INCREASING EARTHQUAKE INSURANCE COVERAGE IN CALIFORNIA VIA PARAMETRIC HEDGES

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ABSTRACT

California has the highest earthquake risk of any state in the United States. The Federal Emergency Management Agency (FEMA) reported in 2017 that 73% of the nation’s annual losses to earthquakes were expected to be concentrated in California and the Pacific Northwest. California alone constitutes 61% ($3.7 billion out of an estimated $6.1 billion annual losses nationwide). Despite this overwhelming accumulation of risk, recent estimates of earthquake insurance coverage rates in California range from 10% to 13%. Few small businesses have coverage. Throughout the last 20 years, a variety of financial mechanisms have been developed in the industry as viable alternatives to traditional earthquake indemnity insurance. We explore how parametric hedges, a type of financial derivative used in the reinsurance industry, can be extended to the local California market in order to provide an influx of cash quickly and transparently after an earthquake event. Examples of how these solutions can be tailored to needs ranging from the individual homeowner, to businesses, and to public entities are presented.
Increasing Earthquake Insurance Coverage in California via Parametric Hedges

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California has the highest earthquake risk of any state in the United States. The Federal Emergency Management Agency (FEMA) reported in 2017 that 73% of the nation’s annual losses to earthquakes were expected to be concentrated in California and the Pacific Northwest. California alone constitutes 61% ($3.7 billion out of an estimated $6.1 billion annual losses nationwide). Despite this overwhelming accumulation of risk, recent estimates of earthquake insurance coverage rates in California range from 10% to 13%. Few small businesses have coverage. Throughout the last 20 years, a variety of financial mechanisms have been developed in the industry as viable alternatives to traditional earthquake indemnity insurance. We explore how parametric hedges, a type of financial derivative used in the reinsurance industry, can be extended to the local California market in order to provide an influx of cash quickly and transparently after an earthquake event. Examples of how these solutions can be tailored to needs ranging from the individual homeowner, to businesses, and to public entities are presented.

Earthquake Underinsurance in California

Earthquake risk in California is the highest of any state in the country. The Federal Emergency Management Agency (FEMA) reported in 2017 that 73% of the nation’s annual losses to earthquakes were expected to be concentrated in California and the Pacific Northwest, and that California alone constitutes 61% ($3.7 billion out of an estimated $6.1 billion annual losses nationwide) [1]. The 2017 FEMA risk model employed the 2014 update of the U.S. Geological Survey (USGS) National Seismic Hazard map [2], which in turn incorporated the latest view of active faults in California from the Uniform California Earthquake Rupture Forecast (UCERF3)

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The state’s high seismic risk is attributed both to its proximity to active faults and its high exposure of population and critical infrastructure, a combination that makes California a prime incubator for innovation in earthquake insurance [4].

After the high losses following the 1994 M6.7 Northridge event in Los Angeles, private insurers covering 93% of the California market opted to stop writing and/or strictly limit new earthquake policies rather than risk insolvency [5]. In response, the state legislature established the California Earthquake Authority (CEA) in 1996, a not-for-profit, publicly managed, privately funded entity. At its inception, the authority offered only one standardized earthquake policy called a “Mini Policy,” which provided more limited coverage than what had previously been available in the market, carrying a 15% deductible and only covering primary residences [5]. After the CEA was established, residential earthquake coverage rates accelerated in 1996 to an all-time high of 33% of California residents with homeowners policies [6, 7]. More recent (2006-2016) earthquake coverage rates in California range from 10.07% to 13.07%, with even lower coverage for small businesses [4, 6, 7, 8, 9]. In 2016, the total residential CEA earthquake coverage was 10.27% of homeowners, down from 14.2% in 2000 [7].

California homeowners are not required to purchase earthquake coverage and individuals are unlikely to voluntarily purchase insurance against natural disasters without firsthand experience [10]. Many California residents incorrectly believe that they already have earthquake coverage from their standard homeowners policy [8], a notion that coexists with a low level of faith in the insurance industry to honor claims after a serious disaster [11].

California property owners interested in purchasing coverage have expressed difficulty finding affordable options despite a reduction in costs from $3.10/$1,000 of coverage in 2010 to $2.51/$1,000 in 2017 [7]. Costs vary by location, so the same coverage can cost 10 times as much for a pre-1950 house near the Hayward fault in Oakland versus a post-1990 house in Pismo Beach. Homeowners interviewed after the 2014 Napa earthquake showed high general awareness of the existence of earthquake insurance but a low level of knowledge about specifics, especially newer policy options [12]. The sharp rises in California home values in the last decade make consumers even more vulnerable to the actual replacement losses. In 2000, the median home price in Los Angeles was $192,000 but by 2015 it had risen to $484,000 [13]. The CEA products available to homeowners have been diversified since the authority was created. Homeowners can now purchase several levels of deductibles from 5% to 25%, inclusion of breakables (collectibles), loss of use, and increased building code contingencies. Renters also can cover personal property.

