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# OPTIMAL CHOICE OF CATASTROPHE LOSS FINANCING THROUGH SECURITIZATION FOR JAPANESE P/C INSURERS

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## I. *Introduction*

In line with the surge in frequency and severity of natural and man-made disasters, financing catastrophe losses has become a crucial challenge for property and casualty insurers (hereafter, P/C insurers). According to Sigma (2004), the total loss attributable to catastrophic events in 2003 amounted to approximately 70 billion US dollars, a figure that has been on the increase since the 1970s.[1] Of this amount for 2003, 58 billion dollars was caused by natural catastrophes and 12 billion was from man-made disasters. Insured properties are especially exposed to catastrophes, including hurricanes and earthquakes, and thus, primary P/C insurers need to hedge the catastrophe risk of their portfolios of property insurance policies covering not only straight fire, but also flood and earthquakes, etc. by efficient mechanisms to finance possible enormous losses.

The traditional solution for primary insurers to have the capacity to underwrite such property risks is to limit their losses through reinsurance transactions. Excess-of-loss contracts allow them to transfer single-event claims above a given amount to single or multiple numbers of reinsurers. They can alternatively shift a given percentage of losses onto other reinsurers by proportional reinsurance arrangements.

Unfortunately, reinsurance capacity fluctuates due to such factors as the insurance cycle, increased liability risks and frequent insolvencies. Among these factors, it is catastrophic event that significantly impairs reinsurance capacity. The period from the late 1980s to the early 1990s experienced an increase in severe natural disasters, including Hurricane Andrew in 1992, the Northridge Earthquake in 1994 and the Great Hanshin-Awaji (Kobe) Earthquake in 1995. During this period, the availability of reinsurance was heavily undermined.

This predicament, however, motivated innovation in financing catastrophe losses, and

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[1] Sigma (2004), pp.3-9.

new instruments were developed. Creation of the catastrophe bond (hereafter, CAT bond) was one such innovation. While a large part of catastrophic risk is at present hedged through conventional reinsurance, the use of CAT bonds is gradually increasing.[2] By securitizing insurance risks through CAT bonds, primary insurers can reduce the credit risk to which they would otherwise be exposed. Instead, whereas in the case of reinsurance losses are paid on an indemnity basis, insurers utilizing CAT bonds, some of which do not pay losses based on actual losses, can be exposed to basis risk. The American Academy of Actuaries (1999) defines basis risk as the risk that there may be a difference between the performance of the hedge and the losses sustained from the hedged exposure.[3]

As discussed in detail later, the degree of basis risk depends on the characteristics of the insurance portfolio to be financed, such as comparative size and level of diversification. Primary insurers, therefore, would need to analyze their own portfolios of insurance policies in order to make their optimal choice of instrument.

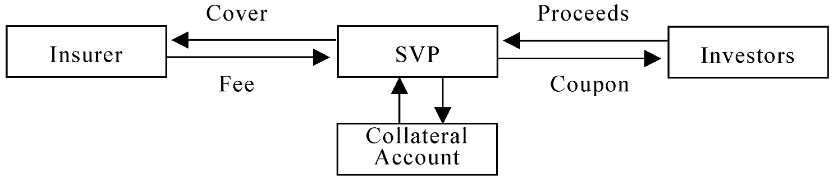
This paper analyzes the basis risk of fire insurance portfolios (including flood and earthquake coverage) held by 20 P/C insurers operating in the Japanese market that write more than 97 percent of the total direct net premium of fire insurance in the market. Basis risk is measured by applying the formula proposed by Doherty (2000)[4] to the accounting data of those insurers for 10 years, and is decomposed into two factors; the "market representation indicator" and the "market share indicator." Focusing on these two indicators, we categorize insurance portfolios into several types, on the assumption that other conditions are equal, and then show optimal financing tools for each type of portfolio.

## II. *Basis Risk of Catastrophe Bond*

### 2.1 Brief Description of Catastrophe Bond

In a typical transaction of a CAT bond, a special purpose vehicle (SPV) is established.[5] The SPV stands between primary insurers and investors, and facilitates and administers the CAT bond transactions.

FIG. 1. EXAMPLE OF CATASTROPHE BOND TRANSACTION




[2] Sigma (2004), pp.14-18.
[3] American Academy of Actuaries (1999), p.9.
[4] Doherty (2000), pp.625-627.
[5] SPVs are often established in such tax-advantageous legislations as Bermuda and the Cayman Islands.

Tynes (2000) simply describes how CAT bond transactions proceed in general, which is summarized as follows:[6]

1 The SPV designs a bond or a bond series promising to repay the principal at maturity and to pay a specified coupon unless a catastrophic event occurs, and to make reduced or terminated payment if an event does occur.

