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A maturity scale for earthquake insurance development based on the California experience

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ABSTRACT: Since 1985, the annual average insured loss share for earthquake insurance is constant despite a large variability from one country to another. Consequently, comparing countries' experience can contribute to identify most appropriate insurance solutions to fill the protection gap. In this study, we present a maturity scale for earthquake insurance, which is a tool widely used by insurance companies to define their action plans for a better risk management and development strategy. At the same time, public authorities could leverage them as a compass to enhance prevention measures.

This maturity scale compiles various types of information such as the level of risk monitoring, the premium affordability, the market demand, the investment in prevention measures and the solvency level of insurance companies. From the analysis of the earthquake insurance development in California, four different grades have been identified for the maturity scale: Emerging, Standard, Advanced and Sustainable.

1 INTRODUCTION

While the occurrence of earthquakes around the world is stable, consecutive economic damage is increasing since 1973 (OECD 2018). To help people recover from such disasters, insurance is an essential socio-economic tool (Noy et al. 2017). Therefore, we have collected from the EM-DAT and the Swiss Re Institute databases the insurance losses and the total direct economic losses for 100 earthquakes that occurred between 1985 and 2016 and over 31 countries. The annual average insured loss share has been calculated as the ratio between the sum of insurance losses and the sum of the total damage for each year. Figure 1 shows that, at the worldwide scale, the annual average insured loss share is constant at 15% since 1985, meaning that insurance protection has increased as fast as the total direct economic losses

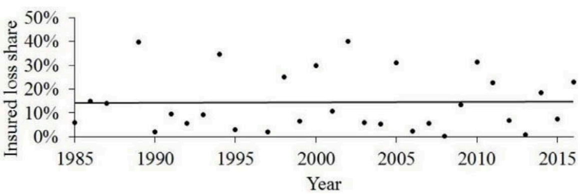

Figure 1. Annual average insured loss share caused by earthquakes between 1985 and 2016. Sources: EM-DAT and Swiss Re Institute).

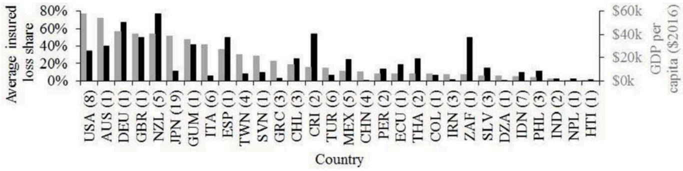

Figure 2. Average insured loss share between 1985 and 2016 (black bars) and GDP per capita in 2016 (grey bars) for 31 countries. The number of earthquakes affecting each country between 1985 and 2016, according to the EM-DAT and the Swiss Re Institute databases, is given in parentheses. Sources: EM-DAT, Swiss Re Institute and UNDATA.

caused by earthquakes. Consequently, insurance protection at the worldwide scale has not been extended to new population groups since 1985.

From the same dataset, the average insured loss share by country for the period 1985-2016 has been also calculated as the sum of insurance losses between 1985 and 2016 divided by the sum of total direct economic losses between 1985 and 2016. Figure 2 shows the result for the 31 countries and puts in light that some countries have a high average insured loss share (e.g. New Zealand and Mexico), while some others have not (e.g. Japan and Turkey).

Furthermore, the difference in average insured loss share cannot be explained only by the GDP per capita (Figure 2). Indeed, insurance solutions in New Zealand, and Mexico are more effective than those existing in Japan and Turkey respectively, despite a comparable GDP per capita. As a consequence, the flat trend of the annual average insured loss share (Figure 1) means that since 1985 a lot of countries with a low average insured loss share have not managed to adopt better insurance solutions already used in countries with a comparable GDP per capita.

In this context, this paper introduces a new maturity scale for earthquake insurance. A maturity scale is a common tool in insurance industry for expanding the business. Based on a set of variables, each level gives the characteristics that must be observed for each variable. Those considered for this maturity scale are the following: the level of risk monitoring, the premium affordability, the market demand, the investment in prevention measures and the solvency level of insurance companies. In light of the evolution of the California earthquake insurance since 1906, we identify 4 different levels: *Emerging, Standard, Advanced* and *Sustainable*, each being detailed hereafter in a dedicated section.

2 LEVEL *EMERGING*: THE BIRTH OF THE EARTHQUAKE INSURANCE (EMERGING LEVEL: CALIFORNIA 1906–1925)

First earthquake insurance policies was issued in 1916 as a separate policy covering damage induced by ground-shaking (Goltz et al. 1985). Nevertheless, most of damage from the 1906 San Francisco earthquake was caused by fires and covered by the fire insurance. Consequently, earthquake insurance was in its infancy until the 1925 Santa Barbara earthquake.

