Product Design and Technical Analysis of An Index-based Insurance for Earthquake Risk

By Matthew James
Last revised 26 September 2017

ABSTRACT

In recent years, there is a growing demand in building financial resilience against Natural Catastrophe (Nat CAT) risk with index-based insurance. With its many cost and practical advantages, index-based insurance shows great potential in providing effective risk protection to hundreds of millions across developing communities. In the second of a series of three white papers, we examine the key technical design considerations of a hypothetical index insurance product for earthquake risk in China. These design considerations are key to developing robust, science-based, and regulatory-compliant index insurance products. As part of the deeper technical analysis, we conduct vigorous benchmarking tests using market leading commercial risk models to examine the performance of the index-based earthquake product. Key findings from this study reveal that the working range of risk metrics for the index-based products are comparable with conventional indemnity products, hence demonstrating the viability of scientifically-driven index-based Nat CAT insurance in Asia.

Key words - Index-based insurance, Technical Analysis, Risk Metrics, Earthquake Risks

1. INTRODUCTION

As established in the previous paper, traditional indemnity insurance approaches are largely inadequate in delivering insurance for the masses in Asia. This is mainly due to operational complexities and prohibitive administration costs of indemnity insurance. As a result, large populations in developing Asia are left unprotected against natural catastrophes and related risks that threaten their assets and livelihoods.

1.1. Index-Based Insurance

In recent years, index-based insurance has been progressively introduced to increase insurance protection in Asia. Unlike traditional insurance which indemnifies actual losses, index-based insurance disburses payouts based on a catastrophe event hitting a certain pre-defined index (e.g. hurricane wind speed, rainfall volume, and earthquake magnitude). This approach negates the need for lengthy and laborious loss assessment, and helps affected communities obtain funds quickly for reconstruction and recovery efforts.

Some of the prominent index-based insurance programmes in Asia include Maipark’s Earthquake Index Insurance (supported by World Bank) in Indonesia, and Swiss Re’s index-based policy for typhoons in Hong Kong. Though index-based insurance largely simplifies the payout process as compared to traditional indemnity insurance, it also comes with its own share of challenges. One key technical consideration to manage is the ‘Basis Risk’ of the product.

1.2. Basis Risk

While the estimated losses in index-based insurance should ideally be equal to actual losses, there will be eventual variances between the estimated payout and actual losses suffered by a policyholder. This variance is known as ‘Basis Risk’. Basis risk occurs when a policyholder experiences an actual loss but does not receive an adequate payout; or when a policyholder receives a payout larger than his/her actual losses.

By adopting an actuarially-driven product design framework, basis risk can be systematically managed at admissible levels. The framework outlines the practical considerations for designing an index-based insurance such as selection of hazard index, classification of assets as well as construction of payout structures. Further technical and benchmarking analysis can demonstrate that the underlying basis risk concerns has indeed been adequately managed. In this paper, we provide an overview of the key design considerations of a hypothetical index-based insurance product for earthquake risk in China. Following which, the proposed solution is
benchmarked and tested using a commercial market leading risk model to evaluate the expected performance of the insurance product.

In this paper, we will provide an overview of the key design considerations of a hypothetical index-based insurance product for earthquake risk in China. Following which, the proposed solution is benchmarked and tested using risk models of commercial risk modelling companies to evaluate the expected performance of the insurance product.

1.3. Catastrophe Risk Modeling

Catastrophe risk modeling is the process of using computer-assisted calculations to calculate the losses due to a plausible catastrophic event such as a hurricane or earthquake. It allows insurers, reinsurers, financial institutions, and government agencies to evaluate and manage catastrophe risk. A risk model typically includes the following components:

- **Event Module**
  The Event module is a catalogue of simulated events that capture the frequency, severity, location, and other characteristics of plausible catastrophes.

- **Hazard Module**
  The Hazard module calculates the intensity of the hazard at each affected site for each of the simulated event within the Event Module.

- **Vulnerability Module**
  The Vulnerability Module assesses the degree to which structures, their contents, and other insured properties are likely to be damaged by the hazard.

- **Financial Module**
  The Financial Module calculates the expected financial damages for the affected site as a result of physical damage.

