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EARTHQUAKE CAT MODELS: AN END-USER PERSPECTIVE

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Abstract: *Modern earthquake CAT (CAT) models are sophisticated numerical tools used in the assessment of risk from ground shaking and other co-seismic hazards. Despite decades of refinement, the models have limitations, contain areas of great uncertainty and can misrepresent complex loss drivers (e.g. liquefaction or cumulative losses from consecutive events during the Canterbury earthquake sequence in New Zealand). Different assumptions made by model developers in the hazard module methodology and arguably a lack of detailed damage (vulnerability) data often result in large variations in loss estimates between independent models for the same region. These and other CAT model deficiencies can instil a lack of confidence, leading the user to seek alternative opinion and modify the loss curve accordingly. This study provides an overview of some of the challenges encountered in evaluating and adjusting earthquake CAT models when forming a view of risk as a re/insurance end-user. Given the aforementioned limitations, and recognising the models are primarily meant to be a guide in the business decision making process rather than a prediction of claims, some comments on alternative forms of risk transfer and decision-support tools are provided as a topic for future debate.*

Introduction

During a breakout session on earthquake CAT models at the 6th Annual CAT Risk Management & Modelling Europe 2019 conference, several questions were posed to an audience of ~30 attendees comprising representatives from re/insurance companies, re/insurance brokers and CAT model developers and analysts. When asked which component of earthquake CAT models participants were most likely to adjust when tailoring an internal view of risk, event rates (hazard) and vulnerability were the two most commonly chosen categories.

Earthquake CAT models have become increasingly sophisticated and succeeded in significantly reducing epistemic uncertainties in the hazard and vulnerability modules since their inception in the late 1980's (Grossi et al. 2005). However, challenges remain in projecting robust long-term views of hazard and in accurately quantifying the vulnerability of structures to ground shaking. This paper outlines a few of the key issues inherent in the hazard and vulnerability modules of an earthquake CAT model and highlights some of the recent efforts by the AXA XL Science & Natural Perils group to overcome these limitations.

Hazard

The hazard component of most earthquake CAT models follows the procedures of probabilistic seismic hazard assessment (PSHA). Developed by Cornell (1968), PSHA is used to simulate what the long-term seismicity might look like for a particular region (typically expressed as the probability of exceeding a ground shaking value within a specified time period). However, the degree of subjectivity involved in the process makes it important to rigorously and objectively test these assumptions, and understand the sources of and relative contributions to model uncertainty. The following subsections identifies two sub-components which can significantly influence (i.e. reduce or increase) hazard and, ultimately, loss estimates in earthquake CAT models.

Historical Data

A robust seismic hazard assessment depends critically on the quality, consistency and homogeneity of the catalogue used as input for the analysis. According to Husen and Hardebeck (2011), even the 'best' earthquake catalogues are heterogeneous and inconsistent in space and time because of the limitations in instrumentation used to collect data and the many man-made errors in reporting. As a result, key aspects of seismic hazard analysis often

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depend on poorly constrained input parameters, whose values are chosen or modified based on the modellers' preconceptions.

Ground Motion Prediction Equations (GMPEs)

It is common for CAT modellers to select several GMPEs and assign weights to each equation based on expert opinion. This presents a significant source of uncertainty as the intensity output represents the weighted mean of all GMPE outputs. Logic trees are frequently used in modern seismic hazard analyses to capture this uncertainty, but there is currently no robust framework available to model end-users to assist with reviewing and ranking GMPE selection, especially since model vendors often do not disclose the specific weightings assigned to each GMPE for different regions.

Vulnerability

The vulnerability module is often labelled the 'black box' of CAT models because the underlying data and methods used to develop vulnerability curves are sometimes withheld from model end-users. Consequently, validating the vulnerability module in earthquake CAT models can be frustrating as tests are time consuming yet also inexhaustive since analysts can never be sure the full parameter space has been tested. Similarly, it is often unclear to the end-user whether empirical or statistical (or a combination of both) data are used to construct the vulnerability curves, making it near impossible to quantify uncertainty. While modelling companies are beginning to reveal more information on the vulnerability module, a general lack of internal data and validation methods make it difficult for most insurance companies to validate the vulnerability curves, especially since individual organisations do not commonly capture damage and loss data detailed enough for robust analyses. Furthermore, claims data are rarely shared within the insurance industry as companies are typically reluctant to part with the data as they are considered valuable to internal calibration and validation exercises and contain confidential client information. This makes it even more challenging to both vendor companies and re/insurance entities to resolve the problems faced in reviewing and validating the vulnerability module.