2.1 *Risk monitoring*

Despite the 1906 San Francisco and the 1925 Santa Barbara earthquakes, insurance companies considered that the occurrence of another strong earthquake was unlikely until 1927 (Geschwind 1997). Therefore, the premium amount collected was treated as pure profit and therefore was not reserved for paying future claims (Geschwind 1997).

2.2 *Premium affordability*

During the period 1906–1925, the insurance premium was low, at an average rate of 4 cents per $100 coverage (Goltz et al. 1985). By comparison, Gilbert (1909) assessed that based on historical damage caused by earthquakes between 1800 and 1908, the average insurance premium should have been above 72 cents per $100 coverage. In conclusion, the level *Emerging* is characterized by underpriced insurance premium, which is in line with the lack of risk monitoring.

2.3 *Market demand*

Since 80% of the losses from the 1906 San Francisco earthquake were due to following fires, they were covered by the standard fire insurances (Goltz et al. 1985). Consequently, people did not buy an earthquake insurance, considering the damage caused by ground shaking as insignificant (Goltz et al. 1985).

2.4 *Investment in prevention measures*

Even if officials and mass media downplayed the consequences of the 1906 San Francisco earthquake (Natural Hazards Observer 2006), a basic building code against wind effect was however required during reconstruction works in the city (Popov 1994). Furthermore, some technical reports (Natural Hazards Observer 2006) and scientific papers (Gilbert 1909) were published highlighting the importance of prevention measures.

2.5 *Solvency level of insurance companies*

Even if many insurance companies went bankrupt after the 1906 San Francisco earthquake (Insurance Information Institute 2018), insurance companies' solvency regarding earthquake risk was not considered until the 1925 Santa Barbara earthquake (Geschwind 1997; Eren and Lus 2014) for which the total insured loss exceeded the total premium amount collected to cover earthquake risk between 1921 and 1924 (Freeman 1932).

3 LEVEL *STANDARD*: AN EMPIRICAL INSURANCE MODEL (STANDARD LEVEL: CALIFORNIA 1926–1994)

The 1925 Santa Barbara earthquake has exacerbated the need to manage earthquake risk in California, fostering academic research on the destructiveness of a major earthquake (Geschwind 1997), highlighting the need for earthquake mitigation plans (Natural Hazards Observer 2006), and boosting earthquake insurance market (Goltz et al. 1985). Despite the model successfully faced major earthquakes like the 1933 Long Beach, the 1971 San Fernando and the 1989 Loma Prieta earthquakes, it did not sustain the extreme losses caused by the 1994 Northridge earthquake, pushing the insurance sector into an unprecedented crisis (Pomeroy 2010).

3.1 *Risk monitoring*

Until the 1994 Northridge earthquake, insurance companies have underestimated the loss they could face (Monning et al. 2014). Indeed, the insured losses after this event was 7 time higher than the estimates from actuarial models for this kind of earthquake (Osteraas and Gupta 2008). Even if the 1994 Northridge earthquake was caused by an unknown seismic fault at that time (Grossi et al. 2008), the modeling gap was mostly due to inadequate buildings vulnerability and repair cost models (Osteraas and Gupta 2008). After this event, insurance companies did not longer rely on statistical models, using instead stochastically and physically based models for assessing earthquake losses (Grossi et al. 2008).

3.2 *Premium affordability*

In the late 20s, insurance companies understood that damaging earthquakes in California are frequent and the buildings stock at that time highly vulnerable (Geschwind 1997). Consequently, they sharply increased the insurance premium (Freeman 1932; Geschwind 1997), from an average of 4 cents in 1925 (Goltz et al. 1985) to 179 cents in 1927 (Freeman 1932) for a $100 coverage. However, because, on one hand, insurance companies were unable to price the risk

(Dong 2002; Muir-Wood 2016), and on the other hand the market was very competitive (Muir-Wood 2016), the premium was pulled down at 20 cents per $100 coverage in the early 70s (Kunreuther et al. 1978) and stayed at the same level until 1994 (Mulligan 1994).

3.3 *Market demand*

The 1925 Santa Barbara earthquake produced a surge of earthquake insurance demand (Goltz et al. 1985), which has been amplified by an aggressive selling strategy from insurance companies (Geschwind 1997). Later, the 1971 San Fernando earthquake boosted also the market demand, as well as the 1985 Assembly Bill AB2865 (McAlister 1984) which imposed to insurance companies to offer an earthquake cover aside the residential fire insurance. At the beginning of 1994, 31% of people had an earthquake insurance (source: CDI).