The CEA simplifies offerings by basing its pricing on a breakdown of the delineation of the state into 19 seismic zones with rates averaged across each zone. Because these zones are relatively large, low-risk residents in a high-risk zone effectively subsidize their high-risk neighbors. This opportunity has been seized upon by private insurers who have historically
tapped into non-CEA customers “cherry picking” these low-risk customers in high-risk zones and offering them attractive alternatives to the CEA products [14]. The success of this approach suggests that remaining uninsured California residents may be willing to purchase coverage at the right price, if educated as to what the coverage provides, if the product is easy to buy, and if the insurer is prompt to pay.

**Parametric Hedges versus Indemnity Insurance**

Affordability is, therefore, not the only drawback associated with traditional insurance products. The lengthy claim period and lack of transparency typically represent additional challenges to the policyholder. Consider the process represented in Fig. 1. The payment process for insurance indemnity products is activated at the moment the claimant issues a notice of damages to the insurer, which is followed by a loss adjustment process that may take weeks or, more typically, months. The loss adjustment practice is subjective and plagued with uncertainties. Not uncommonly, the policyholder discovers during the claiming process that exclusions and deductibles leave a significant portion of the loss without coverage. In fact, recent field research shows there is a great deal of misinformation and lack of understanding of what is being bought on the part of the consumer [12].

![Figure 1. Indemnity versus parametric insurance mechanisms.](image-url)

The 2010-2011 Canterbury earthquake sequence in New Zealand exemplified some of these drawbacks. The complexities of the local insurance market together with an unforeseen extent of secondary damages, primarily due to liquefaction, prevented expedient claims settlement. The fact that the damages were caused by a sequence of earthquakes over more than
A year placed an unmanageable burden on public insurance personnel. To assess damages, many engineers had to be brought in from other countries. These engineers often lacked local knowledge of construction practices, leading to reported disputes between engineers and policyholders. Moreover, the legislation in place at the time lacked clarity regarding liability in the case of an earthquake sequence and with respect to land and property damages. This confusion had to be settled in court thus prolonging the affair considerably. By November 2013, only 60% of the claims had been settled [15]. While a recent report from the Insurance Council of New Zealand states that private insurers have settled 90% of residential claims and $20.31 billion has been paid out in total as of September 2017, the traditional indemnity policies and complex market structure remain as they were [16].

Types and Characteristics of Parametric Hedges

As indicated in Fig. 1, a streamlined alternative to indemnity-based damage payments involves the use of parametric triggers. There are multiple ways to define a parametric hedge for earthquake risk cover. In essence, any form of derivative that associates physical measurements of an earthquake event to an expected loss can be used as a parametric hedge. Wald & Franco [17] describe the most common types of parametric earthquake insurance solutions that have been deployed in the market in recent decades. Often, these have been classified according to whether they use the fundamental parameters of an event such as hypocenter location and moment magnitude, or, site-specific shaking intensity metrics such as peak ground acceleration or spectral acceleration at a particular period of vibration. These have been sometimes referred to as first generation versus second generation solutions, respectively. Proposals to design these solutions have used optimization [18] or tabulation methods [19], both processes relying on simulations obtained from earthquake risk models. Recently, this type of analysis has been revisited using more modern statistical techniques within the realm of machine learning [20].

Succinctly, this parametric hedge system consists of defining a series of geographic regions (for example, a grid of cells of 1x1 decimal degrees in latitude and longitude as we use in this paper), where payment conditions are defined according to a particular function of the event’s moment magnitude, often a binary-valued step function that pays zero below a certain moment magnitude threshold and a predetermined amount at magnitudes equal to or larger than the threshold. Note that second generation solutions, more complex but better suited to represent local damage conditions, continue to be studied and used in the market. Several techniques to advance the design of second generation intensity indices have been presented in recent years [21, 22, 23]. Employing such advanced parametric indices relying on the USGS ShakeMap system is a potential strategy in California, where the data needed are available to compute such indices reliably. Ongoing data assimilation developments in the next generation of ShakeMap [24], present opportunities for fine-tuning loss calculations as well as avoiding large swings in shaking metrics both spatially and as a function of period.
Parametric hedges, regardless of their typology, state that a predetermined payment should be disbursed if certain physical and measurable conditions are met. The speed and transparency achieved through this type of mechanism is far superior to the one offered by the indemnity process. The clear pre-establishment of payment conditions significantly reduces the room for legal battles between insureds and insurers and the rapid influx of cash reduces post-earthquake financial pains.

