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SEISMIC RISK IDENTIFICATION BASED ON THE EXPECTED ANNUALIZED LOSSES

BY

GENOVEVA PERJU and GABRIELA-MARIA ATANASIU

A new method for the seismic risk identification is proposed based on the average measure of the expected annualized losses from earthquake occurrence. We show up how can be identified the risk for insurance decisional purposes. The analysis is useful for insured as well as for insurance company. When risk is considered from time dynamical perspective we emphasize the advantage of diversification for earthquake risk mitigation.

1. Introduction

In setting rates for catastrophic risks, insurers have traditionally looked backwards by relying on historical data to estimate future risks. Such procedures are likely to work well if there is a large database of past experience to form the basis for extrapolation into the future. Low probability – high consequence events generally have a relatively small historical database. In fact, many technological and environmental risks are associated with new processes, so that past performance data are lacking [2].

In this paper we are proposing an alternative way of measuring the expected natural hazard economic loss by avoiding the reliance on the scarce historical data for the extreme hazards. We introduce an average expected annualized loss (EAL) measure, in this case for the earthquake as extreme event. This average measure of EAL it is the mean that facilitates the risk classification and therefore the decisional process of earthquake risk mitigation. A new measure for the average expected annualized loss is introduced which we use to provide a standard for earthquake risk classification and estimation. Finally, a study case is provided for a real estate investment under seismic risk.

2. Defining Loss Estimation

The average yearly amount of loss accounting for the frequency and severity of various levels of loss using a common term in earthquake loss estimation can be measured using the EAL proposed by P o r t e r *et al.* [3]. The computational relationship of EAL is

$$\text{EAL} = V \int_{s=0}^{\infty} y(s)v(s)\,\mathrm{d}s, \tag{1}$$

where: V denotes value exposed to loss (*e.g.*, replacement cost of the building); s refers to some seismic intensity measure; $y(s)$ is the mean seismic vulnerability function, defined here as the average level of loss as a fraction of V given an occurrence of s; $v(s)$ – the average annual frequency of experiencing shaking intensity, s.

Performing the calculus one considers a range of the most common earthquakes magnitudes as presented in the Table 1:

Table 1
Earthquakes Characterization Function of their Annual Incidence

Earthquake magnitude	Number per year
>8	0...1
7...7.9	18
6...6.9	120
5...5.9	800
4...4.9	6,200
3...3.9	49,000
2...2.9	350,000
1...1.9	3,000,000

Using the first and second mean theorem for definite integrals Eq. (1) becomes:

$$\text{EAL} = V \int_{s=1}^{8} y(s)v(s)\,\mathrm{d}s = 7Vy(c)v(c), \tag{2}$$

where $y(c)$ and $v(c)$ are the mean values of the seismic vulnerability function, respectively of the annual frequency of experiencing a shaking intensity, s.

Based on the transformation in Eq. (2), a medium value of the EAL for the case of Romania is shown below.

As suggested by Porter (*op. cit.*), $y(c)$ represents the average level of loss as a fraction of V for the given occurrence of s. The medium probability of loss occurrence to a medium value of the shaking magnitude is

$$y(c) = [1 \;\; 0.75 \;\; 0.5 \;\; 0.33 \;\; 0.25]. \tag{3}$$

In what follows, we consider a full range of the most common possible frequencies of earthquake occurrence and loss probabilities, as presented in Table 2.

Table 2
The Quantitative Earthquake Risk Matrix Identification

Frequency	Loss probability				
	100%	75%	50%	33%	25%
1/1 (1.0)	7 V	5.25 V	3.5 V	2.31 V	1.75 V
1/2 (0.5)	3.5 V	2.65 V	0.25 V	0.17 V	0.13 V
1/3 (0.33)	2.33 V	0.25 V	0.165 V	0.11 V	0.08 V
1/4 (0.25)	1.75 V	0.19 V	0.125 V	0.08 V	0.06 V
1/5 (0.2)	1.4 V	0.15 V	0.1 V	0.07 V	0.05 V
1/6 (0.16)	1.12 V	0.12 V	0.08 V	0.05 V	0.04 V
1/7 (0.14)	0.98 V	0.11 V	0.07 V	0.05 V	0.04 V
1/8 (0.12)	0.84 V	0.09 V	0.06 V	0.04 V	0.03 V
1/9 (0.11)	0.77 V	0.08 V	0.055 V	0.04 V	0.03 V
1/10 (0.1)	0.7 V	0.08 V	0.05 V	0.03 V	0.03 V

Table 2 is an easy to use indicator on how much loss would occur under seismic risk as proportion from the initial investment. It is straightforward a preliminary classification of the seismic risk based on EAL results. In providing the above decision matrix we have used the actual insurance rate that suggests that the insured could cover about 10% of the total value of the investment. In this case the managerial implications for the insured are highly different from what is generally suggested in the insurance literature. In Table 3 is presented a qualitative matrix for earthquake risk identification.