3.4 *Investment in prevention measures*

The first earthquake mitigation program was set in the aftermath of the 1933 Long Beach earthquakes under the Riley Act and the Field Act (Natural Hazards Observer 2006). Since then, after each significant earthquake new mitigation plans have been put in place by the authorities (Wiley et al. 2000). Furthermore, seismic design codes have been initiated after the 1933 Long Beach earthquake but culminated only in the early 50s (Popov 1994).

3.5 *Solvency level of insurance companies*

Despite no insurance company went bankrupt after the 1994 Northridge earthquake, one was near the insolvency (Monning et al. 2014) and 3 insurance companies have been fines $3.5bn in 2000 for having restricted claims payments for an amount adjudged at $262.6m. (Ellis 2000). Furthermore, rating agencies have downgraded many insurance companies forcing them to reduce their exposure to earthquake risk (Monning et al. 2014) and pushing the sector into a crisis (Pomeroy 2010).

4 LEVEL *ADVANCED*: AN INSURANCE MODEL DESIGNED TO FACE EXTREME EVENTS (ADVANCED LEVEL: CALIFORNIA 1995–2018)

The insurance crisis following the 1994 Northridge earthquake ended by the creation of the California Earthquake Authority (CEA) in December 1996, a private-funded and state-managed insurance company dedicated to earthquake cover for residential properties (Pomeroy 2010).

4.1 *Risk monitoring*

Earthquake risk is monitored with very complex stochastic models, at the state-of-the-art of earthquake-related sciences (Grossi et al. 2008), including very extreme losses as the USGS *ShakeOut* scenario (Jones et al. 2008) and the Jaiswal et al. (2017) study providing return period losses up to 2,500 years. Insurance pricing and risk management directly derive from these physical seismic models combined with complex building vulnerability curves.

4.2 *Premium affordability*

CEA's insurance premium amounts are based on stochastic models to assess damage that can causes any kind of earthquakes, in order to collect enough money for sustain an extreme earthquake (CEA 2018a) or a series of consecutives severe earthquakes in a short timeframe. Although premiums are risk-based, they do not match the consumers' point of view. For example, consumer activists considered that the large premium increase after the 1994 Northridge earthquake was about increasing the profitability of insurance companies and not pricing the risk (Reich 1996; Jaffee and Russell 1997).

4.3 *Market demand*

Most of Californians do not buy earthquake insurance because on one hand they do not think that an earthquake could impact them and on the other hand for low income people the current premium amount is not affordable (Dixon 2014). As a consequence, the share of insured people decreased from 37% in 1993 to 31% in 1994 and 13-14% since 2003 (source: CDI).

4.4 *Investment in prevention measures*

After the conviction of 3 insurance companies for having restricted claims payment after the 1994 Northridge earthquake, the California Insurance Commissioner required them to finance for $10m. a research and education foundation instead of paying the fines for a total amount of $3.6bn (Ellis 2000).

4.5 *Solvency level of insurance companies*

The CEA is designed to sustain an earthquake with a return period up to 400-550 years (CEA 2017), i.e. more severe than the 1994 Northridge earthquake, the 1906 San Francisco earthquake, and the USGS *ShakeOut* Scenario (Pomeroy 2010). However, in case of a very extreme earthquake exceeding the CEA's claim-paying capacity, insurance policies contain a clause of pro-rata payments, meaning that affected policyholders would be partially refunded.

5 LEVEL *SUSTAINABLE*: CURRENT INITIATIVES FOR A SUSTAINABLE INSURANCE MODEL (SUSTAINABLE LEVEL)

Against the current low level of people covered, two kinds of innovative solutions are developed to bring more and more people to get access to earthquake insurance. On one hand, insurance policies are redesigned for offering a lower, more attractive rate. On the other hand, prevention measures are fostered to decrease the expected loss following an earthquake and so the premium amount.

5.1 *Risk monitoring*

Earthquakes do not occur randomly in time, but according to a time-dependent process. This is taken into account in some recent risk assessment studies (e.g. UCERF3; Field et al. 2014, Field et al. 2015) which have released both a time dependent (short term) and a time independent (long term) model. These two time scales are relevant for the insurance industry because while the premium amount is calibrated on a long term view, the minimum solvency capital is reassess each year and, consequently, consider only extreme losses that could occur over the following year. For this reason, time dependent model can be very valuable to better estimate the minimum solvency capital.