2 After issuing CAT bonds, the SPV puts the proceeds into the collateral account and keeps them in a safe investment. Using returns from the investment, the SPV pays the stipulated coupon, generally higher than that of other types of bonds, to the investors.

3 If no catastrophe occurs before maturity, the principal is returned to the investors. If a catastrophe does occur, then the SPV pays cover to the insurers, while coupon payments for investors are reduced or terminated and the principal may also be reduced, or, at worst, relinquished.

## 2.2 Types of CAT Bonds and their Basis Risk

CAT bonds use a variety of trigger mechanisms to determine whether a catastrophe qualifies for coverage. As discussed below, the manner in which CAT bonds are generally handled is based on indemnity, industry-indices, parameters, and modeled indices. Being different from conventional reinsurance, in which the payment is made based on the amount of actual losses that the primary insurer paid for primary insurance contracts, some types of CAT bonds bring about basis risk, the level of which partly depends on the type of trigger used.

*Indemnity-based* CAT bonds are, like reinsurance, based on the primary insurer's own loss and, thus, do not expose primary insurers to significant basis risk.

*Index-based* tools, on the other hand, are subject to a certain level of basis risk. Under this scheme, primary insurers recover the loss they suffer based on the total loss of the industry or in a certain regional block. Thus, the payment from the CAT bond does not always match the amount of actual loss suffered by the insurer.

*Parameter-based* triggers also expose primary insurers to basis risk, since recovery depends solely on the location and magnitude of the event, such as the scale of an earthquake, precipitation, wind speed, etc. Compared to others, this scheme is transparent, but is subject to basis risk.

*Model-based* CAT bonds use losses estimated by third-party models for their trigger. The physical parameters of the catastrophe are entered into the model to make a projection of the expected losses to the primary insurer's portfolio. Since it is not necessary to wait until the payout settlement on actual losses, the primary insurer can recover quickly, but there is a possibility that the ultimate amount of actual loss is different from the CAT bond payout.

## 2.3 Researches on Basis Risk Estimation

How should insurers quantitatively evaluate their basis risk when they choose catastrophe loss financing tools? Major (1999) empirically measured basis risk by estimating insurer-specific deviations from statewide indices in a study examining the hedging effectiveness.[7]

[6] Tynes (2000), pp.14-15.
[7] Major (1999), pp.391-432.

Major calculated the correlation between a catastrophe loss index and an individual insurer's book of businesses by constructing a computer simulation model and applying actual property-exposure data from ten randomly chosen P/C insurers from 1988 to 1995. The primary finding was that more narrowly defined geographical areas should help reduce basis risk and that, as a result, indices based on catastrophe losses by zip code provide better hedges than statewide indices.

Harrington and Niehaus (1999) also estimated the hedging effectiveness of state-specific catastrophe financing tools based on Property Claims Services (PCS)[8] by analyzing the historical correlation between catastrophe losses and individual insurers' losses.[9] They estimated the R-squared between state-specific loss ratios, by summing catastrophe/non-catastrophe losses and those based on catastrophe losses alone. The loss ratios were calculated based on data on homeowners, commercial multiple peril, and fire insurance lines from 20 states during the period 1974 to 1994. One of their major findings was that higher mean and median R-squared values were observed when using industry average loss ratios, including both catastrophe and non-catastrophe losses. This implies that a trigger based on the total loss provides a better hedge than one based on catastrophe loss alone.

Cummins et al. (2000) analyzed the basis risk of index-based CAT bonds for 255 insurers holding 93 percent of the insured residential property values in Florida.[10] They obtained county level losses for each insurer by conducting a simulation according to a model developed by Applied Insurance Research (AIR).[11] They then used two types of indices; a statewide index-based on insurance industry losses in Florida, and intra-state indices of quadrants of the state, and found that financing tools based on a statewide index can effectively hedge catastrophe losses for only certain types insurers, namely, several insurers with the largest market share in the state, and a limited number of smaller insurers with insurance portfolios that were highly diversified throughout the state.

Studies by Major, Harrington and Niehaus offer a significant insight into the trigger design of financing instruments, while Cummins et al. emphasize the importance of analyzing insurance portfolios held by individual insurers. In the following sections, we conform to the findings of Harrington and Niehaus, and estimate basis risk based on the total losses, including those caused by catastrophe and non-catastrophe events. Then, as pointed out by Cummins et al., we analyze the characteristics of insurance portfolios of some individual insurers in the Japanese P/C insurance market. For this analysis, we adopt Doherty's model as discussed in detail in the next section.

## III. *Model, Applied Formula, Data and Preconditions*

### 3.1 Model and Applied Formula

We estimated the basis risk of 20 primary P/C insurers operating in the Japanese market,

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8 PCS is a service unit of Insurance Service Office, Inc. (ISO), a major insurance advisory and consulting organization in the U.S., that provides information on insured property losses from catastrophes.

