (3) segmentation by region, and (4) initiatives expected of non-life insurance companies (Table 3).

Table 3: Points to note when subdividing flood insurance premiums

Points	Description
(1) Basic data used for subdivision	- To evaluate possibility of floods, "flood hazard map" will be used to ensure comprehensive and objective information so as to gain customers' understanding about subdivision of insurance premiums. - Ministry of Land, Infrastructure, Transport and Tourism is improving flood risk maps that show flood areas by the frequency of inundation. Such information will be used and reflected in the review of insurance premiums.
(2) Premium rates comparison by subdivision	-·Subdivision of premium rates is ideal in terms of improving the risk awareness of owners with high-risk properties (announcement effect). - If disparities in flood risk are reflected straightaway to premium rates, people living in high-risk areas would be unable to buy flood insurance and concerns would arise that society might be insufficiently prepared for floods. - Therefore, a rate structure that also takes into account the affordability of insurance for high-risk policyholders is desirable.
(3) Segmentation by region	- Consumers would more easily accept subdivision of premium rates if it is conducted according to the "flood hazard map." - On the other hand, there is concern that excessive regional fragmentation may lead to higher system costs and other related costs, which in turn may lead to higher premium rates.
(4) Initiatives expected of non-life insurance companies	- From the viewpoint of enhancing the effectiveness of risk announcement effects, non-life insurance companies are expected to collect and provide latest information on risks. - Careful explanation to customers in insurance solicitation after subdivision of flood insurance premium rates.

Source: report by the advisory panel on fire insurance and flood insurance rates (JFSA 2022)

Box 1: Losses incurred by financial institutions due to natural disasters

Due to occurrence of more frequent and severe natural disasters, financial institutions' losses incurred from natural disasters have increased significantly in recent years. For example, if the amount of actual losses in 2011 is 1, losses in 2018 is nearly 50 times, that for 2019 is almost 30 times, and in 2020 losses are at a level over 40 times.

3.5 Impact on actual default rates

Figure 5 shows the actual default rate of mortgage-backed securities (MBS) within one year of origination published by the Japan Housing Finance Agency.[11] The actual default rate had been on a declining trend since 2011, but rebounded in 2015 and has been on an uptrend. This could be due to the impact of recent natural disasters. It should be noted, however, this result does not apply to all financial institutions that offer mortgage loans, since it is based on the actual default rate of MBS issued by the Japan Housing Finance Agency.

Regarding the impact the rebound of actual default rates from 2015 had on banks' capital adequacy ratios, we examined the level of PD estimated by banks adopting internal ratings-based (IRB)[12] approaches. We found that the PD of banks adopting IRB approaches were on a declining trend. This could be because the PD of banks adopting IRB approaches were estimated conservatively, and so even when the actual default rate of mortgage portfolios of banks adopting IRB approaches had increased due to climate-related risks, this did not lead to a revision of PD by banks adopting IRB approaches.

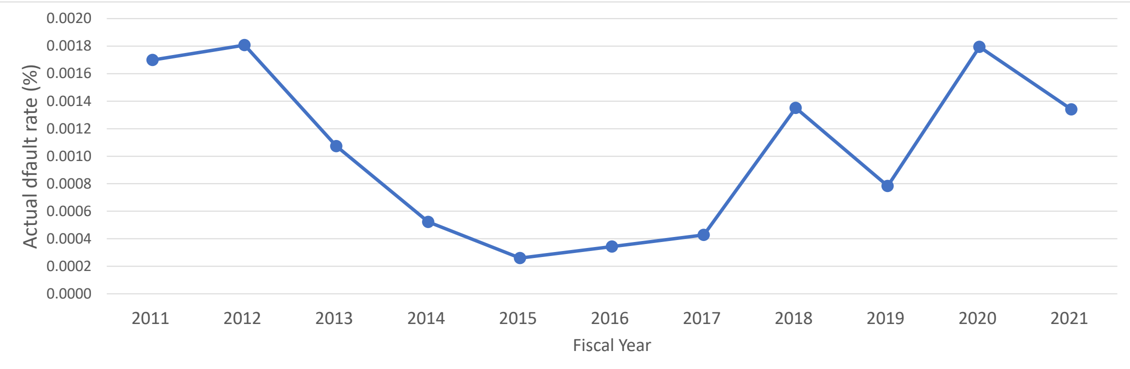

Figure 5: Actual default rate of mortgage loans

Source: Japan Housing Finance Agency, "Factors and Other Monthly Data" for MBS

Box 2 shows an example of a method used in practice for estimating PD. The PD estimation method is based on the long-term average of time-series actual default rate data, to which a conservative buffer is added to take into account various uncertainties related to the PD estimation. The allowance for the conservative buffer is also required by the Notice of the Capital Adequacy Regulations,[13] and through back-testing and forward-looking stress testing, conservative assumptions of PD is ensured.

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[11] Cumulative rate of replacement and partial cancellation (long-term delinquencies) for a one-year period after origination is used for actual default rate.

[12] In internal ratings-based approach, financial institutions estimate PD, LGD and exposure at default (EAD) themselves and calculate capital requirement ratios using risk weight function determined by authorities.

[13] Criteria (JFSA Notice No. 19 of 2006) for judging whether a bank's capital adequacy is appropriate in light of assets held, based on the provisions of Article 14-2 of the Banking Act.

Box 2: PD estimation method (a practical example)

When the actual default rate in Pool A for years between year x and year x + 9 is as shown in the table below, the PD for Pool A is calculated as the long-term average of actual default rate plus a conservative adjustment value (Equation (1)).