Some of the prominent risk modeling companies include AIR Worldwide (AIR), Risk Management Solutions (RMS), and CoreLogic. Risk Management Solutions’ (RMS) probabilistic seismic risk model of China is developed jointly with the Institute of Engineering Mechanics (IEM) in Harbin. It is one of the most advanced risk models for seismic risk in China. Hence, we have decided to utilise RMS’ risk model in a benchmarking exercise to analyse the performance of the index-based insurance.

2. PRODUCT DESIGN FRAMEWORK

This section serves to discuss the basic steps in designing a viable index-based insurance product, which is outlined in the following diagram.

- **i. Definition of Insurance Scope**
  The scope of an insurance policy refers to the key operation parameters set forth by insurance companies. This includes the peril coverage, occupancy type, insured limits, expected insurance portfolio and more. These parameters are dependent on regulatory requirements, business strategies, market conditions, political situation, and other factors.

- **ii. Selection of Hazard Index**
  The next step is selection of a suitable hazard index as a payout trigger. The key consideration here is to select an index that is appropriately related to the underlying hazard. For instance, in the case of hurricanes, wind speed could be selected as a viable index. Furthermore, it is important to select an index that is independently reported, transparent and verifiable to avoid payout delays and claims disputes. Historical data of the index should also be sufficient and accessible to support the product design process.

- **iii. Classification of Buildings**
  In the case of earthquake risk, buildings of different structural characteristics will respond differently to the same level of seismic hazard. The level of damages to a building is inherently based on its structural characteristics. In this framework, buildings are segregated into various classes based on their structural characteristics (such as construction material, height, age of the buildings, building code and others).

By doing so, insurance rating and payout functions can be developed with reference to the vulnerability functions for each of these building classes. This process helps improve the correlation between the expected losses (based on the index) and actual losses on the ground, thus mitigating part of the associated basis risk.
iv. Constructing of Payout Structure

A key feature of an index-based insurance product is the mechanism by which the payout will be triggered by hazard index. This is known as ‘payout structure’. In essence, the payout structure should appropriately reflect the level of losses experienced by the insured corresponding to the severity of the event.

In this framework, the payout structure is designed using vulnerability functions. A vulnerability function relates the severity of hazards to level of damages for each of the classes of buildings. For example, the following diagram shows a vulnerability function (in red) of a reinforced concrete building. The payout structure (in blue) of the insurance policy is designed with reference to the vulnerability function. It is instructive to look at the differences between and indemnity based product and an index passed product using the chart in Figure 2.

Fig. 2: Hypothetical Payout Structure of an Index-based Insurance and Vulnerability Curve of a Reinforced Concrete Building. (For example, if an earthquake of intensity 7 occurs, a reinforced concrete building will experience 50% damage. Hence, a payout equivalent to 40% of the sum insured will be made.)

For the indemnity based product, the vulnerability function will be used to develop the risk metrics and to price the policy. When an earthquake occurs it affects different sites differently depending on the earthquake site intensity. The insurers believes, or better hopes that actual losses will not be very different from the losses indicated by the vulnerability curve used in the design of the insurance product. Policy payout is determined through the following sequence: policy holder files a claim, the insurer authorises an agent (claim adjuster) to verify and adjust the claim (given the policy conditions and exclusions), possible some negotiations, and in extreme cases litigation.

Index based product bypasses this lengthy and expensive process, by providing payout based on reported site intensity by the reporting agency. In this case, the insurer uses the model to develop the risk metrics, design the product, and furnish the payouts based on the modelled vulnerability (no post event site inspections). Therefore the uniformity requirement (in our case residential occupancy with occupancy specific dominant construction classes) is important. It has been observed at many hazard events that there is wide variation in the losses at lower intensities as compared to those at higher intensities. In order to minimise the resultant basis risk, such “white noise” of losses should be properly eliminated. This leads to step wise payout structure as shown in the Figure 2, which can be developed for any county or group of counties.

v. Analysis of Risk Metrics

By overlaying the hazard module and exposure module on top of the policy payout structure, we can generate an Event Loss Table (ELT), which comprises of estimations of the losses (and its frequency) for each of the event. The ELT can be tabulated to present Exceedance Probability Curve (EP Curve), Average Annual Loss (AAL), Sigma, and other risk metrics pertaining to the insurance product.

vi. Pricing of Insurance Product

The finalised risk metrics of the insurance product indicates the pure premium and suggested premium loadings for the product. Pure premium reflects the fundamental costs of the underlying risk. An insurance company can ‘load’ the pure premium upwards to include the catastrophe loading, data uncertainty loading, business expenses (such as product development, marketing, and salaries), as well as a target profit margin.