9 Harrington and Niehaus (1999), pp.49-82.

10 Cummins, Lalonde and Philips (2000), pp.1-39.

11 AIR, a wholly owned subsidiary of ISO, develops and provides catastrophe modeling technologies.

which was based on the assumption that these insurers use the index-based CAT bond scheme under which the industry's total loss is used as the trigger. In our estimation, we applied Doherty's model to data covering a ten-year accounting period for the said insurers.

Doherty designed a simple measure of basis risk of an industry index-based CAT bond as follows:[12]

$$b = 1 - r_{im} \quad (1)$$

According to this formula, the level of basis risk for this type of CAT bond depends solely on $r_{im}$; the correlation between the actual loss sustained by an insurer using the instrument and that of the industry total. The closer $r_{im}$ is to unity, the lower the basis risk. Doherty refined the formula and decomposed it into two factors.[13] Consider an insurer *i* having a loss from its book of business amounting to $L_i$. The loss suffered by all insurers other than *i* is subscripted as $L_j$. The total loss of the market is calculated as:

$$L_m = L_i + L_j$$

Covariance between $L_i$ and $L_m$ is:

$$\begin{aligned} \mathrm{Cov}\ (L_i, L_m) &= \mathrm{Cov}\ (L_i, L_i + L_j) \\ &= \mathrm{Cov}\ (L_i, L_i) + \mathrm{Cov}(L_i, L_j) \end{aligned}$$

Thus, the correlation coefficient between $L_i$ and $L_m$ can be obtained as follows:

$$\begin{aligned} r_{im}\sigma_i\,\sigma_m &= \sigma_i^2 + r_{ij}\sigma_i\,\sigma_j \\ r_{im} &= \sigma_i/\sigma_m + r_{ij}\sigma_j/\sigma_m \end{aligned}$$

By substituting this in formula (1) above, basis risk is:

$$\begin{aligned} b &= 1 - r_{im} = 1 - (\sigma_i/\sigma_m + r_{ij}\sigma_j/\sigma_m) \\ &= (1 - r_{ij}\sigma_j/\sigma_m) - \sigma_i/\sigma_m \quad (2) \end{aligned}$$

Doherty defines the first part of this equation $(1 - r_{ij}\sigma_j/\sigma_m)$ as the representation risk and the latter $(\sigma_i/\sigma_m)$ as the market share risk. The component of representation risk $(r_{ij}\sigma_j/\sigma_m)$ indicates how representative of the whole market *i*'s portfolio is. Other things being equal, when *i*'s portfolio is as highly diversified as the whole market, the value of $(r_{ij}\sigma_j/\sigma_m)$ is close to unity.[14] We focus on this factor and refer to it hereafter as the "market representation indicator." Market share risk $(\sigma_i/\sigma_m)$ represents how *i*'s portfolio dominates the market; the bigger the market share, the closer to unity the market share risk $(\sigma_i/\sigma_m)$. We refer to this as the "market share indicator."

### 3.2 Outline of Fire Insurance in Japan

In order to clarify the characteristics of the data to be used in our analysis, we feel it best to first provide a brief description of Japanese fire insurance, focusing on the risks that it covers.

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[12] Doherty (2000), pp.596-598.
[13] Doherty (2000), pp.625-627.
[14] Both $(r_{ij})$ and $(\sigma_j/\sigma_m)$ come close to 1.

Within the general insurance market, fire insurance is the second largest insurance line after automobile insurance. The direct net premium written in 2004 amounted to 1,109 billion yen, accounting for 14.6 percent of total general insurance.[15]

In the Japanese market, the most commonly purchased personal line fire insurance products are comprehensive policies such as *comprehensive dwelling house policies*, *savings-type comprehensive dwelling house policies*,[16] and *storekeepers' comprehensive policies*.[17] Although the range of protection varies among the policies and insurers chosen by policyholders, these comprehensive types of policy generally cover not only straight fire, but also lightning strike, explosion and eruption, wind, hail, snow, water damage, theft, etc. Unlike American homeowners insurance, they provide protection for property risks only, and do not cover liability risks. There are also *basic dwelling house policies* and *apartment complex policies* providing narrower coverage. The premium volume for these types of policies is relatively small.

Policyholders of personal fire insurance have an option to attach an earthquake insurance clause to their policies. In light of the high risk of earthquakes in Japan, 30.6 percent of policies covering dwelling risks, and 16.4 percent of households attach earthquake protection.[18] The earthquake insurance clause covers fire, destruction, burial or flood caused by earthquake, volcanic eruption or tsunami.

