

# **Cat-in-a-Circle vs. Cat-in-a-Grid: Assessing the Performance of Parametric Earthquake Risk Transfer Solutions for Portland, OR**

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## **ABSTRACT**

Parametric insurance ties policy payouts to measurable physical parameters of catastrophic events, enabling fast, transparent payments without traditional claims adjustments. Corporations and governments increasingly use parametric solutions alongside traditional coverage. For earthquake risk transfer, the insurance market uses different parametric mechanisms, some of them based on event parameters like moment magnitude and hypocenter location. The first parametric earthquake policies, developed in the late 1990s, used a “Cat-in-a-Circle” approach: payouts occur if an event’s epicenter falls within a defined circle and attains or exceeds a certain magnitude threshold. This simple approach remains common; however, it performs poorly in regions with faults causing long ruptures where epicenters may lie outside the circle of coverage. This paper compares the Cat-in-a-Circle approach to a more flexible “Cat-in-a-Grid” solution for the Portland metropolitan area in the United States. Performance is measured according to the Loss Capture Ratio, the quotient of average annual recoveries from the parametric solution over the average annual recoveries of a traditional (re)insurance cover. Whereas both solutions are designed to have similar premiums, the Cat-in-a-Circle option achieves a Loss Capture Ratio of only 20% versus 88% for the Cat-in-a-Grid alternative.

*Keywords: Earthquake Risk Transfer, Parametric Solutions, Basis Risk Quantification*

## **INTRODUCTION**

Cat-in-a-Circle parametric solutions use a circle to distinguish between earthquake events that should pay (those with an epicenter within the circle) and those that should not (the ones outside the circle). This is an extremely simple mechanism that has permitted the participation of the investor collective in the insurance business with hundreds of millions of dollars since the late 1990s. The Parametric Re and Concentric Re transactions of 1997 and 1999, for example, implemented these geometries to transfer earthquake risk in the vicinity of Tokyo (see Artemis, 1999a; 1999b). However, the ability of these solutions to capture the risk along complex fault zones is very limited.

Franco (2010) started experimenting with Cat-in-a-Grid solutions, parametric earthquake insurance products that use the same four fundamental parameters of the earthquake (latitude, longitude, depth of the hypocenter, and moment magnitude) in combination with a geometry that discretizes the crust into regular volumes (hexahedra or cuboids). Based on fundamental earthquake descriptors, both Cat-in-a-Circle and Cat-in-a-Grid solutions are commonly referred to as “first generation” triggers. The first commercial transaction of a Cat-in-a-Grid typology was the Acorn Re catastrophe bond transaction in 2015, designed to protect the Kaiser-Permanente

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corporation on the western US seaboard (see Artemis, 2015). Over time, we have presented diverse numerical procedures (e.g. de Armas et al., 2016; Franco, 2013, 2014; Bayliss et al., 2020; Franco et al., 2024; Guidotti et al., 2024) to build these types of transactions while minimizing their error (or basis risk), and several examples to showcase their power to become a standardized risk trading option (e.g. Franco et al., 2018; 2019; Franco & Guidotti, 2022a; Guidotti et al., 2022).

Note that Cat-in-a-Circle or Cat-in-a-Grid transactions are not the only alternatives to transfer earthquake risk via parametric solutions. There is another group of techniques that rely on the distributed shaking hazard intensities of an earthquake to determine payouts, such as the values of Peak Ground Acceleration (PGA) or Pseudo Spectral Acceleration (PSA), Velocity (PSV) or Displacement (PSD) at the insured locations. These are commonly denoted as “second generation” indices (Wald & Franco, 2017) and, in some circumstances, they may constitute the most appropriate approach. However, they are often riddled with uncertainty, and they are operationally more complex (Franco & Guidotti, 2022b).

Whether they involve “first generation” or “second generation” approaches, earthquake parametric risk transfer solutions are subject to basis risk, which is defined as the difference between the expected parametric recovery based on the actual loss experienced by the insured, and the actual recovery triggered by the parametric protection. If the parametric payout is lower than the expected payout based on the loss incurred, then we have an instance of negative basis risk; otherwise, it is positive basis risk. Understanding the sources of basis risk and being able to quantify it are crucial steps to assess the performance of alternative parametric solutions, which otherwise would be extremely challenging to compare.