3. HYPOTHETICAL INDEX-BASED EARTHQUAKE INSURANCE FOR CHINA

Based on the product design framework outlined in Section 3, the following hypothetical index-based earthquake insurance in China was designed.

3.1. Policy Scope

For this hypothetical product, the scope is defined as follows:

i. Peril: Earthquake,
ii. Policy Coverage: All provinces in China,
iii. Occupancy Type: Residential buildings only, and
iv. Insurance Unit: County level (Premium ratings developed for 2,800 counties nationwide)

3.2. Trigger Index

Modified Mercalli Intensity (MMI) was selected as the trigger index. Unlike Richter scale magnitude that measures the absolute energy released at the epicentre, MMI reflects the intensity of ground-shaking at a specific location. Since the impact from an earthquake dissipates as the distance from the epicentre increases, MMI is a highly suitable choice for index trigger as it reflects geographical variation of event intensities within the disaster zone. MMI is determined by the authorised agency based on post event damage surveys and assessment of the performance of the structures.
(structural and non-structural damages). For China, a primary source of MMI data is the China Earthquake Administration (CEA). With thousands of seismic stations across the nation, CEA provides ground motion data and MMI intensity maps within days following major earthquakes. Secondary sources for MMI data include the United States Geological Survey (USGS), Swiss Seismology Service (SED) and others.

3.3. Classification of Buildings

Based on available inventory data and vulnerability functions for residential buildings in China, we have selected the following four dominant construction classes for this policy:

i. Unreinforced masonry (URM)
ii. Reinforced masonry (RM)
iii. Reinforced concrete (RC)
iv. Composite (C)

Buildings with unknown construction materials are allocated into the “Composite” class. Its vulnerability functions at individual counties are computed using a weighted average of the construction classes based on reported credible, well benchmarked exposure data provided by the risk modelling agency, the insurance company, government agencies, or independent research. However, it is noted that such data may be challenging to obtain in Asia. The NatCatDAX initiative spearheaded and executed by Institution of Catastrophe Risk Management (ICRM) and Monetary Authority of Singapore (MAS), would be an enabler for index based insurance products in South East Asia.

3.4. Structure of Payout Trigger

With reference to vulnerability and inventory data, three basic types of payout structures have been engineered in accordance to the different construction classes stated in Section 3.3. The payout structure for composite class is determined based on a weighted average of the construction materials within each county.

3.5. Analysis of Risk Metrics

Next, we compile the Event Loss Table (ELT) by overlaying the stochastic catalogue (comprising of 100,000 years of seismic events) on top of the Industrial Exposure Database (IED) of China and payout structures for each construction class. The resultant risk metrics are then benchmarked using risk models from leading commercial risk modelling company RMS. Key results of the analysis can be found in Section 4.

3.6. Pricing of Insurance Policy

The resultant risk metrics (AAL, Sigma, etc.) are made available to insurance companies for consideration in their final pricing decisions. For certain geographical regions of higher CAT risk or low data availability, an underwriting may choose to place a higher loading on top of the AAL (Pure Premium) based on a multiple of the AAL or a percentage of the Sigma.

For this hypothetical product, the pure premium is loaded with a homogenous factor of 1.67 to account for all overhead expenses and profit margin, as well as for Cat loading. This loading factor reflects typical loading factor used in the industry - and of course, it is highly company and market specific.
4. BENCHMARKING ANALYSIS OF THE HYPOTHETICAL INDEX-BASED EARTHQUAKE INSURANCE FOR CHINA

All index-based insurance design must be thoroughly analysed before deployment. This can be accomplished by benchmarking the risk metrics against that of a commercial risk model. In this analysis, we have selected RMS’ risk model as the benchmark. In further text, risk metrics from RMS’ model are referred to as “Spectral Response”.