*General fire insurance policies* are commercial line fire insurance products that cover property risks for business entities including offices, factories, and warehouses. The basic coverage provides protection against property loss arising from straight fire, lightning strike, explosion and eruption, wind, hail and snow.[19] Policyholders can attach extended coverage clauses for earthquakes, water damage, and various types of risks.

### 3.3 Data and Preconditions

We applied Doherty's model to ten-years of historical data using accounting statistics provided by Japanese P/C insurers. These accounting figures are publicly disclosed by individual insurers and compiled by the Insurance Research Institute.[20] We made *direct net claims paid* for fire insurance to be the proxy of losses sustained by individual primary insurers. Direct net claims paid represent the amount of claims paid before subtracting recovery from reinsurance, and can be regarded as the amount that insurers paid for their primary insurance policies. The figures cover losses from all personal and commercial fire insurance policies held by 20 P/C insurers writing 97.2 percent of direct premiums of fire insurance in the market (see Appendices). We used the data of total direct net claims paid, without dividing them into

[15] Figures are based on *Insurance: Annual Special Issue*, *The Statistics of Japanese Non-life Insurance Business 2002* published by Insurance Research Institute, pp.52-53.

[16] Direct premium written for dwelling risks comprises approximately 35 percent of total fire insurance excluding earthquake insurance, while the remainder is for store, factory, warehouse, and other risks, as well as for housing loan fire insurance, according to *Fire Insurance Statistics Fiscal 2002* compiled by Non-life Insurance Rating Organization of Japan.

[17] Policies for small-sized store owners with a similar range of protection as comprehensive dwelling house policies, and generally regarded as belonging to the personal line.

[18] As of March 31, 2004. Figures are calculated by Non-life Insurance Rating Organization of Japan.

[19] Warehouse general fire policy excludes wind, hail and snow damage. However, a policyholder can, of course, extend their coverage to such risks by attaching extended coverage clauses.

[20] *Insurance: Annual Special Issue*, *The Statistics of Japanese Non-life Insurance Business*, *2002*, pp.52-53.

catastrophe and non-catastrophe losses, based on the assumption that the distribution of catastrophe losses coincides with that of total losses. This assumption is consistent with the results found by Harrington and Niehaus (1999)[21] implying that a trigger based on the total losses is not inferior to a trigger based on catastrophe losses alone, as discussed in the previous section. Actually, the amount of total losses of fire insurance is significantly influenced by catastrophe losses, including those caused by flood or earthquake, as non-catastrophe losses such as straight fire and theft, etc. are incommensurably small in size compared with catastrophe losses once they occur.

For our calculations, figures for the most recent decade of fiscal years 1993 to 2002 are used (see Appendix 1). Along with the deregulation that eased market entry in 1996, some new insurers entered the P/C insurance market. For these new entrants, most of whom are affiliated with life insurers, the time span was a seven-year period from 1996 to 2002.

Data for insolvent insurers have been excluded. Although their remaining businesses were, in some cases, relocated to surviving insurers, the impact of such relocations was both temporary and negligible considering their volume. For the same reason, we have excluded data from insurers that withdrew from the market. Further, after 2001, several insurers merged into single entities. Their past figures have been added up according to their present entities, and are regarded as those for single insurers.

## IV. *Analysis of Fire Insurance Portfolios in the Japanese Market*

### 4.1 Overview of the Results

The level of basis risk for each fire insurance portfolio among 20 sample insurers is listed in Appendix 2, and is depicted in Graph 1 below.

Generally, insurers with a larger market share[22] including Tokio Marine, Sompo Japan, and Mitsui Sumitomo have lower basis risk. Some of these insurers were created after recent mergers, but their predecessors had had a long history in business,[23] having underwritten fire insurance nationwide, and having held highly diversified portfolios. On the other hand, insurers with a smaller market share generally have a higher basis risk. These insurers include new entrants and niche players, e.g. Sumi-Sei, JI and Daido Fire.

We also computed the market representation indicator and the market share indicator by decomposing basis risk. Graph 2 plots the same 20 insurers' portfolios two-dimensionally, representing these two indicators.