Table 3
The Qualitative Earthquake Risk Matrix Identification

Frequency	Loss probability				
	100%	75%	50%	33%	25%
1/1 (1.0)	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk
1/2 (0.5)	Unacceptable risk	Unacceptable risk	Medium risk	Medium risk	Medium risk
1/3 (0.33)	Unacceptable risk	Medium risk	Medium risk	Medium risk	Low risk
1/4 (0.25)	Unacceptable risk	Medium risk	Medium risk	Low risk	Low risk
1/5 (0.2)	Unacceptable risk	Medium risk	Low risk	Low risk	Low risk
1/6 (0.16)	Unacceptable risk	Medium risk	Low risk	Low risk	Low risk
1/7 (0.14)	High risk	Medium risk	Low risk	Low risk	Low risk
1/8 (0.12)	High risk	Low risk	Low risk	Low risk	Low risk
1/9 (0.11)	High risk	Low risk	Low risk	Low risk	Low risk
1/10 (0.1)	High risk	Low risk	Low risk	Low risk	Low risk

The qualitative analysis of earthquake risk suggests that in fact all losses below 10% from the exposed value are low rank risk. This implies that the insurance owner should ignore the risk. The only type of risk that should be decided to be transferred to the insurer company is the medium and high risk while the unacceptable risk might even involved a disinvestment decision.

3. Study Case

As an example let us consider that the mean annual frequency of the earthquakes in Romania is expected to be a small value, approaching 0. Therefore one can consider that $v(c) = 0.1$, which is the frequency of one earthquake in ten years.

Eq. (2) becomes

$$\text{EAL} = 7Vy(c) = \begin{cases} 7V \times 1 \times 0.1, \\ 7V \times 0.75 \times 0.1, \\ 7V \times 0.5 \times 0.1, \\ 7V \times 0.33 \times 0.1, \\ 7V \times 0.25 \times 0.1, \end{cases} \tag{4}$$

or

$$\text{EAL} = \begin{cases} 0.7V, \\ 0.52V, \\ 0.35V, \\ 0.23V, \\ 0.17V, \end{cases} \tag{5}$$

while V is the value exposed to the loss.

The last result in the Eq. (5) has an important significance for the risk acceptance and risk mitigation decisions. It follows that the maximum expected annualized loss of an earthquake with the maximum magnitude and a possible occurrence of once event in ten years is of $0.7V$.This suggests that there is a critical level of the annual frequency of the earthquake magnitude that once exceeded the EAL, exceeding also the value of the exposed loss in itself.

Consequently the interpretation of this computational result is presented in terms of investment. Let's supposes an initial investment of 50,000 euro in the case of a building exposed to the possibility of earthquake occurrence. In this paper, $V = 50{,}000$ euros. If one expects a high frequency of occurrence, for example once at every five years in case of an earthquake of a magnitude on Richter scale of 7, that might generate a total damage of the building and therefore a total loss of 50,000 euro, the expected annualized loss might exceed that initial investment of V. Therefore the insurance path of risk mitigation looses its economic rationality above certain values of EAL higher than the initial investment.

Table 4
The Expected Annualized Losses in the Case of a 50,000 Euros Investment

Loss probability	Frequency									
	1	0.5	0.33	0.25	0.2	0.16	0.14	0.12	0.11	0.1
100%	350,000	125,000	116,500	87,500	70,000	56,000	49,000	42,000	38,500	35,000
75%	262,500	132,500	12,500	9,500	7,500	6,000	5,000	4,500	4,000	4,000
50%	175,000	12,500	8,250	6,250	5,000	4,000	3,500	3,000	2,750	2,500
33%	115,500	8,500	5,500	4,000	3,500	2,500	2,500	2,000	2,000	1,500
25%	87,500	6,500	4,000	3,000	2,500	2,000	2,000	1,500	1,500	1,500

However, choosing an appropriate portfolio of investments with low or unacceptable seismic risk, a part of the earthquake risk can be mitigated through diversification. For an investment of 50,000 euros the real estate portfolio of investments we can see the effects of the diversification through the following analysis.