The key benchmarking analysis includes the comparison of Occurrence Exceedance Probability Curve, the comparison of Ratio of Losses, as well as the comparison of the Pure Premium between the two responses. The following sections entail the key results of the benchmarking analysis.

4.1. Occurrence Exceeding Probability Curve (OEP)

The Occurrence Exceedance Probability Curve (OEP) represents the probability of any single event occurring within a defined period (typically a year) greater than a loss size. The following diagram represents the complete OEP curves of both index-based response and spectral response. The graphs can be segmented into three layers based on the return period:

i. Low Risk (Return period of less or equal to 25 years),
ii. Working Risk (Return period of between 25 and 100 years), and
iii. Excess Risk (Return period of 100 years and above).

The manner in which these layers are segmented is dependent on the insurance company. Generally, an insurance company would retain the Low Risk and Working Risk Layers, and transfer the Excess Risk to external parties. This can be achieved through reinsurance, insurance linked securities and other financial instruments.

Hence, from the perspective of an insurance company, return periods of less than 1000 years is considered to be relevant.

Consequently, it is most appropriate to focus on the comparisons within this range within this range.

4.2. Ratio of Losses

The following figures the ratio of losses between index-based response and spectral response. It provides a quantitative comparison between the two approaches.

For Low Risk layer, predicted losses from index-based response are higher by as much as 38% and lower by as much as 25%. In the Working Risk Layer, predicted losses from index-based response are lower by 29%, and in the excess layer the differences are as much as 35%. While the variation increases at the extreme points, the ratios of losses between the two approaches are within a similar magnitude for all points in the comparison. Further calibration of
the policy design and structure can help narrow the spread of points towards a ratio of 1.0

4.3. Pure Premium

Pure premium is the annual risk cost of an insurance product excluding all overhead costs and profit loadings. The following diagram compares the pure premium and standard deviation of index-based and spectral responses.

![Pure Premium and Standard Deviation Diagram]

**Fig. 9: Pure premium and Standard Deviation of an index-based and spectral responses.**

Pure premium of an index-based response (4.72 billion RMB) is 14% lower than the spectral response (5.54 billion RMB). This shows that the pure premiums for both approaches are within reasonable limits of each other.

On the other hand, standard deviation of index-based response (11.50 billion RMB) is 40% lower than the spectral response (19.30 billion RMB). The large disparity between the two standard deviations is expected given the added complexity of RMS’ risk model. RMS’s risk models includes more sources of uncertainty (construction classes, age and height differentiation), resulting in larger standard deviation.

It is important to note that the results do not prove that any one approach is better than the other. Instead, it serves to prove that the risk metrics of an index-based insurance are in the same ballpark area as the benchmark.

5. CONCLUSION REMARKS

This study shows that a methodological, scientifically-driven approach to index-insurance product design is important in determining the appropriate trigger design, premium pricing, product sustainability and ease of implementation of the product. Each of the key technical considerations highlighted above has an impact on the risk metrics and performance of the final product, which can be investigated in greater detail with in-depth analyses and comparisons. These analyses and comparisons offer various angles for understanding the performance of index-based insurance products. These results can be used to iteratively improve the product towards market implementation. Further benchmarking analyses include basis risk quantification, historical event reconstruction, and many others.

6. NEXT STEPS

The final paper in the series will present an economic analysis of a nationwide index-based earthquake insurance for China, including economic viability and sustainability for key stakeholders involved in the programme – primary insurers, reinsurers as well as the government.

CITATIONS


ACKNOWLEDGEMENT

The work would not have been possible without the unwavering support from several organisations. We would like to thank the Monetary Authority of Singapore (MAS) for financially supporting our work under the Financial Sector Technology and Innovation (FSTI) – Proof of Concept Scheme. We would also like to extend deepest gratitude to Risk Management Solutions, Inc (RMS) for providing the data and technical support in completing the analysis work.