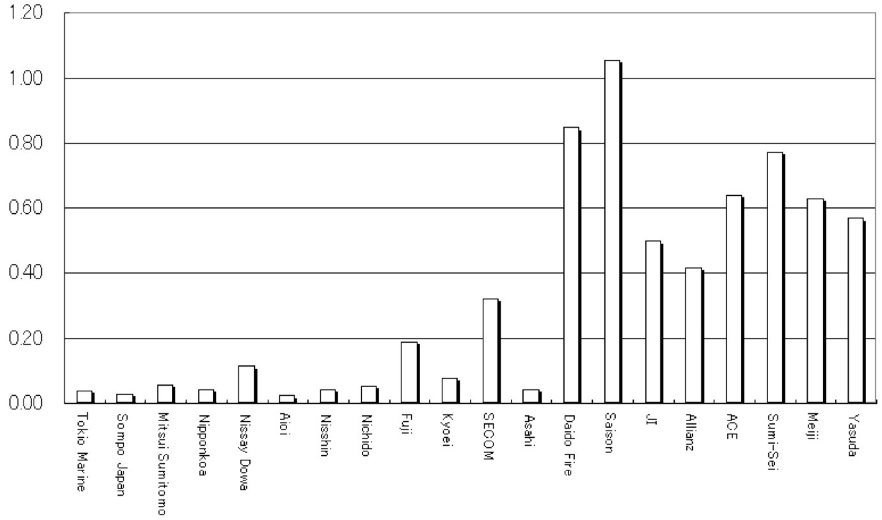
Based on the level of these factors, we can categorize the insurers' portfolios into three groups as indicated in Graph 2; Group 1 (large and diversified), Group 2 (small but diversified), and Group 3 (small and undiversified). In the following sections, we analyze the characteristics of each group, and discuss what type of CAT bond would be appropriate in

[21] Harrington and Niehaus (1999), pp.49-82.

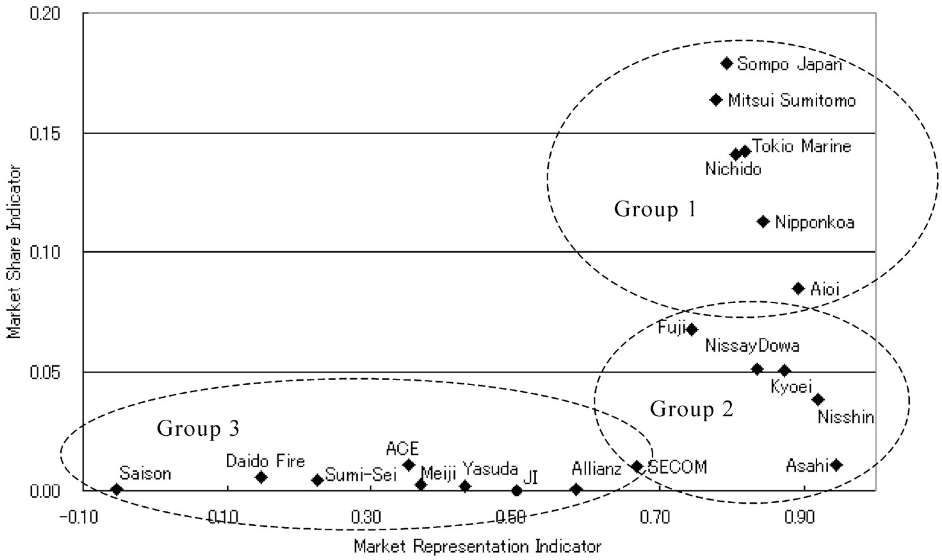
[22] Market share of 20 insurers, based on direct net premiums including savings premiums in 2002, are listed in Appendix 2.

[23] Although Sompo Japan, Mitsui Sumitomo, Nipponkoa and Aioi were newly started insurers after mergers, their predecessors had a long history. Yasuda Fire, for example, is one of Sompo Japan's predecessors and was established in 1888.

GRAPH 1 BASIS RISK OF JAPANESE P/C INSURERS




GRAPH 2 MARKET REPRESENTATION AND MARKET SHARE INDICATORS OF JAPANESE P/C INSURERS



order to effectively hedge catastrophe risks of fire insurance portfolios.

### 4.2 Large and Diversified Portfolios

Group 1 consists of portfolios held by the six largest insurers with respect to the volume of direct premiums for fire insurance; namely, Tokio Marine, Sompo Japan, Mitsui Sumitomo, Nipponkoa, Aioi and Nichido.[24] All of these insurers were established prior to World War II, and had been operating nationwide, having underwritten both personal and commercial line risks. The government policy of industry regulation that limited excessive competition among insurers, and which continued until 1996, allowed them to hold a large volume of premium written, cover a wide operating area, and have a well-diversified product mix and customer basis.

These insurers justifiably have market share and market representation indicators standing at higher levels, and thus, have lower basis risk. For such insurers, CAT bonds based on the industry index (i.e. amount of loss incurred by the industry as a whole) may be appropriate in effectively financing catastrophe losses. However, a dominantly high market share brings about another risk factor; moral hazard. Moral hazard refers to the tendency for those covered by insurance to change their behavior in a way that leads to larger claims against the insurer.[25] For example, the primary insurer may ease its underwriting procedures, and make generous payments without a thorough claim investigation. If an insurer has an extremely large market share, it may easily exert influence on the industry index. Aware of the possibility of moral hazard, investors may not purchase index- and indemnity-based CAT bonds for such insurers. Therefore, parameter-based or model-based tools may be appropriate for such market giants.[26]

### 4.3 Small but Diversified Portfolios

Portfolios belonging to the second group are relatively small in size but well diversified. Fuji, Nissay Dowa, Kyoei and Nisshin all hold such portfolios, and most of these insurers had existed for a long time before deregulation. For example, Asahi, in the bottom right-hand corner, was established in 1951, and developed its operations under the extensive regulation. Protected by such regulation, this type of insurer can be assumed to hold a diversified insurance portfolio despite its small size.