The first publicly traded earthquake parametric hedge in the reinsurance context was brought to the market in 1997 and since then, these tools have been present as a complement and sometimes substitute to traditional indemnity solutions [25]. The greatest obstacle faced for the wider implementation of these tools has been their basis risk, the difference between payment outcomes and actual losses. Parametric hedges tie a pre-determined recovery to a set of physical conditions but these do not always correlate well with damage outcomes. In the realm of first generation solutions, for instance, we know that earthquake events with roughly similar epicenters may still produce vastly different damages depending on other essential parameters such as the faulting depth and geometry. While the design process of parametric hedges is typically geared towards matching payments to expected damages, uncertainties are unavoidable.

It is, however, critical to discern when these uncertainties matter and when they do not. If the desire is to protect a particular exposure asset, say a home, through a parametric hedge, it is necessary that the basis risk be small. Otherwise, the insured can face the lucky, but yet undesirable, state of over-insurance, receiving a payment for an earthquake that did not cause significant damages. Or more tragically, the insured may face a state of under-insurance, in which no payment is received for an event that caused the complete loss of the asset. Since a perfect correlation between physical, measurable parameters of an earthquake and the damages caused to a single asset is difficult to establish, the usage of parametric hedges rather than indemnity products might not be prudent in this case.

In contrast, let’s assume that the risks to be covered are not physical damages to property but rather loss of income to a small business located within the area affected by the event. As the actual losses become more intangible and more exacerbated by disruptions to neighborhoods and districts, the parametric hedge strategy becomes more appealing. For instance, an owner of a coffee shop situated at the center of an area heavily affected by an earthquake will not find it easy to operate profitably, even if the shop itself did not experience physical damages. Disruptions to its customers, or to the electrical or water supply, may force them to cease operations altogether for some time. As the policy is expected to protect broader, less tractable damages, the existence of some basis risk is less concerning. The expectation is that the policy pays a reasonable amount if a disruptive event occurs in the vicinity.

In sum, it is in these particular circumstances where parametric hedges shine the brightest: when rapid and transparent recoveries are needed to assist payment of hard-to-assess
losses. It is no coincidence that some of the most well-known parametric transactions of this kind have been designed to cover post-event emergency operations of national or supra-national administrations such as the recently triggered IBRD/FONDEN 2017 CAT bond [26], with its long history [27], or the Caribbean Catastrophe Risk Insurance Facility (CCRIF) [28].

**Design of Parametric Hedges**

As mentioned in the previous section, basis risk is a measure of error when approximating loss through a parametric mechanism and most design algorithms are geared towards its minimization. But the meaning of basis risk is progressively blurred as losses become less tangible. In those particular cases, where there is no easy way to quantify actual losses with precision, no conclusive statement can be given about basis risk either. Therefore, we briefly introduce an alternative pursuit in the design of these transactions, namely the maximization of risk transfer constrained by the desired premium payment.

The mathematical design problem consists of finding the appropriate thresholds of magnitude for a series of geographic zones (cells on a grid) such that the maximum portion of risk to a given portfolio of assets is transferred. Briefly:

Find \( \{M_k\} \) to maximize \( \sum_k \sum_i r_i \times l_i \times H(m_i - M_k) \) 

where \( V_k, k=\{1,2,\ldots,K\} \), are the epicentral regions (grid cells) defined in the parametric mechanism, \( i, i=\{1,2,\ldots,N\} \), represents a simulated earthquake event associated with the model used for the design and with epicenter within region \( V_k \), with annual rate of occurrence \( r_i \), loss \( l_i \), and magnitude \( m_i \), \( H(\cdot) \) is the Heaviside step function and \( M_k \) is the magnitude trigger condition necessary for an event located in region \( V_k \) to cause a payment. Risk is computed as the product of the event rate and loss. As more events trigger the parametric hedge, the expected frequency and the cost increase. Therefore, a pricing constraint imposes a limit on trigger frequency:

\[
\sum_k \sum_{i \in V_k} r_i \times H(m_i - M_k) < R
\]

where \( R \) is the maximum annual rate of triggering the payment desired, often expressed as a return period, which is associated with pricing. Solving this optimization problem for different values of \( R \) produces a Pareto-optimal front as the one pictured in Fig. 2. As the magnitude trigger levels \( M_k \) increase, it is less likely for an earthquake to trigger a payment and therefore, the return period increases. As the solution moves towards the right of the graph, coverage and price decrease. The “art” of the design consists in finding solutions that provide satisfactory cover while constraining its price to an affordable budget.