In this paper, we focus on “first generation” triggers and illustrate the limitations of Cat-in-a-Circle parametric solutions, based on fundamental earthquake descriptors. These solutions should generally be considered only in certain, specific circumstances, where the tectonic setting is such that circle structures are able to capture most loss-causing events. Cat-in-a-Grid solutions, in contrast, maintain the same operational simplicity but offer a greater ability to adapt to more complex and varied tectonic settings and reduce basis risk. The core contributions of this paper are: i) to design two different parametric solutions (i.e. Cat-in-a-Circle and Cat-in-a-Grid) for the same geographical area (i.e. the Portland, OR Combined Statistical Area), having similar frequency characteristics (i.e. similar cost for the client), and ii) to measure and compare the basis risk of both solutions using the same metric, i.e. the Loss Capture Ratio (LCR) introduced by Franco & Guidotti (2025) with respect to varying target layers of the reference Ultimate Net Loss (UNL) or traditional indemnity protection.

This paper provides an objective, data driven methodology to assess the performance of these different parametric solutions, which is aimed at guiding the decision process of insureds, often presented with multiple, alternative options with only their cost and superficial aspect as differentiating elements. At similar frequency of triggering payouts, and hence cost, alternative parametric solutions should be assessed measuring their capacity to provide protection within the target layer of interest to the client. Measuring the performance of different parametric solutions within the target layer of the insured’s interest allows us to focus on those events with a parametric response not matching those of traditional indemnity (negative basis risk), and therefore to favor the parametric solution that minimizes such discrepancy. It is important to clarify that the basis risk we are referring to and quantifying in this paper, is the model, or “epistemic”, basis risk, which is based on an available earthquake model; insureds should be aware of the “aleatory” component of basis risk, which is not captured by numerical models and inherent within the nature of any parametric transaction.

In the next section we present two parametric designs for the Portland, OR Combined Statistical Area, following both the Cat-in-a-Circle and the Cat-in-a-Grid approaches. We then quantify and compare the performance of both solutions in terms of basis risk using the Loss Capture Ratio (LCR) (see Franco & Guidotti, 2025). The concluding section draws some final considerations.

## PARAMETRIC SOLUTIONS FOR PORTLAND METROPOLITAN

We design two parametric solutions as candidates to transfer earthquake losses in the Portland, OR Combined Statistical Area (CSA), which includes the counties of Columbia, Washington, Yamhill, Polk, Benton, Linn, Marion, Clackamas, Multnomah, Skamania, Clark and Cowlitz (see Figure 1, left). Modern, commercial-grade earthquake models use Monte Carlo simulation to produce a catalog of synthetic events (see, for example, Grossi et al., 2005). For each simulated event, we extract its associated modeled loss, its rate of occurrence, and its hypocenter location, which we use to develop the discretized distribution of risk (annual rate of occurrence times loss) shown in Figure 1, center and right. The cells' dimensions are  $0.25 \times 0.25$  decimal degrees and the events are stratified across two layers of depth, a superficial layer of [0-50km) and a deeper layer of [50km-100km). As expected, locations near the urban area of Portland show the highest concentration of risk alongside offshore regions in proximity of the Cascadia subduction zone. Events in the deeper layer cause higher risk concentrations southwest and north of Portland. A first glance at the risk maps, with at least two risk hotspots located far apart, suggests an evident limitation of the Cat-in-a-Circle solution: covering the risks in the city of Portland, would mean automatically neglecting the risks offshore.

The first design, a Cat-in-a-Circle, is based on two concentric circles, centered -as suggested by intuition- in proximity of the city of Portland with a radius of 50km and 100km, respectively, covering all events with depths up to 100km (Figures 1 and 2). Events within the inner circle pay 25%, 50%, 75%, and 100% of the total placed limit for M6.0, M6.5, M7.0, and M7.5 events, respectively. The payouts for events within the outer circle are half of the payouts within the inner circle (Table 1). These payout levels and dimensions of the circles can be finetuned so that the probability of triggering a payout is commensurate with the budget of the client. Coverage for lower magnitude events is more expensive, because those events occur more often. This design displays an annual probability of attachment (probability of producing the lowest level of payout) of 0.85%.