The long-term average of actual DF rate is 1.14% by simply averaging the actual DF rates for each year (Equation (2)). The conservative adjustment is calculated as 0.44%, which is obtained by multiplying the sample standard deviation of the actual DF rates for each year, 0.23% (Equation (3)), by 1.96 (Equation (4)). The reason for multiplying by 1.96 is to obtain the maximum value that fall within a 95% confidence interval, assuming that actual DP rates for each year would follow a normal distribution. Finally, the PD is calculated as 1.58% by adding 0.44% to 1.14%.

(Example) Actual Default Rate for Pool A, Unit:%

x	x + 1	x + 2	x + 3	x + 4	x + 5	x + 6	x + 7	x + 8	x + 9
1.10	1.20	0.80	1.30	1.60	1.10	1.10	0.90	1.00	1.30

$$\text{PD of pool A} = \text{average actual default rate} + \text{conservative adjustment} \cong 1.58\% \quad (1)$$

$$\text{average actual default rate} = \frac{\sum_{i=1}^{N} DF_i}{N} = 1.14\% \quad (2)$$

DF_i: actual default rate for each year

$$\sigma_{DF} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(DF_i - \overline{DF})^2} \cong 0.23\% \quad (3)$$

$$\text{conservative adjustment} = \sigma_{DF} \times 1.96 \cong 0.44\% \quad (4)$$

Assuming that a natural disaster occurs in year x + 10, and the actual DF rate for that year is 1.5%. The actual DF rate of 1.5% is lower than the PD of 1.58%, so the PD is considered to have been at a conservative level sufficient to absorb the shock of the natural disaster. In this case, the PD is likely to remain at 1.58%.

Conservative adjustment is implemented primarily to secure a sufficient level of required capital by absorbing estimation errors due to uncertainties in observed data, the impact of economic cycles, sudden events (financial crises, natural disasters, etc.). There are various types of methods for conservative adjustment; in addition to a method using standard deviation described above, there is a method of determining a conservative adjustment value by comparing with the level of actual historical default rate.

3.6 Pricing for climate-related risks

3.6.1 Risk management of mortgage loans at execution and during life of loans

At present,[14] Japanese financial institutions do not seem to set loan interest rates that take account of climate-related risks at the time they execute mortgage loans. Therefore, they do not adjust the level of mortgage loan rates by, for example, the level of risk on the hazard map. However, we confirmed that some financial institutions are offering preferential rates on loans for energy-efficient housing. As suggested by Benjamin Guin and Perttu Korhonen (2020), energy-efficient housing is considered to have a low default risk, and therefore, it is reasonable from a risk management perspective to offer preferential rates for energy-efficient housing.

In addition, under current practice, repayment capacity of mortgage debtors tends to be evaluated based on their regular income (the basis for cash flow generation). This indicates that even if a debtor's house is damaged by a natural disaster, as long as the debtor's regular income is not affected, that is, as long as there is no problem with the salary from the company they work for, it is considered there is no major problem with repayment.

On the other hand, during the loan term of mortgage loans, we can assume climate-related risks are reflected as a result of mark to market of collateral values. For example, in areas where rivers have flooded due to natural disasters, climate-related risks are reflected by a fall in housing prices in those areas. In areas where the risk level of hazard maps is revised as having higher risk, climate-related risks are likely to be reflected through changes in housing prices in the areas. However, it should be noted that housing prices are not determined solely by how high the risk level of hazard maps is, but by various factors such as convenience and accessibility, and supply-demand balance.

3.6.2 Risk mitigation effect and regulatory implications of fire insurance

Fire insurance is a scheme under which insurance money is paid to mortgage debtors who have fire insurance policy when their houses are damaged by fire, earthquake, hurricane and/or flood. Debtors who have suffered damages can rebuild their lives with the insurance money, and also continue to repay their mortgage loans. Therefore, fire insurance is considered to have a considerable effect on reducing credit risk. However, at present, fire insurance is not recognized as a credit risk mitigation method under the

[14] As of December 2022 when the author had interviews with financial institutions.

standardized approach[15] adopted by many financial institutions under capital adequacy regulations. On the other hand, financial institutions that adopt IRB approach can consider fire insurance as a credit risk mitigation factor and a risk driver for making the pool category when estimating their PD or LGD. If fire insurance has a statistically significant effect in reducing the actual default rate, it may be adopted as a risk driver for making the pool category.

Box 3: The role of earthquake insurance

Earthquakes are natural disasters, but it would be appropriate not to include them in the category of climate-related risks. However, given the frequent occurrence of earthquakes in Japan, we summarize how earthquake insurance functions in terms of risk management.

Earthquake insurance is a highly public insurance product operated jointly by the government and non-life insurance companies under the "Act on Earthquake Insurance." An earthquake insurance policy cannot be purchased alone, and is only available in a set with fire insurance. Earthquake insurance underwritten by non-life insurance companies is eventually reinsured by the government to avoid the risk of large insurance claims incurred by non-life insurance companies. In other words, for risk events such as earthquakes that would cause tremendous damages, we are prepared against damages practically by the national scheme (General Insurance Association of Japan 2023).

A similar scheme exists in the United States, through which the government accepts risk of natural disasters. The National Flood Insurance Program (NFIP) provides insurance for floods, which account for 80% of the damages caused by natural disasters in the United States. NFIP was founded in 1968 and is the only federally managed natural disaster insurance business operating in the United States (Matsuoka 2010).