The solutions presented in this work carry the additional constraint that the variation in trigger magnitude per unit of geographic distance should be lower than a given constant.
Specifically, modeled earthquakes occurring in two contiguous cells should not produce vastly different payouts. Smooth behavior of neighboring payment conditions eases the minds of insureds and insurers since large variations due to modeling or instrumental errors are less likely [19]. These design principles have been successfully applied in the market, namely through the Acorn Re transaction of 2015 to protect the Kaiser-Permanente corporation from monetary loss in case of an earthquake on the West Coast of the U.S. [29], as well as for the recent—and triggered—FONDEN 2017 transaction [26], which provided the Mexican government with $150 million for early event response after the September 8th M8.1 event near Guatemala [30].

Figure 2. Pareto-optimal front to maximize risk transfer at a given pricing level, where pricing is established as a function of trigger frequency or return period.

To illustrate these parametric hedges in a simple scenario, let us consider one single asset in Los Angeles. Let’s assume that we desire to structure some coverage for a house within the ZIP code 90210. An earthquake risk model can be used to compute expected damages to this asset. If the characteristics of this exposure are well known, these can be used to produce a somewhat more accurate assessment of risk. Recall, nevertheless, that catastrophe risk models work based on assumptions on large sets of building classes and that these may not represent the behavior of one particular exposure and its geographic context with precision. However limited, this analysis is useful to obtain a rough perspective on the existing physical risk for this particular asset if we desired a cover solely for the purpose of restoring physical damage.
Figure 3. Parametric hedge designs for Los Angeles (a), San Francisco (b) and California (c).
Instead, imagine that we desire not only to represent damages to this particular home but to the general resilience of its neighborhood. As mentioned in the previous section, damage to neighborhoods and city sections or to the infrastructure servicing those neighborhoods is a better proxy of utility post-event. If there are no gas, transportation, electricity or water services, residential occupancy is dubious and short-term indirect losses (on top of any direct physical losses) may be substantial until these services are restored. These are the “less tangible” effects we were referring to earlier. In these circumstances, it may make sense to model risk differently, by using a “proxy for general damages” rather than by only modeling the expected damage to the asset of interest. For this purpose, we often use an “industry run,” which tries to capture the risk associated not with one asset in particular but with the building stock in the vicinity of the asset. This is often a better representation of general disruption and a better usage of earthquake risk models, since they are well suited to compute damages to large groups of buildings.

The resulting design corresponding to losses to the industry in ZIP code 90210 can be observed in Fig 3a. Two maps are shown, each representing the trigger conditions at return periods of 50 and 100 years, respectively. These parametric hedges have been built to maximize risk transfer not to a single asset located in the ZIP code but to the entire ZIP code. It is easy to extend the concept to an entire city or county. San Francisco, for instance, has recently undertaken several initiatives to improve its resilience to natural disasters. A magnitude 7.2 earthquake on the San Andreas Fault has the potential to damage or destroy more than 100,000 residential buildings in the city and displace hundreds of thousands of residents [31]. In order to get residents back into their homes quickly, the city will also need a mechanism for efficient damage assessment and smooth transfer of funds. A parametric earthquake trigger designed to protect San Francisco’s exposed risk can obviate the need for the former and facilitate the latter. Assuming that San Francisco’s total insured value is approximately $64 billion, two parametric hedges are developed in order to maximize risk transfer for events likely to cause more than $2 billion in citywide losses. Note that the parametric design can be tailored to any layer of interest. In this case, the design is equivalent to implementing an expected deductible of $2 billion. Two possible designs with return periods of 50 and 100 years are shown in Fig 3b.

Finally, a scenario is presented in which the portfolio at risk extends throughout all of California. This may be the case for a mortgage portfolio of a bank or similar scenario. In this case, the assets at risk are widely distributed with obvious concentrations around the San Francisco and Los Angeles area. Fig 3c shows the parametric design for the same return periods as in the other cases, this time covering events that may cause losses throughout the state.

Conclusions

We have summarized the low insurance penetration in California as well as the low public perceptions of the community; neither reflects positively on the insurance industry. We have also presented the argument that indemnity-based insurance alone may not be naturally suited to
satisfy the needs of the community, especially in the context of the community resilience debate. Parametric hedges constitute a device to increase insurance cover in California, complementing other existing indemnity solutions. Although the discussion of basis risk tends to obfuscate the utility of parametric hedges, we have presented a set of conditions under which parametric insurance solutions may shine when compared to indemnity structures.

To illustrate the potential for the customization and wider adoption of these tools, we have provided some simple examples with traits analogous to recent parametric CAT bonds already widely deployed in the reinsurance and capital markets. These show the capability of tailoring these transparent and straightforward derivatives to different stakeholders yet within a clear and common framework amenable to all stakeholders in the risk transfer chain.

References