Despite the inability to delve deeply into the underlying methods of the vulnerability module, significant disparities in the curves assigned to different building stocks are evident when extracting the little information available. Figure 1 shows the vulnerability curves selected for two different building types in California by two independent modellers. In both the wood and unreinforced masonry examples, each modeler has applied a different curve demonstrating a lack of model developer consensus which, without a strong validation framework, instills low confidence in the end-user that either model offers a robust view of building vulnerability.

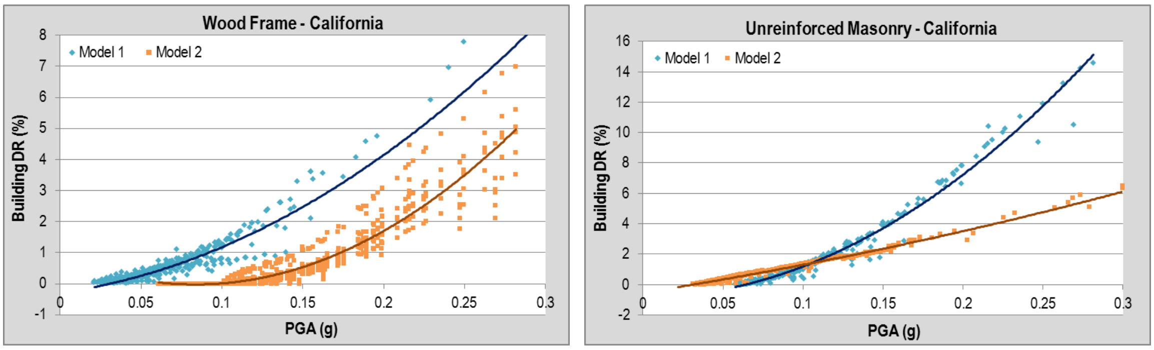

Figure 1. *Anonymised examples of the different vulnerability curves assigned by independent models for two common building types in California.*

Good quality claims data can help model analysts in validating the vulnerability module, but these data are typically not disaggregated to a level where robust conclusions can be made about building performance during earthquakes. Similarly, losses incurred in the past are often not equivalent to future losses and, internally, a re/insurance company may struggle to validate the vulnerability curves if there is insufficient data. Sharing claims data and working towards a transparent and unified global view of vulnerability would improve the industry's capacity to comprehensively and confidently review the vulnerability module within earthquake (and other) CAT models.

Towards Improved Risk Assessment

Recognising the sources of uncertainty within the hazard and vulnerability modules of a CAT model, the AXA XL Science and Natural Perils group have initiated a number of research projects with various external research institutions to address the aforementioned issues. For example, we are promoting the deployment of a formalised and potentially automated sensitivity analysis toolbox (SAFE) for analysing uncertainty in model output. Not only does it capture crucial information about uncertainty and model sensitivity, but from the results one can infer where best data-investment decisions should be made and which components of the model require added scrutiny during the validation exercise.

Making business decisions amidst high uncertainty is challenging. To address this problem, we are collaborating on a project that looks to develop a multi-tiered decision-making framework which reflects our risk appetite, and test current business decisions against that framework. This method manages to capture scientific information, uncertainty, attitudes of the agent, and the seriousness of the decision, and suggests an objective and traceable “best” decision. Instead of aspiring to converge on precise answers outside of a decision framework, the project aims to treat information about the solution space bounds as being vitally important to that final decision.

The use of parametric insurance products has increased in recent years in an effort to 1) provide transparency to clients and investors, 2) facilitate rapid settlement of claims without moral hazard, 3) develop alternative risk transfer tools which utilise high quality and unbiased third-party data (e.g. from the USGS) to assist the claims process, and 4) be much cheaper to develop than traditional cat models. A general desire for global risk diversification makes such products highly appealing in the insurance and reinsurance market (Franco, 2010), and AXA’s Global Parametrics team currently design a broad range of parametric products to cover risks in many forms, both in mature and emerging markets.

Due to the sheer volume of decisions that need to be made during model development, CAT modellers are not always able to be fully transparent about each individual decision and the underlying scientific rationale that goes into the hazard and vulnerability modules, so it is important to rigorously and objectively test these assumptions, and understand the sources of and relative contributions to model uncertainty. Acknowledging their limitations, earthquake CAT models should be viewed as guides to forming a view of risk rather than a claims prediction tool.

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