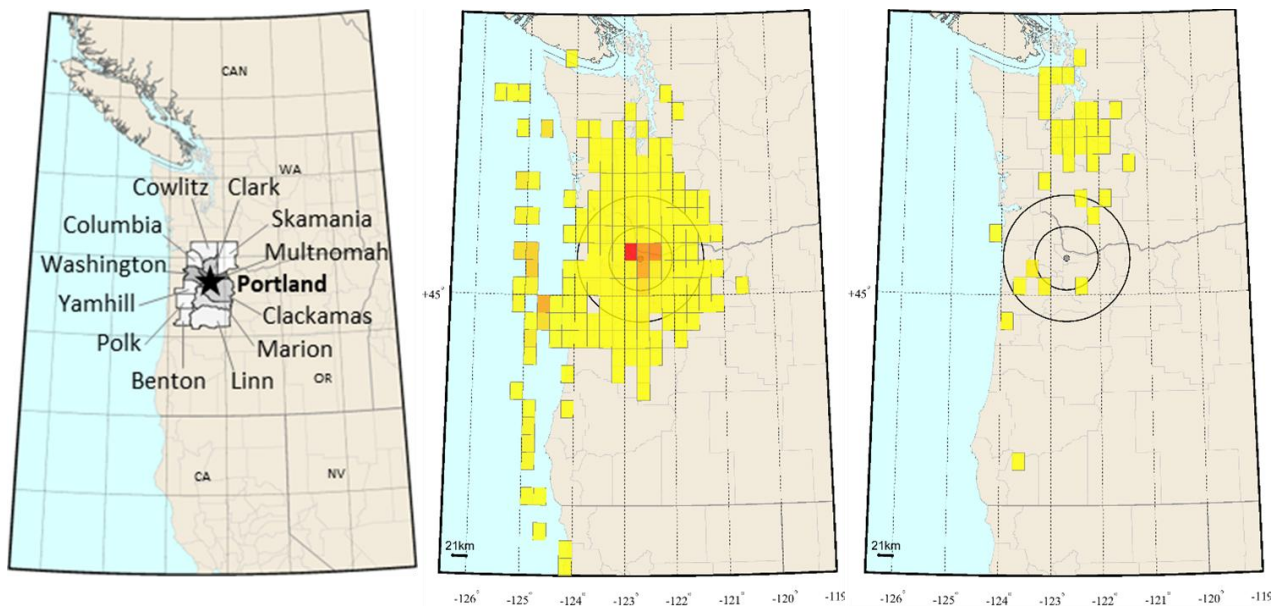


**Figure 1.** Description of the counties included in the loss analysis (left). Distribution of average annual loss discretized across cells of  $0.25 \times 0.25$  decimal degrees for depths of 0-50km (center) and 50-100km (right). For superficial earthquakes, risk to the Portland CSA is concentrated near the city of Portland as well as on offshore faults along the Cascadia Subduction Zone. For deeper events, higher risk concentrations are associated with locations north of the Portland. Note that while the circles manage to cover superficial events near Portland, they miss both the deeper and offshore events. Also, the circles cover areas that pose no serious risks to the Portland CSA according to the model, spending valuable premium budget on areas that contribute little loss.

The second design, a Cat-in-a-Grid (Figure 2), uses two depth layers of payout “cuboids” of 0.25x0.25 decimal degrees x 50km size, resulting in a total number of 1,920 cuboids, and covering events with depths of up to 100km (for more information about including depth as a parameter, a consideration that is not always present in commercial transactions, please see Franco & Guidotti, 2022a).

**Table 1.** The Cat-in-a-Circle design consists of two concentric circles, providing monetary recovery (in % of the total limit) for events with a depth lower than 100km and with their epicenter located within either the inner or outer circle, according to their magnitude, as indicated in the following table.

**Table 2.** The Cat-in-a-Grid Design consists of 1,920 cuboids, or boxes; this table lists as an example eight boxes in proximity to the City of Portland (with depths up to 50km). Each box is assigned a payout structure linearly with the magnitude of the seismic event, between an attachment threshold (paying 25% of the limit) and an exhaustion threshold (paying 100% of the limit).