If the scale of wind and flood damage in Japan increases in the future along with an increase in climate-related risks, there is a possibility that the same system as earthquake insurance might be applied to wind and flood damage.

4. Quantitative Impact Analysis

4.1 Path diagram for climate-related risk transmission

In order to examine the quantitative impact of climate-related risks on mortgage portfolios, we prepared a path diagram (Figure 6) showing how such risks lead to deterioration of profitability, which is considered to be the largest risk for mortgage portfolios. Factors causing deterioration in profitability include an increase in the number of defaults (increase in PD), a decrease in the value of collateral (increase in LGD),

[15] In the standardized approach, capital requirement ratios is calculated using risk weight determined by authorities for each class of exposure.

and a decrease in income due to a decrease in the outstanding balance of loans (decrease in exposure at default, EAD) as a result of early repayment.

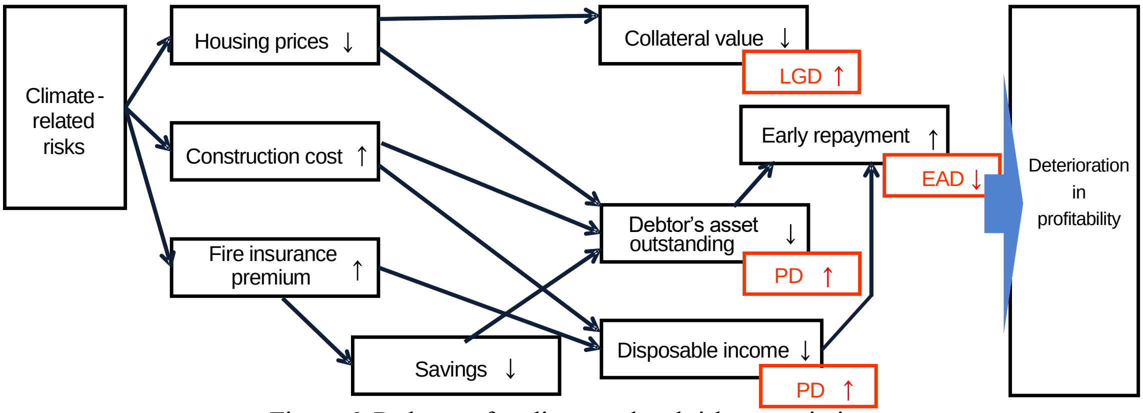

Figure 6: Pathways for climate-related risk transmission

There are three pathways from climate-related risks, and these events may occur alone or simultaneously. The risks may increase further, especially when events occurring in each pathway affect each other.

4.1.1 Transmission path of decline in housing prices

- With the materialization of climate-related risks, housing prices decline due to floods, etc.
- A decline in housing prices leads to a decrease in the value of collateral, which in turn leads to an increase in LGD. An increase in LGD means a decrease in the value that can be recovered in the event of default, thereby deteriorating the profitability of mortgage portfolios.
- A decline in housing prices incentivizes homeowners to sell their houses at higher prices as possible, encouraging earlier sale. The sale of homes leads to earlier repayment of mortgage loans and a decrease in the EAD. A decrease in the EAD leads to a decrease in interest income and a deterioration in the profitability of mortgage portfolios.
- A decline in housing prices leads to a decrease in the value of assets, which in turn leads to a decrease in the outstanding asset balance of borrowers (debtors). A decrease in the outstanding asset balance reduces repayment capacity, which in turn leads to a rise in PD. A rise in PD leads to an increase in credit costs, which in turn leads to a deterioration in profitability.
  - However, the decline in housing prices is not a decline in cash assets such as savings used for repayment, the impact on the PD is expected to be small.
  - Nevertheless, a decrease in asset balance of borrowers (debtors) induces early sale of homes due to reduced repayment capacity, and leads to a decline in EAD. The decline in EAD results in a decrease in interest income, which deteriorates the profitability of mortgage portfolios.

4.1.2 Transmission path of an increase in construction cost

- As climate-related risks materialize, changes in vegetation due to global warming will cause prices of housing materials to soar, pushing up construction costs.
- A rise in construction costs leads to an increase in housing acquisition costs, which in turn leads to a decrease in asset balance of borrowers (debtors). This reduces repayment capacity of borrowers and leads to an increase in PD. A rise in PD increases credit costs, and may lead to deterioration in profitability.
  - A decrease in asset balance of borrowers (debtors) induces early sales of homes due to reduced repayment capacity, and leads to a decline in EAD. The decline in EAD results in a decrease in interest income, which deteriorates the profitability of mortgage portfolios.
- A rise in construction costs leads to an increase in mortgage loans and a decrease in disposable income due to the increased burden of loan repayments, thereby reducing repayment capacity and raising the PD. A rise in PD increases credit costs, and this leads to a deterioration in profitability.

4.1.3 Transmission path of an increase in insurance premium

- Materialization of climate-related risks causes more frequent and more severe natural disasters. This increases fire insurance claims and leads to higher fire insurance premiums.
- An increase in fire insurance premiums leads to a decrease in savings of borrowers (debtors) and hence outstanding balance of assets. A decrease in asset balance reduces repayment capacity and increases PD. A rise in PD increases credit costs, and this leads to a deterioration in profitability.
  - A decrease in asset balance of borrowers (debtors) induces early sales of homes due to reduced repayment capacity, and leads to a decline in EAD. The decline in EAD results in a decrease in interest income, which deteriorates the profitability of mortgage portfolios.
- An increase in fire insurance premiums leads to a decline in disposable income and reduces repayment capacity, and increases PD. A rise in PD increases credit costs, and this leads to a deterioration in profitability of mortgage portfolios.
  - A decrease in disposable income induces early sale of homes due to reduced repayment capacity, and leads to a decline in EAD. A decline in EAD decreases interest income, which in turn leads to a deterioration in profitability of mortgage portfolios.

