THE IMPACT OF DAMAGE FUNCTIONS USED TO DETERMINE THE CAT BONDS TRIGGER

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Seismic risk management is a key factor for reducing the adverse economic impact of devastating earthquakes. Hence, hard and soft measures are needed to be combined effectively to increase resistance and resilience against earthquake disasters. The hard measures include retrofitting and seismic upgrading of existing buildings and construction of safer buildings with improved designs and materials. On the other hand, soft measures can be taken through earthquake insurance and risk transfer security. The fundamental difference between the two methods is that the former reduces the severity of seismic damage physically, while the latter shares the seismic loss with a third-party based on a pre-agreed scheme (Goda, 2015).

An earthquake insurance is a contract by which the insurer pledges to pay policyholders (e.g., owners of properties and enterprises) in an event of a major destructive earthquake. Insurers also transfer the catastrophe risk to a reinsurer, in order to avoid insolvency, based on a risk-sharing agreement. It should be noted that reinsurers achieve geographical risk diversification through their national/global portfolios. However, due to the huge potential size of the catastrophic earthquakes, it is possible to break the risk-bearing capacity of the insurer and the reinsurer.

One of the financial means that reduces the risk of insolvency of insurers and transfers the insurance risk to the capital market (where investors gather financial transactions) is the catastrophe risk (CAT) bonds that provide insurers with sufficient financial reserve to pay claims arising from the destructive event. The mechanism of CAT bonds is that a single-purpose reinsurer (SPR) issues multi-year bonds to investors and collects funds. In the event of pre-agreed/specified trigger conditions, an SPR releases the principal to the insurer (sponsor) and if the trigger event does not occur until the maturity of bonds, the principal along with profit is paid back to the investors. CAT bonds are more attractive to investors due to higher returns than ordinary securities, and their independence from other financial products in the market.

The trigger mechanism, which is considered in this research, is based on the parametric loss estimation in which CAT bonds are triggered when the estimated loss of the event using the parameters that characterize earthquakes is greater than the design loss associated with an exceedance probability. These parameters are determined by a reliable third body (e.g. USGS in United States) after the earthquake.

One of the main concerns associated with CAT bonds is the basis risk, which means that the actual insurer losses are different from the estimated loss (payment received by the sponsor). The basis risk is made up of model risk and trigger risk. Model risk is due to errors in numerical catastrophe models, while the trigger risk is associated with inaccuracy of an adopted trigger mechanism in terms of physical seismic parameters. Therefore, it is necessary to use an appropriate parametric solution to minimize this basis risk. The first generation of the CAT bond trigger is known as "CAT-in-a-box". It defines a theoretical box of the main parameters of the seismic event such as magnitude and location of the hypocenter so that the produced loss is more than the design loss (Franco, 2010). The second generation of the CAT bond triggers is the station intensity–based method that estimates the loss of each event using site-specific shaking intensity information recorded by strong motion stations, such as peak ground acceleration (PGA) or spectral accelerations (Sa) (Goda, 2013).

The design of the CAT bonds triggers is carried out by probabilistic seismic risk analysis of the building portfolios and associated modeled loss. In the first step, the information of the portfolio is collected, then the major earthquake scenarios are generated by the Monte Carlo method, and the parameters such as seismic intensity measure (IM) at different stations is estimated. Then, the engineering demand parameter is calculated based on seismic demand prediction models, and finally, the damage factor and economic costs are evaluated for each scenario. Using the sum of seismic losses for individual buildings, total economic loss is calculated for all earthquake scenarios. Using polynomial formulation, total damage is estimated in terms of seismic parameters. An example of the calculation of the estimated loss for an event ($\tilde{L}_{tot.j}$) is shown in the following equation.

$$\tilde{L}_{tot.j} = \sum_{s=1}^{K}\left[\alpha_{s,1}.g_{s,j} + \alpha_{s,2}.(g_{s,j})^2 + \alpha_{s,3}.(g_{s,j})^3\right] \tag{1}$$

where $g_{s,j}$ is the intensity measured of the earthquake generated by the event *j* in the station *s* and $\alpha_{s,1}$, $\alpha_{s,2}$ and $\alpha_{s,3}$ are the polynomial coefficients. The coefficients of this formulation are obtained by fitting the polynomial so that basis risk is minimized. To investigate the effectiveness of the trigger, the basis risk should be calculated as indicated below (Pucciano et al., 2017).

$$BR = \frac{\sum_{\forall j \in H}\left|\tilde{L}_{tot.j} - L_{tot.j}\right|}{\sum_{\forall j \in H} L_{tot.j}} \tag{2}$$

Where $L_{tot.j}$ is equal to the total loss of event *j* and $\tilde{L}_{tot.j}$ is the estimated loss for event *j*, which is a function of the earthquake parameters, calculated by Equation 1. *H* represents all simulated events.

For the evaluation of structural seismic vulnerability in seismic risk analysis, predefined damage functions are used. These functions are very effective in calculating the coefficients related to the loss estimation equation, so that if the used damage functions do not match the reality, the value of the basis risk increases. In the first stage of the current study, the coefficients of the loss estimation equation are calculated based on the initial damage functions. Afterwards, based on the secondary (real) damage functions, the total loss of each event is calculated, and finally, the sensitivity of the basis risk is determined to incorrect damage functions.

REFERENCES

Franco, G. (2010). Minimization of trigger error in cat-in-a-box parametric earthquake catastrophe bonds with an application to Costa Rica. *Earthquake Spectra, 26*(4), 983-998, doi:10.1193/1.3479932.

Goda, K. (2013). Basis risk of earthquake catastrophe bond trigger using scenario-based versus station intensity–based approaches: a case study for Southwestern British Columbia. *Earthquake Spectra, 29*(3), 757-775.

Goda, K. (2015). Seismic risk management of insurance portfolio using catastrophe bonds. *Computer-Aided Civil and Infrastructure Engineering, 30*(7), 570-582, doi:10.1111/mice.12093.

Pucciano, S., Franco, G., and Bazzurro, P. (2017). Loss predictive power of strong motion networks for usage in parametric risk transfer: istanbul as a case study. *Earthquake Spectra, 33*(4), 1513-1531.