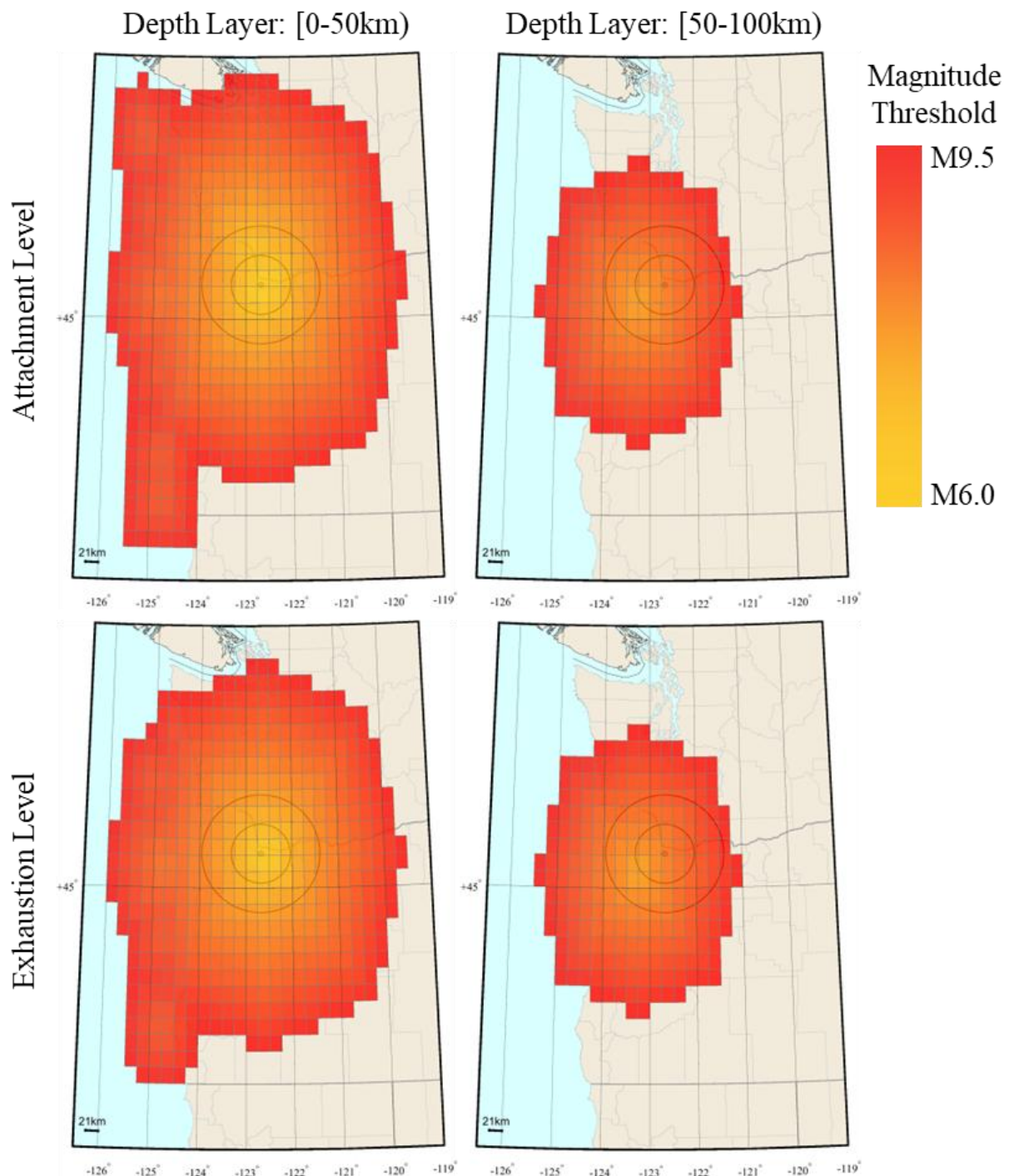


**Figure 2.** Distribution of coverage for the Cat-in-a-Grid solution for the Portland CSA. The maps at the top correspond to the minimum magnitude required to trigger a partial payout of 25% of the total limit (Attachment Level). The maps at the bottom correspond to the minimum magnitude required to trigger a full limit payout (Exhaustion Level). The map on the left corresponds to the minimum magnitude required for superficial events (0-50km in depth) to produce a payout to the structure. The map on the right shows the minimum magnitude thresholds for the deeper layer of events (50-100km). Note that the gridded definition of payout conditions adapts to the risk distribution with much more flexibility than the Cat-in-a-Circle solution. This is naturally due to the higher number of degrees of freedom in the design. While the coverage is much more extensive (compared to the outline of the circle solutions on the maps), the cost of these policies is similar. The Cat-in-a-Grid compensates for additions in coverage in areas with high contribution to the risk by dropping coverage in other areas (within the circle footprints) that do not contain much risk.