The deterioration in profitability of mortgage portfolios also has an impact on the capital adequacy ratio, which can be summarized as follows (Table 4).

Table 4: Relationship between mortgage portfolios and capital adequacy ratios

	Standardized approach	IRB approach
Increase in PD (increase in number of defaults)	N.A. because PD is not used for calculation of capital adequacy ratios	Decrease due to an increase in risk weight and also risk-weighted assets
Rise in LGD (fall in housing prices)	Decrease due to an increase in risk-weighted assets by an increase in risk weight through LTV (Note)	Decrease due to an increase in risk weight and also risk-weighted assets
Decrease in EAD	Increase due to a decline in risk-weighted assets	Increase due to a decline in risk-weighted assets

Note: In finalizing Basel III, the standardized approach applies risk weights ranging from 20% to 70% depending on loan to value (LTV) ratios.

4.2 Incorporating climate-related risks into parameters

Banks that have adopted the IRB approach estimate parameters, such as PD and LGD, themselves in order to calculate regulatory capital requirements. Banks that have adopted the standardized approach also estimate these parameters for internal management purposes and use them in assessing capital adequacy and profitability, although they do not use them in calculating regulatory capital requirements. Therefore, we consider conducting a simulation of capital adequacy ratios by reflecting the impact of climate-related risks to these parameters. We basically proceed with our discussion with reference to stress testing methodologies used by many financial institutions.

Additional adjustment may not be necessary, if the observed period from which actual data to estimate PD or LGD are taken sufficiently covers climate-related risks. This is consistent with the concept of including stress periods in the observed period of actual data when estimating PD or LGD.

4.2.1 Reflecting climate-related risks to PD

Although there are many methods to estimate PD of mortgage loans,[16] broadly there are two methods: (1) estimation based on the actual default rate; and (2) estimation based on a mathematical model. (1) is a method to estimate PD based on the average historical default rates for each pool of mortgage portfolios, taking into account conservative adjustment ranges. (1) is a method that can be implemented with high reproducibility by many financial institutions because it is widely adopted and has a proven track record in practice. (2) is a scoring model mainly used when taking up mortgage loans, in which PD is estimated

[16] For PD estimated by banks adopting IRB approach for calculating capital ratios, conservative adjustment ranges are added to take into account effects of economic cycle on credit risk.

using the attributes of mortgage borrowers (income, LTV, etc.) as explanatory variables.

In this paper, we consider reflecting the impacts of climate-related risks on the basis of (1) and (2) above.

4.2.1.1 Adjustment by estimates based on actual default rates

Estimation based on actual default rates is a method to obtain PD by averaging time-series actual default rates of each loan pool. The features of this estimation method are simplicity and transparency. Let us look at an actual example. Table 5 shows the historical average of the actual default rate for a given loan pool category Y. The historical average is 0.97% (Equation (5)).

Table 5: Actual default rates of pool Y by fiscal year

20X1	20X2	20X3	20X4	20X5	20X6	20X7	20X8	20X9	Average
0.80%	0.85%	0.98%	0.92%	0.75%	0.95%	1.10%	1.30%	1.05%	0.97%

$$average\ \ actual\ \ default\ \ rate\ \ (0.97\%) = \frac{\sum_{i=1}^{n} annual\ \ actual\ \ default\ \ rate}{n} \tag{5}$$

In practice, however, some degree of conservatism is often added to PD, taking into account uncertainty associated with observed actual default rates, business cycles, statistical errors, etc. Therefore, we reflect climate-related risks using the method that adds conservatism approach. Adjustment range is often set by checking the level at which conservatism is secured to certain extent in light of actual data.[17]

Conceptually, climate-related risks are reflected in the form of Equation (6). The challenge here is "how to determine an appropriate adjustment range for climate-related risks." Given that data on climate-related risks are insufficient currently, it is difficult to extract just the part related to climate-related risks and quantitatively determine an adjustment range. Therefore, we consider an alternative method, in which a conservative adjustment range that can cover the maximum possible loss is determined by referring to the historical actual default rate.

$$adjusted\ \ PD = average\ \ actual\ \ default\ \ rate + conservative\ \ adjustment \\ + \ climate - related\ \ risk\ \ adjustment \tag{6}$$

[17] We will not go into detail about adjustment methods, but one way is to, for example, add as an adjustment range n times of standard deviation.

4.2.1.2 Adjustment by estimates based on mathematical model

Ergeshidze (2017) developed a logit model to estimate PD of mortgage borrowers, using data of three large banks in Georgia. So, we examine how we can reflect the impacts of climate-related risks on mortgage portfolios using these existing logit models.