The correlation coefficient between losses sustained by the individual insurers in Group 2 and the industry index is high, while the impact of their losses on the index is small. Therefore, index-based CAT bonds are perfectly appropriate for these insurers, minimizing both basis risk and moral hazard.

[24] In 2002, Tokio Marine and Nichido formed a joint holding company, Millea Holdings, and are scheduled to merge in October 2004.

[25] Milgrom and Roberts (1992), p.167. This definition can be applied to the case where a primary insurance is protected by reinsurance or other financing tools.

[26] These insurers can also use reinsurance in which the moral hazard can be reduced by experience rating. However, the cost of reinsurance can be relatively higher due to the high credit risk involved in the transaction.

TABLE 1. APPROPRIATE CATASTROPHE FINANCING TOOLS BY TYPE OF PORTFOLIO

| Group | Mkt. Rep. Indicator | Mkt. Share Indicator | Characteristics of Portfolio | Appropriate Financing Tools |
|---|---|---|---|---|
| 1 | High | High | Diversified, Large | Index-based CAT Bonds, Parameter-based CAT Bonds, Model-based CAT Bonds |
| 2 | High | Low | Diversified, Small | Index-based CAT Bonds |
| 3 | Low | Low | Undiversified, Small | Reinsurance, Indemnity-based CAT Bonds, Parametric-based CAT Bonds |

### 4.4 Small and Undiversified Portfolios

Group 3 comprises portfolios of smaller-sized insurers including new entrants and niche players. Life-affiliated insurers such as Sumi-Sei, Meiji and Yasuda belong to this group. These insurers came into the market in 1996 when deregulation made it possible for life insurers to underwrite P/C insurance through affiliated insurers. Daido Fire, on the other hand, is a niche player, established in 1971, that operates intensively in Okinawa Prefecture, one of Japan's major typhoon-prone areas, while JI and ACE place greater emphasis on personal accident insurance rather than fire insurance.[27]

Market share indicators for these insurers are very low and market representation indicators vary among individual insurers but are relatively low compared with the other groups. Basis risk may be too high in cases where they utilize index-based CAT bonds to finance catastrophe losses because of the low market representation indicator. Instead, traditional reinsurance such as excess of loss coverage may be appropriate for these insurers. They can also use indemnity-based CAT bonds. However, considering their size, it is more cost effective for them to be provided with loss control and underwriting services by reinsurers than to do these affairs by themselves.

An insurer operating in a limited geographical area may utilize parameter-based instruments. For example, Daido Fire can design its CAT bond contract by setting a certain precipitation or flood level on a certain geographical point as a parameter to invoke payment in order to hedge the significant risk of typhoons.

## V. *Conclusions*

From the analysis of basis risk among Japanese P/C insurers, we found that financing tools for effective hedging of catastrophe risk depend on individual portfolios. Other things being equal, an optimal choice of catastrophe financing by type of portfolio is summarized in Table 1.

[27] The positions of SECOM and Allianz are ambiguous. SECOM has a relatively long operating history, established as Toyo Fire in 1950, but its size is assumed to be insufficiently large to hold a well-diversified portfolio as others in Group 2. Allianz, an affiliate of the Allianz Group, started operating in 1990, and its longer experience may allow the insurer to have a more diversified portfolio than other smaller insurers. These two insurers can be regarded as intermediates between Group 2 and 3.

For portfolios with higher market representation and market share indicators, that are relatively large in size and highly diversified, insurers can choose index-based CAT bonds to effectively transfer possible catastrophe losses without being exposed to serious basis risk. In cases where the portfolio is dominantly large, however, only parameter- or model-based tools may be available due to the investors' awareness of the potential moral hazard.

Index-based CAT bonds are well suited to portfolios with high market representation indicators but small market share, thus minimizing basis risk and moral hazard simultaneously.

For smaller and undiversified portfolios, traditional reinsurance including arrangements for excess of loss is appropriate. Indemnity-based CAT bonds can be also utilized, if the insurer is of a size that is large enough to execute prudent underwriting and to provide control services to customers without the reinsurer's support. Also, an insurer operating in a limited area can hedge its catastrophe risk by designing a parameter that correlates to its losses as the trigger of a CAT bond.