## COMPARING PERFORMANCE

In this paper we use the Loss Capture Ratio (LCR), introduced by Franco & Guidotti (2025) to provide an objective comparison between the two solutions. Given a target insurance layer (a policy limit above a deductible or a limit above an “attachment” for reinsurance), the Loss Capture Ratio quantifies the proximity in performance of a parametric solution to its indemnity equivalent, also referred to as Ultimate Net Loss (UNL). We assume here, as is common in the industry, that indemnity insurance has no basis risk and always pays as it should, although we acknowledge that indemnity insurance, in many instances, is far from a perfect mechanism. The LCR is defined by the following equation:

$$LCR = 100 \cdot (\sum_{i=1}^N R_i \cdot \alpha_i) / (\sum_{i=1}^N R_i \cdot UNL_i) \quad (1)$$

where  $\alpha_i = \min(UNL_i, PAR_i)$ ,  $N$  is the number of the events in the UNL target layer,  $R_i$  is the rate of event  $i$ ,  $UNL_i$  is the indemnity payout for event  $i$  and  $PAR_i$  is the parametric payout for event  $i$ . The LCR expresses the ratio of average annual recoveries from the Parametric Solution over the average annual recoveries of the UNL. For any given UNL layer, the LCR is highest when the parametric response is closest to that of the UNL coverage. Note that positive basis risk contributions arising from the parametric solution are not included in the calculation of the LCR. While the two solutions have been designed to have a similar cost to the insured, the Cat-in-a-Grid option mimics traditional indemnity coverage to a Loss Capture Ratio of 88% versus the 20% LCR of the Cat-in-a-Circle solution for a target limit of USD 1b and a target Attachment Return Period of 200 years (Figure 3). In Figure 3, we can track the variation of the Loss Capture Ratio as a function of the return period of the attachment level, or deductible, maintaining the same policy limit. Intuitively, increasing the return period of attachment (i.e. the deductible), would mean that the insurance layer is targeting the more destructive, less probable events.