Equations (7) and (8) are prepared by the author using a logit model, applying the estimated results of PD indicated in Ergeshidze (2017).

$$P(y_i = 1) = \frac{1}{1 + e^{-Z}} \tag{7}$$

$$Z = -8.2 + 5.6 * PTI_i + 2.14 * LTV_i + 1.08 * CH_i + 1.04 * InBank_i \tag{8}$$

Payment to Income Ratio (PTI) means the repayment ratio, which is obtained by dividing the amount of repayment by income. Loan to value ratio (LTV) is the ratio of mortgage loans to the appraisal value of real estate, which is obtained by dividing mortgage loan values by the appraisal value of real estate. Credit history (CH)[18] means a borrower's past repayment status. For example, when repayment was made without delay in the past, the borrower's repayment status is good. InBank (a type of client)[19] means whether there is a payroll account of a borrower at a financial institution that has provided mortgage loans. In the equation, *i* refers to individual borrowers. The impact of each variable on PD is shown in Table 6.

Table 6: Relationship between Explanatory Variables and Default Probability

Each variable	Probability of default
Increase in PTI	Increase (higher risk)
Increase in LTV	Increase (higher risk)
Good CH	Decrease (lower risk)
InBank (customers with payroll account)	Decrease (lower risk)

4.2.1.2.1 Adjustment with dummy variables

When a residential property, for which mortgage loan is provided, is located in a disaster hazard area,[20] we consider adjustment method to incorporate increased risk, by adding a dummy variable DHA (disaster

[18] CH is equivalent to "Credit_History" in Ergeshidze (2017).
[19] InBank is equivalent to "Income_inbank" in Ergeshidze (2017).
[20] Disaster hazard areas can be designated by local municipal bodies in ordinances based on the provisions of Article 39 of the Building Standards Act. This is a system in which areas exposed to significant risks due for example to tsunamis, storm surges, floods, etc., are designated as disaster hazard areas by ordinances, and restrictions on construction necessary for preventing disasters are imposed, such as prohibition of construction of residential buildings.

hazard area) to Equation (8) (see Equation (9)). The dummy variable is a variable having a value of 0 or 1, and is used as an explanatory variable representing an attribute. In this example, the dummy variable is expressed as 1 when the property is located in a disaster hazard area, and 0 when the property is not in the areas.

$$Z = -8.2 + 5.6 * PTI_i + 2.14 * LTV_i + 1.08 * CH_i + 1.04 * InBank_i + \beta * DHA \qquad (9)$$

$$\beta\text{: } regression\ \ coefficient\ \ of\ \ DHA$$

If the property to be evaluated is located in a disaster hazard area, 1 is entered for DHA and, if not 0 is entered. By doing so, the level of PD can be adjusted. However, the challenge here is "how to appropriately obtain β."

We consider a method for calculating β using the level of the actual default rate. For example, if the actual default rate in the disaster hazard area is 1.20% and the actual default rate in the non-disaster hazard area is 0.65%,[21] the odds ratio between the two is approximately 1.84. This means that default is approximately 1.84 times more likely in the disaster hazard area (Table 7).

Table 7: An example of calculation for β

	PD	Odds 1/ (1-PD)	Odds ratio (A)/ (B)
Disaster hazard areas	1.20%	0.0121 (A)	Approx. 1.84
Non-Disaster hazard areas	0.65%	0.0066 (B)	

Now, with respect to Equation (9), we calculate the value of β so that it is approximately 1.84 times easier to default when DHA is input as 1. The value of β can be calculated using Solver[22] that would make the odds ratio to be approximately 1.84 times. Here, the result of calculation is, β = 0.61. In addition, when Equation (9) is calculated as DHA = 1, and PTI, credit history and InBank fixed at 0.3, 0, and 0 respectively, the value of PD when LTV is changed from 0.30 to 1 is as shown in Figure 7. The broken line in Figure 7 represents the adjusted PD, and the solid line represents the unadjusted PD.

[21] Actual default rates in this paper are values set for explaining adjustment method.
[22] Solver is a Microsoft Excel add-in program you can use for what-if analysis. In this example, value of β that makes the odd ratio to be 1.84 is obtained.

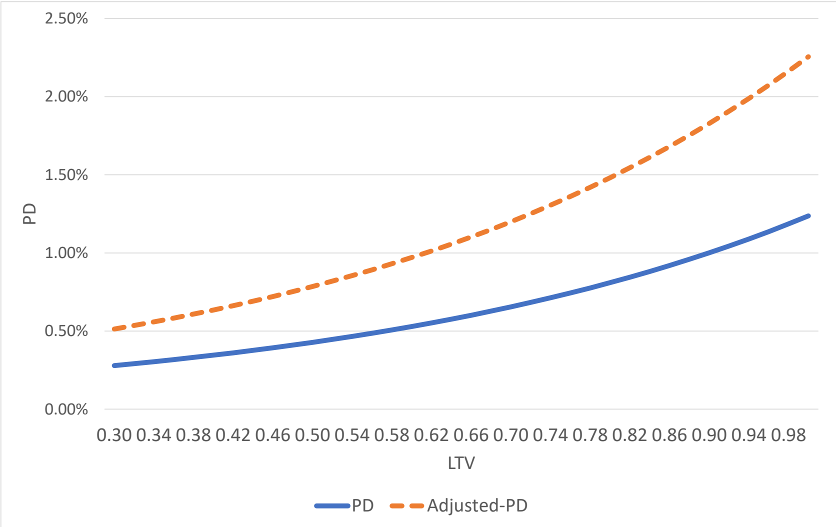

Figure 7: Comparison of PD before and after adjustment

Source: Data prepared by the author based on data from Ergeshidze (2017).

The advantage of the adjustment method using dummy variables is that there is no need to carefully consider the attributes of individual borrowers, so that adjustment can be implemented with fewer steps and at lower cost. On the other hand, the disadvantage is that it is not possible to make detailed adjustments for individual borrowers. The method of making adjustments for individual borrowers will be described in the sub-model method below.