The analysis of insurers' portfolios and the optimal financing tools for them discussed above implies that primary insurers can make better decisions to effectively finance catastrophe losses by understanding the characteristics of their insurance portfolios, especially the levels of market representation and market share. The Model used in the analysis enables insurers to quantitatively estimate these indicators.

In this paper, we have focused on financing catastrophe losses. It is obviously a crucial issue for insurers to manage catastrophe risk. At the same time, however, insurers are now starting to formulate comprehensive risk management strategies, considering not only underwriting risk but also a wider range of financial needs including growth opportunity and leverage in order to maximize their corporate value. To respond to the increasing need for comprehensive risk management and financing strategies, further, continued studies are needed to ascertain how an insurer should integrate catastrophe loss financing with other parts of its comprehensive risk management strategy for the purpose of maximizing its corporate value.

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## Appendix 1

### Direct Net Claims Paid for Fire

| Insurer \ FY | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|
| Tokio Marine | 60,155,188 | 55,027,784 | 53,920,569 | 55,628,709 | 55,615,262 |
| Sompo Japan | 60,331,881 | 51,983,975 | 43,571,109 | 57,722,305 | 48,162,922 |
| Mitsui Sumitomo | 69,559,161 | 60,684,579 | 48,542,859 | 54,886,547 | 63,227,517 |
| Nipponkoa | 47,649,742 | 44,282,184 | 35,282,419 | 41,719,751 | 35,860,224 |
| Nissay Dowa | 16,233,476 | 17,169,890 | 10,009,309 | 13,742,770 | 12,084,558 |
| Aioi | 34,166,947 | 33,813,831 | 26,965,728 | 29,013,363 | 30,547,278 |
| Nisshin | 11,526,533 | 11,302,076 | 7,983,441 | 9,408,202 | 7,764,877 |
| Nichido | 33,563,687 | 31,995,678 | 27,303,405 | 27,434,440 | 25,389,664 |
| Fuji | 24,696,037 | 25,234,780 | 15,488,318 | 18,341,145 | 17,736,627 |
| Kyoei | 17,235,307 | 12,163,609 | 10,831,995 | 10,709,313 | 11,011,166 |
| SECOM | 2,284,224 | 2,438,435 | 1,859,161 | 1,995,256 | 2,126,337 |
| Asahi | 3,092,577 | 2,530,276 | 1,981,655 | 2,168,843 | 2,269,476 |
| Daido Fire | 610,501 | 430,408 | 340,220 | 650,153 | 830,585 |
| Saison | 240,215 | 245,333 | 251,699 | 249,548 | 401,282 |
| JI | 102,966 | 53,688 | 74,783 | 65,919 | 69,625 |
| Allianz | 1,646 | 3,690 | 26,913 | 17,910 | 9,686 |
| ACE | | | | 1,158,924 | 1,517,650 |
| Sumi-Sei | | | | 3,325 | 122,536 |
| Meiji | | | | 3,460 | 164,736 |
| Yasuda | | | | 7,620 | 57,881 |
| Total | 381,450,088 | 349,360,216 | 284,433,583 | 324,948,579 | 315,034,241 |

Source: *Insurance*: *Annual Special Issue*, *The Statistics of Japanese Non-life Insurance Business*, 1993-2002,

INSURANCE BY 20 P/C INSURERS

| 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|
| 70,424,048 | 86,992,624 | 60,148,410 | 58,604,984 | 54,869,994 |
| 69,527,252 | 88,744,992 | 57,730,963 | 55,598,953 | 49,053,083 |
| 73,273,157 | 85,281,127 | 57,377,560 | 51,698,120 | 48,719,176 |
| 55,310,650 | 58,739,349 | 46,531,296 | 39,430,194 | 35,724,129 |
| 20,970,248 | 21,734,101 | 16,685,028 | 13,618,894 | 15,200,071 |
| 39,185,674 | 46,299,401 | 35,484,697 | 28,077,455 | 27,191,410 |
| 13,283,036 | 15,752,518 | 9,539,645 | 8,911,675 | 6,662,800 |
| 34,554,927 | 58,543,256 | 33,069,544 | 26,519,528 | 22,068,071 |
| 26,577,814 | 26,049,252 | 19,837,374 | 16,815,704 | 12,999,015 |
| 15,420,037 | 20,604,487 | 11,253,486 | 11,732,154 | 8,768,908 |
| 3,098,458 | 4,168,738 | 2,451,512 | 2,249,545 | 3,598,282 |
| 3,727,512 | 4,661,336 | 2,860,325 | 2,825,408 | 2,558,119 |
| 470,157 | 1,306,095 | 841,981 | 803,927 | 1,670,643 |
| 304,295 | 292,064 | 268,347 | 362,702 | 276,274 |
| 76,733 | 111,087 | 90,599 | 111,027 | 68,545 |
| 37,706 | 167,457 | 112,956 | 86,159 | 55,644 |
| 175,308 | 3,012,766 | 2,182,377 | 1,595,781 | 1,582,738 |
| 392,754 | 823,514 | 733,524 | 692,236 | 951,091 |
| 321,613 | 571,267 | 479,542 | 442,297 | 536,412 |
| 161,309 | 425,942 | 382,469 | 363,540 | 261,666 |
| 427,465,228 | 524,669,330 | 358,457,748 | 321,031,805 | 293,259,080 |