5.2 *Premium affordability*

Several innovative insurance solutions are currently developed to offer lower prices, like Jumpstart Recovery, a parametric insurance which pays out to the insured a predefined compensation amount as soon as a given type of earthquake occurs (Jergler 2017). Meanwhile the CEA decreased on average their tariff by 10% in 2016 for being more attractive (CEA 2016).

5.3 *Market demand*

Following the 10% decrease adopted by the CEA in 2016, the rate of people insured against earthquakes by the CEA has never grown so fast since 1996: +0.6% in 2016 and +0.8% in 2017. Meanwhile, the California state promotes earthquake insurance through aggressive advertising campaigns (Fuller 2018). Also, the occurrence of severe earthquakes outside California may have raised risk awareness of Californian people, supporting insurance demand.

5.4 *Investment in prevention measures*

The CEA and the California Governor's Office of Emergency Services jointly launched the Earthquake, Brace & Bolt initiative which aims at promoting simple seismic retrofitting work with both a $3,000 grant for paying part of the work, and a premium discount between 5% and 20% depending to the building vulnerability (CEA 2018b).

5.5 *Solvency level of insurance companies*

In France, the earthquake risk is covered under the so-called *CAT-NAT* insurance regime since 1982. It includes the unlimited French State guarantee in case of extreme losses (CCR 2011). Benefiting from this financial guarantee the insurance companies' solvency is no longer threatened by the occurrence of an earthquake in France and its overseas territories.

6 CONCLUSIONS

Based on all these findings about the evolution of the earthquake insurance in California, the characteristics of each variable for each level are summarized in the Appendix (Table 1). Figure 3 presents the synthetic view of the maturity scale.

It shows especially that market demand decreases at the *Advanced* level as a consequence of the premium increase, from a commercial-based to a risk-based assessment. Nevertheless, this change in premium amount is also related to a decrease of insurance companies' insolvency risk. Overall, the *Advanced* level is an improvement compared to the *Standard* level because an insurance protection for few people provided by financially robust insurance companies is preferred to one covering more people but potentially running for bankruptcy in case of a devastating earthquake.

This maturity scale contributes to develop earthquake insurance in light of the evolution observed in California over one century including the 5 major axes in the management of the earthquake risk. First, it should be used to rank the current level of countries exposed to earthquake risk. Then, it would pilot the further development for improving earthquake insurance solutions.

This maturity scale allows also to identify the different priorities for promoting earthquake insurance. For instance, while prevention measures are not necessary to launch earthquake insurance (*Emerging* level), they must strongly be promoted by public authorities when insurance companies extent the market of earthquake insurance (*Standard* level). Nevertheless, back-testing the maturity scale by comparing to others countries would definitely contribute to assess the quality and to assert the added-value of this maturity scale. The maturity scale can also warn countries that they are actually downgrading, if they jump from a rating to a lower one, which could happen over time due to passivity or complacency towards this rare risk.

Figure 3. Summary of the maturity scale developed in this study.

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Appendix

Table 1. Detailed description of the state of each variable of the Maturity scale for each level.

Variable	Emerging	Standard	Advanced	Sustainable
Risk monitoring	Not material: A destructive earthquake is not expected to occur again	Experienced: Recent events showed the destructive power of an earthquake	Controlled: The risk is monitored and extreme events are modeled	Anticipated: The risk is monitored both at short term and long term view.
Premium affordability	Very low: The risk being ignored, the premium is low and considered as a profit	Commercial-based: The premium amount reflects the market and does not take into account the risk level	Risk-based: The premium is calculated based on the risk in order to guarantee the solvency of the insurance company	Economic-based: The premium depends on both the risk and the consumers' expectations
Market demand	Low: People do not feel the need to be protected against the risk	High: Following the last earthquakes, insurance need is spreading over the population	Low: High premiums lead to a trade-off between the risk and the cost. Only few people prefer to be insured, especially if no earthquake has occurred recently	High: Most of people purchase an earthquake insurance encouraged by a significant premium amount decrease and a better risk awareness
Prevention measures	Emerging: Only academic researches work on prevention measures. Applications are very few and on a very simple basis.	Institutional: Prevention measures are managed by the authorities and considered as a public mission	Risk holders: Prevention measures are supported both by the officials and the insurance companies	Economical: Prevention is funded by the market and is recognized as the only long-term efficient risk reduction process
Solvency level of insurance companies	Low: The solvency of insurance companies is questionable because the earthquake risk is not monitored	Medium: Insurance companies are subject to solvency regulations.	High: Insurance companies' reserves are designed to face a very extreme loss	Secured: Additional mechanisms are used to support insurance companies if their reserves are exceeded.