4.2.1.2.2 Adjustment using sub-models

Sub-model adjustment is a method to estimate each explanatory variable in Equation (8) using a different model (sub-model) that accounts for climate-related risks. For example, estimation is performed to obtain LTV_i of each borrower *i* using explanatory variables such as current collateral value *i*, occurrence of natural disasters *i*, and disaster hazard area *i*. Equation (10) estimates the adjusted collateral value, which is the denominator of LTV, and Equation (11) calculates the adjusted LTV_i.

$$\begin{aligned} &adjusted\ \ collateral\ \ value_i \\ &\quad = \alpha + \beta_1 * current\ \ collateral\ \ value_i + \beta_2 * occurence\ \ of\ \ natural\ \ disaster_i \\ &\qquad\qquad + \beta_3 * disaster\ \ hazard\ \ area_i \end{aligned} \tag{10}$$

$$adjusted\ \ LTV_i = \frac{outstanding\ \ balance\ \ of\ \ mortgage\ \ loan_i}{adjusted\ \ collateral\ \ value_i} \tag{11}$$

The advantage of sub-model adjustments is that they allow for granular PD estimates tailored to individual borrowers. On the other hand, the disadvantage is that since they increase the number of parameters to be estimated, such as α and β, this can lead to estimation errors (model risk)[23] and hence to a loss of robustness and reliability of the model.

4.2.2 Reflecting climate-related risks to loss given default (LGD)

As with PD, there are broadly two ways for estimating LGD for mortgage loans: (1) estimation based on actual LGD ratios and (2) estimation based on mathematical models. The adjustment method for climate-related risks using (1) and (2) is basically the same as that of PD.

4.2.2.1 Adjustment based on actual LGD ratios

The estimation method based on the actual LGD is based on the historical average of the actual LGD for each pool category. This estimation method is characterized by its simplicity and transparency. For example, Table 8 shows annual average of actual LGD for a given pool category Z. The historical average is 37.1%.

Table 8: Actual Loss Given Default of Pool Z by Fiscal Year

20X1	20X2	20X3	20X4	20X5	20X6	20X7	20X8	20X9	Average
35.0%	33.3%	38.0%	40.0%	45.0%	42.5%	38.8%	29.5%	32.0%	37.1%

$$average\ \ actual\ \ LGD\ \ ratio\ \ (37.1\%) = \frac{\sum_{i=1}^{n} annual\ \ actual\ \ LGD\ \ ratio}{n} \qquad (12)$$

However, as with PD, LGD used in practice often incorporates some degree of conservatism, taking into account the uncertainty of observed actual LGD ratios, business cycles, statistical errors, etc. Therefore, we reflect climate-related risks using the method that adds conservatism approach. In practice, the adjustment range is often set by checking the level at which conservatism is secured to certain extent in light of actual data.

Conceptually, as with PD, climate-related risks are reflected in the form of Equation (12). However, the challenge is how to determine the appropriate adjustment range for climate-related risks. Given that data on climate-related risks are insufficient currently, it is difficult to extract just the part related to climate-related risks and quantitatively determine an adjustment range. Therefore, one approach would be to determine a conservative adjustment at a level that covers the maximum possible loss, by referring to historical actual loss given default rates.

[23] Here, model risk means an increase in statistical errors by an increase in the number of parameters to estimate.

$$adjusted\ LGD = average\ actual\ LGD\ ratio\ +\ conservative\ adjustment \\ +\ climate - related\ risk\ adjustment \quad (13)$$

4.2.2.2 Adjustment by estimates based on mathematical model

This adjustment method is the same as that for PD described in 4.2.1 above. It is assumed that adjustments are made using dummy variables or the sub-model method. However, since the use of mathematical models for LGD estimation is limited in practice, at least in Japan, this paper does not go into the details of this adjustment method. Challenges associated with adjustment are the same as those for PD.

5. Potential Risk Management Concerns

At present, both physical and transition risks related to climate-related risks are gradually becoming apparent. In this section, we examine risk management concerns related to climate-related risks on a forward-looking basis.

5.1 Reduced risk mitigation effect of fire insurance

In recent years, fire insurance premium rates have been raised by a number of non-life insurance companies in response to more frequent and severe natural disasters. As a result, there is a possibility that coverage of fire insurance will be reduced in the future due to the increased burden on non-life insurance companies for insurance payment. There is also a concern that while people would purchase fire insurance, they might limit or not include compensation coverage for flood damages so as to save on insurance premium as much as possible. Furthermore, there is also a concern about a declining number of fire insurance policyholders due to the soaring fire insurance premiums, and this could affect the sustainability of fire insurance systems.

While most financial institutions would not be affected in terms of the level of required capital by declines in fire insurance coverage and the number of fire insurance policyholders, potential climate-related risks would increase. When a borrower suffers a natural disaster, if the scope of fire insurance coverage is limited, there is a possibility that reconstruction of lives will not proceed smoothly and there can be difficulties in repayment of mortgage loans.

5.2 Fluctuations in housing prices due to policies towards achieving carbon neutrality

Energy conservation measures in the housing and construction sector are being strengthened toward achieving net zero emissions by 2050 and a 46% reduction in greenhouse gas emissions by 2030 (compared to fiscal 2013).[24] The budget request for fiscal 2023 from the Housing Bureau of the Ministry of Land,

[24] See outline of budget requests related to the Housing Bureau of the Ministry of Land, Infrastructure, Transport and Tourism for fiscal 2023 (budget requests made in August 2022).