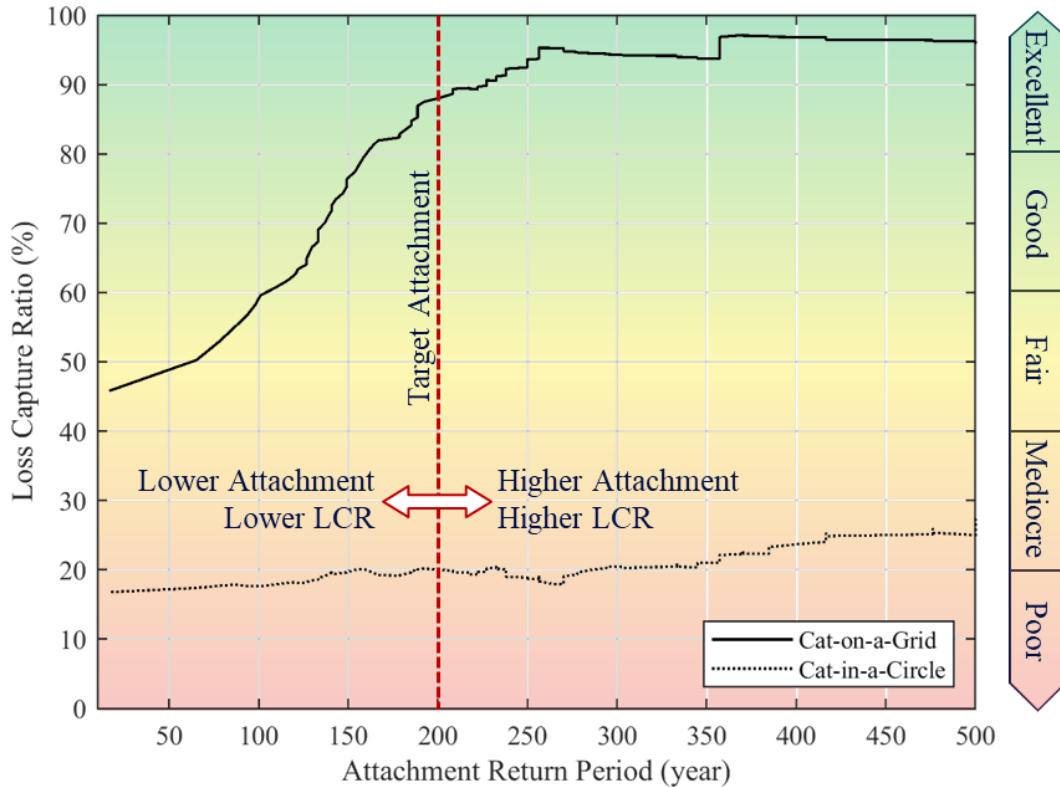


**Figure 3.** Variation of the Loss Capture Ratio for the Cat-in-a-Grid and the Cat-in-a-Circle solution, as a function of the Attachment Return Period. The LCR in the figure has been computed considering an example Limit of the transaction of USD 1b. The vertical dotted line indicates the target Attachment Period of 200 years, denoting the excellent performance of the Cat-in-a-Grid solution (LCR = 88%) and the poor/mediocre performance of the Cat-in-a-Circle solution (LCR = 20%).

We can observe that while the Cat-in-a-Grid solution maintains excellent performance for increasing return periods of the attachment level, with values of the LCR higher than 95%, the performance of the Cat-in-a-Circle solution remains with LCR values lower than 25%. Lower values of the Attachment Return Period mean that the insurance focuses on more frequent, less destructive events. This range is typically characterized by a higher basis risk because loss variability tends to be proportionally higher; however, the performance of the Cat-in-a-Grid solution remains good/fair, with values of the LCR higher than 50%, while the Cat-in-a-Circle solution exhibits a poor performance with values below 20%. It is important to clarify that in the computation of the LCR, the recoveries in the UNL layer are based on the same underlying catastrophe model used to design the parametric trigger, and therefore they represent the ideal scenario that i) the model is able to adequately represent the actual losses experienced by the client; and b) the traditional indemnity layer, through its often complex and lengthy adjudication process, ultimately provides the expected monetary recovery. In any case, the portion of basis risk quantified through the LCR belongs to its epistemic component (i.e. the basis risk component that can be reduced with improved models and parametric designs); basis risk has also an inherent aleatoric component, stemming from the parametric nature of the problem, which cannot be eliminated.

The much superior performance of the Cat-in-a-Grid approach is due to the many more degrees of freedom available to tailor the solution to the risk distribution of the client. Note that, while the sophistication of the solution is higher, the basic mechanism used to determine the payout of the policy is exactly the same as for the Cat-in-a-Circle option. It consists of a geographic comparison to determine whether the hypocenter of the earthquake is located within a specified volume and a numerical comparison of the moment magnitude of the event with the payout thresholds specified in each geographic volume. Naturally, contracts for Cat-in-a-Grid solutions typically include much longer tables than those used for Cat-in-a-Circle options (e.g. Tables 1 and 2). However, most modern contract payouts are handled by automated processes, and the length of the tables is irrelevant. The main consideration is that behind an apparent increase in complexity, the transparency and speed of payout of Cat-in-a-Grid solutions remains the same as that of simpler structures, while providing a much better basis risk performance.

## **CONCLUSIONS**

Insureds are often offered Cat-in-a-Circle solutions to tackle earthquake risks in geographic locations that are affected by extended faults that can produce long ruptures with hypocenters hundreds of km away from the location of the exposures at risk. These settings limit the utility of Cat-in-a-Circle solutions to protect clients from severe losses. Cat-in-a-Circle solutions are easy to design, which is often the reason why they are put in front of insureds as valid options. Agents and brokers can document and price them quickly. However, their performance is extremely poor when compared to more sophisticated Cat-in-a-Grid solutions that easily adapt to the geographic risk distribution of the client. Rather than focusing on what is relatively easier to understand, model, design, and ultimately sell, the parametric industry should increasingly focus on making better, superior solutions more deployable. Otherwise, the immediate advantages of implementing simpler approaches are at risk of being overshadowed by the acrimony, frustration and loss of trust that may arise if parametric policies do not offer the protection insureds expect.

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