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## Appendix 2
## Market Share and Risk Factors for Fire

| Insurer | DNP in 2002 | Mkt. Share | $\sigma_i$ | $\sigma_j$ | $\sigma_m$ |
|---|---|---|---|---|---|
| Tokio Marine | 195,140,150 | 17.6% | 10,288,184 | 62,559,669 | |
| Sompo Japan | 197,038,250 | 17.8% | 12,953,317 | 59,871,950 | |
| Mitsui Sumitomo | 190,610,834 | 17.2% | 11,834,452 | 61,347,815 | |
| Nipponkoa | 129,664,025 | 11.7% | 8,177,093 | 64,587,309 | |
| Nissay Dowa | 57,479,229 | 5.2% | 3,673,453 | 69,136,560 | |
| Aioi | 92,817,758 | 8.4% | 6,142,489 | 66,385,445 | |
| Nisshin | 25,440,247 | 2.3% | 2,776,600 | 69,716,915 | |
| Nichido | 85,840,878 | 7.7% | 10,164,859 | 62,838,417 | 72,370,458 |
| Fuji | 53,512,272 | 4.8% | 4,891,044 | 68,461,603 | |
| Kyoei | 35,648,522 | 3.2% | 3,632,840 | 69,033,556 | |
| SECOM | 11,741,971 | 1.1% | 753,383 | 71,861,095 | |
| Asahi | 11,547,247 | 1.0% | 806,216 | 71,599,459 | |
| Daido Fire | 1,992,868 | 0.2% | 412,555 | 72,308,446 | |
| Saison | 1,183,829 | 0.1% | 53,857 | 72,373,394 | |
| JI | 182,524 | 0.0% | 20,204 | 72,360,335 | |
| Allianz | 1,012,662 | 0.1% | 54,652 | 72,338,557 | |
| ACE | 8,640,059 | 0.8% | 872,388 | 81,953,699 | |
| Sumi-Sei | 4,701,511 | 0.4% | 363,650 | 82,183,173 | 82,265,594 |
| Meiji | 2,316,471 | 0.2% | 209,579 | 82,188,198 | |
| Yasuda | 1,484,148 | 0.1% | 165,282 | 82,194,233 | |

Source: Calculated based on statistical data complied in *Insurance*: *Annual Special Issue*, *The Statistics of Japanese*

INSURANCE BY 20 P/C INSURERS

| $r_{ij}$ | Mkt. Rep. Indicator | Mkt. Share Indicator | Basis Risk |
|---|---|---|---|
| 0.9461 | 0.8179 | 0.1422 | 0.0400 |
| 0.9574 | 0.7921 | 0.1790 | 0.0289 |
| 0.9186 | 0.7787 | 0.1635 | 0.0578 |
| 0.9459 | 0.8441 | 0.1130 | 0.0429 |
| 0.8744 | 0.8353 | 0.0508 | 0.1139 |
| 0.9720 | 0.8916 | 0.0849 | 0.0235 |
| 0.9540 | 0.9190 | 0.0384 | 0.0426 |
| 0.9280 | 0.8058 | 0.1405 | 0.0538 |
| 0.7863 | 0.7438 | 0.0676 | 0.1886 |
| 0.9144 | 0.8723 | 0.0502 | 0.0775 |
| 0.6733 | 0.6686 | 0.0104 | 0.3210 |
| 0.9559 | 0.9457 | 0.0111 | 0.0432 |
| 0.1476 | 0.1475 | 0.0057 | 0.8468 |
| -0.0543 | -0.0543 | 0.0007 | 1.0536 |
| 0.5024 | 0.5023 | 0.0003 | 0.4974 |
| 0.5840 | 0.5837 | 0.0008 | 0.4155 |
| 0.3529 | 0.3515 | 0.0106 | 0.6379 |
| 0.2246 | 0.2243 | 0.0044 | 0.7713 |
| 0.3682 | 0.3678 | 0.0025 | 0.6296 |
| 0.4309 | 0.4306 | 0.0020 | 0.5674 |

*Non-life Insurance Business*, 1993-2002, Insurance Research Institute.