Infrastructure, Transport and Tourism identifies the following five areas as key measures.

1. Achieving carbon neutral housing and buildings
2. Ensuring the safety of housing and living and developing a favorable urban environment
3. Securing diverse housing that enables safe and sound living for everyone
4. Making use of existing housing stock and creating active secondary market
5. Promoting digital transformation and productivity improvements in the housing and construction fields

Regarding key measure 1 "achieving carbon neutral housing and buildings," a type of mortgage loan called "Flat 35" requires all houses to meet energy conservation standards (thermal insulation grade 4 and primary energy grade 4) as a financing requirement from April 2023.[25] This may lead to higher prices for new houses and an increase in borrowers' repayment burden.

Under key measure 2 "ensuring the safety of housing and living and developing a favorable urban environment," relocation of housings in hazard areas[26] is going to be promoted given the frequent and severe natural disasters occurring in recent years. While there would be various factors working complicatedly to hinder relocation, such as convenience of commuting to work and school from current place and peoples' feeling to hesitate changes to life, relocation may accelerate if more residents think it would be a loss not to move with increased subsidies for encouraging relocation. In such a case, we can point out that downward pressure on housing prices in hazard areas may increase due to the impact on the supply and demand in the housing market.

5.3 Fluctuations in housing prices due to increased sensitivity of home buyers to natural disaster risks

Given the increasing frequency and severity of natural disasters in recent years, home buyers' sensitivity to natural disaster risks is likely to increase, and opportunities to choose housings in hazard areas are likely to diminish. As a result, the demand for housings in hazard areas would decrease in the housing market, leading to a fall in prices of the housings. However, there are also observations that a fall in housing prices could stimulate new demand for home purchases, and so the number of residents in a hazard area may not decrease significantly.

In addition, if home buyers' preference for energy-efficient homes increases due to increased environmental awareness and soaring energy prices, prices of energy-efficient housings may increase and those of non-energy-efficient housings may decrease. Further, demand for renovation to increase energy-efficiency may also increase in order to improve the value of existing housings.

[25] Mortgage loans with a fixed interest rate for the entire term provided by more than 300 financial institutions across Japan in collaboration with the Japan Housing Finance Agency.

[26] Disaster hazard areas are designated by local municipal bodies by ordinances (Article 39, Paragraph 1 of the Building Standards Act) and vulnerable housings in such areas are subject to relocation.

6. Conclusion

6.1 Climate-related risks are reflected through housing prices

We did interviews with a number of financial institutions and experts for this report. At these interviews, we heard from many respondents that "climate-related risks in Japan's housing loan portfolios are likely to be reflected through changes in housing prices." That is to say, impacts of climate-related risks are likely to be reflected in the housing loan portfolios as a result of a decline in prices of housings in the affected areas at the time of a natural disaster, through the depreciation of collateral.

On the other hand, many respondents indicated that in practice it would be difficult to calibrate lending rates taking account of climate-related risks. Reasons for this are: (1) competitive considerations; and (2) lack of capacity to quantitatively measure the appropriate value for the interest rate adjustment.

Considering these points, at present it is appropriate to conclude that for Japanese financial institutions climate-related risks are reflected through the housing market. A fall in prices of housings with high climate-related risks would undermine the value of mortgage collateral held by financial institutions that extend loans, thereby increasing risks to mortgage portfolios. Of course, it is difficult to assess clearly whether climate-related risks are reflected in housing prices, as various price determinants are factored into housing prices, but it is assumed that prices of housings in hazard areas with high climate-related risks would fall due to the supply-demand balance. However, as described in 5.3 above, there are observations that a fall in housing prices would stimulate new demand for home purchases, and as a result, the number of residents in hazard areas might not decrease significantly.

6.2 Future Issues

6.2.1 Ensuring the sustainability of fire insurance

According to the report by the advisory panel on fire insurance and flood disaster insurance rates (JFSA 2022), the amount of insurance claim payments for fire insurance has increased significantly in recent years as natural disasters have become more frequent and severe. As a result, fire insurance premiums have been raised repeatedly in recent years (see Box 2 Advisory rate). However, it goes without saying that rises in fire insurance premiums increase the burden on policyholders. Consequently, if the burden of paying fire insurance premiums becomes too heavy, the number of policyholders may decrease, and could undermine the sustainability of fire insurance scheme.

If natural disasters continue to become more frequent and severe, the government may in the future become engaged in fire insurance, for the part concerning flood damages, as is the case with the current earthquake insurance.[27] In such a case, arrangements for fire insurance premiums and requirements for policyholders would become an issue, which this paper will not deal with.

[27] See explanation on earthquake insurance on the website of the Ministry of Finance (available in Japanese only). https://www.mof.go.jp/policy/financial_system/earthquake_insurance/jisin.htm

6.2.2 Mitigation of impacts of transition risks due to policy guidance, etc.

For the society as a whole, one solution to reduce climate-related risks fundamentally would be to encourage people to move out of unsafe housings located in hazard areas. However, policy measures to encourage relocation from unsafe areas is likely to place downward pressure on housing prices and could affect collateral value that cover mortgage loans. This could lead to a decline in banks' capital adequacy ratios and hence their capacity to lend. In addition, for those banks that operate locally and provide community-based financial services, most of them cannot choose their business areas. In such cases, banks may not be able to actively reduce risks and this could worsen banks' capacity to lend.