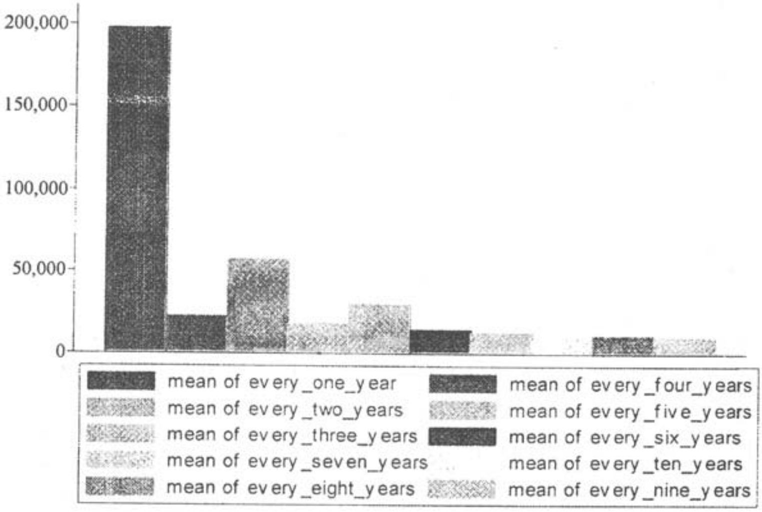

Fig. 1.- The mean value of earthquake Expected Annualized Loss (EAL).

Plotting the mean value of expected annualized loss in Fig. 1, the most significant mean of the average EAL is likely to be for events of high frequency as one earthquake at every one and two years. Therefore a real estate investments portfolio, even

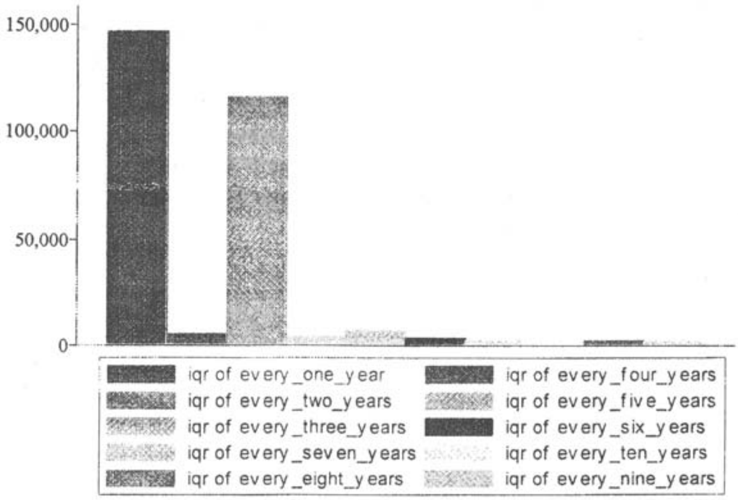

Fig. 2.- The interquantile range of earthquake Expected Annualized Loss (EAL).

if it includes investments slightly affected by seismic events, the total mitigation of risk will not be able to be achieved through diversification. For events with a frequency of occurrence of 1,...,3 years and higher, the mitigation through diversification is possible.

The last result is obvious by plotting the interquantile range of the earthquake EAL (Fig. 2) and we conclude that based on the analysis of the qualitative matrix of earthquake risk identification the results can be easily justified since at one earthquake at every one and two years there isn't the possibility of mitigation through diversification in investment in low risk investments.

4. Final Remarks

If the seismic risk is managed independently, is not taken into account the advantage of the fact that non-correlated risks viewed jointly have a lower volatility than when viewed independently. At the same time, the historical information is widely dispersed and it is not reflecting for each earthquake the same type of geographical or technical condition of occurrence as the previous natural hazard events. In this paper the risk identification analysis introducing the notion of the average expected annualized loss at earthquake is performed. The economic effect of capturing the joint effect is lower transfer expense. The present analysis of earthquake loss risk identification proves the benefit of diversification for the joint effect of loss at earthquake.

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„Gh. Asachi" Technical University, Jassy,
Department of Structural Mechanics

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IDENTIFICAREA RISCULUI SEISMIC PE BAZA PIERDERILOR LA CUTREMUR

(Rezumat)

Se introduce o nouă metodă pentru identificarea riscului seismic luând în considerare o măsură medie a pierderilor economice aşteptate să apară în urma unui cutremur. Se prezintă modalităţile de identificare a riscului în scopul asigurării pierderilor. Analiza este utilă atât pentru asigurat cât şi pentru asigurator. Riscul este considerat dintr-o perspectivă dinamică şi se prezintă avantajul diversificării în scopul diminuării riscului.