Under such circumstances, in reality, an immediate relocation of people living in high risk area due to strong likelihood of natural disasters would be quite unlikely. This is because, as the Ministry of Land, Infrastructure, Transport and Tourism writes in its guidelines for town planning with flood disasters in mind (MLTI 2021), "the direction of town planning for disaster prevention shall be determined with consideration of the overall balance between regional sustainability and town planning, taking into account the urban structure, historical formation process of towns, and demographic, economic, and land use dynamics, etc."

6.2.3 More frequent monitoring of mortgage loans

Currently, monitoring of mortgage loans mostly consists of updating the collateral prices only once a year. Moreover, in many cases, collateral prices are updated not based on onsite inspections but based on standard land values of major roads, published land prices, and actual housing transaction prices. In addition, credit risk assessment is rarely reviewed by updating borrower attributes.

On the other hand, given the increasing frequency and severity of natural disasters in recent years, the term of fire insurance contracts has been shortened to five years from October 2022. Therefore, it would likewise be ideal to improve the frequency and depth of monitoring of mortgage loans.

6.2.4 Ensuring data volume in parameter estimation by banks adopting IRB approach

Banks that adopt the IRB approach estimate parameters for PD, LGD, and EAD when calculating the value of risk-weighted assets of mortgage loans. These parameters are estimated for each pool with similar risk attributes, but climate-related risks are not included in risk drivers that define this pool currently. This is because there are only few examples of mortgage loans exposed to climate-related risks, and so the number of mortgage loans (data volume) is insufficient to form a pool.

In order to incorporate climate-related risks into parameter estimates, time would be necessary to collect data to capture sufficient amount of data for creating pools. As examples of mortgage loans exposed to climate-related risks increase, sufficient volume of data for forming loan pools would be secured. Sufficient amount of data may exist even at present, if data on mortgage loans exposed to climate-related risks are gathered from a number of financial institutions.

References

Baldauf, Markus et al. (2020), "Does Climate Change Affect Real Estate Prices? Only If You Believe In It," *The Review of Financial Studies*, Volume 33, Issue 3, March 2020, pp. 1256-1295. https://doi.org/10.1093/rfs/hhz073

Bank of Japan (2021), "Summary of the International Research Workshop on Climate-related Financial Risks: Interactions of Climate Change and the Financial System."

Basel Committee on Banking Supervision (2022), *Principles for the effective management and supervision of climate-related financial risks*.

Batten, Sandra et al. (2016), "Let's talk about the weather: the impact of climate change on central banks," Staff Working Paper No. 603, Bank of England.

Billio, Monica et al. (2022), "Creditworthiness and buildings' energy efficiency in the Italian mortgage market," SAFE Working Paper No. 352.

Ergeshidze, Aleksandre (2017), "Credit Risk Model: Assessing Default Probability of Mortgage Loan Borrower," 3rd RSEP Multidisciplinary Conference 5-7 April, 2017: 1-9; ISBN: 978-605-307-583-7, Available at SSRN: https://ssrn.com/abstract=3038004 or http://dx.doi.org/10.2139/ssrn.3038004

Financial Services Agency (2021), Report by the Expert on Sustainable Finance "Building A Financial System that Supports a Sustainable Society."

Financial Services Agency (2022), "report by the advisory panel on fire insurance and flood insurance rates," (available in Japanese) https://www.fsa.go.jp/singi/suisai/houkokusyo.pdf.

Financial Services Agency and Bank of Japan (2022), "Pilot Scenario Analysis Exercise on Climate-Related Risks Based on Common Scenarios."

Guin, Benjamin and Perttu Korhonen (2020), "Does energy efficiency predict mortgage performance?" Staff Working Paper No. 852, Bank of England.

Koide et al. (2022), "Flood Risk's Impact on Land Prices" (in Japanese), Bank of Japan Working Paper Series, Bank of Japan.

Magyar Nemzeti Bank (central bank of Hungary) (2019), "GREEN RETAIL LENDING IN HUNGARY," https://www.mnb.hu/letoltes/green-retail-lending-in-hungary.pdf

Matsuoka, Jun (2010), "The U.S. National Flood Insurance Program (NFIP)" (in Japanese), The General Insurance Institute of Japan, Report No. 93, October 2010, http://www.sonposoken.or.jp/media/reports/sonposokenreport093_1.pdf

Ministry of Land, Infrastructure, Transport and Tourism (2021), "guidelines for town planning based on flood disaster risks," https://www.mlit.go.jp/toshi/city_plan/content/001406429.pdf

Ministry of Land, Infrastructure, Transport and Tourism (Housing Bureau) (2023), "Report on the survey result of private housing loans in fiscal 2022."

Network for Greening the Financial System (2019), "A call for action: Climate change as a source of financial risk."

NGFS (2020), "Guide to climate scenario analysis for central banks and supervisors."

NGFS (2021), "NGFS Climate Scenarios for central banks and supervisors."

NGFS (2022), "NGFS Climate Scenarios for central banks and supervisors."

Nguyen, Duc Duy et al. (2022), "Climate Change Risk and the Cost of Mortgage Credit," *Review of Finance*, Volume 26, Issue 6, November 2022, pp. 1509-1549. https://doi.org/10.1093/rof/rfac013

Ouazad, Amine and Matthew E. Kahn (2019, revised in 2021), "Mortgage Finance and Climate Change: Securitization Dynamics in the Aftermath of Natural Disasters," NBER Working Paper No. 26322, National Bureau of Economic Research.

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