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Earthquake insurance: Seismic exposure and portfolio dispersal – Their influence on the probable maximum loss

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ABSTRACT: The aims and methods of the Munich Reinsurance Company's PC program "Earthquake Risk" are described. The program is designed to analyse entire portfolios of insured risks to determine the size of probable maximum losses and of the average annual loss to be expected over the long term. On the basis of past evaluations of risks in various regions of the world, conclusions are drawn as to how loss events of different sizes contribute towards the overall risk prevailing in the regions concerned.

1 INTRODUCTION

There are two preconditions of a technical nature for the insurance of the earthquake risk:

1. It must be possible to calculate a premium that is commensurate with the risk in question, as this forms the basis for technically sound underwriting.

2. It must be possible to determine the size of the probable maximum loss that could result from a major event, or of the accumulation loss as it is called in the insurance business. This is necessary as a basis for calculating the financial reserves that an insurance company needs to set aside for potential catastrophic events as well as to decide what amount of protective reinsurance coverage it needs for the liabilities it has assumed within a particular area.

The first aspect requires a review of all the loss events likely to occur over a long period of time, whereas the second concentrates on that section of the overall loss experience that consists of catastrophes with a relatively small probability of occurrence. In its publication "Guatemala '76 - Earthquakes of the Caribbean Plate" the Munich Reinsurance Company (1976) presented a unified concept designed to deal with both the aspects described. In accordance with the state of the art at that time, this concept consisted of a probabilistic approach to the calculation of premiums for individual risks and a deterministic approach (the so-called scenario method) to the evaluation of the catastrophe potential. It did not, however, yet allow accurate calculation of the premium demand for an entire portfolio consisting of a multiplicity of risks.

The increasing loss potential arising from various developments in the international earthquake insurance market and demonstrated by earthquake catastrophes of the 1980's such as Newcastle/Australia in 1989 (Smolka et al. 1991) makes it necessary to use most efficiently the insurance capacity available for coverage of the earthquake risk. The calculation of the appropriate average price for the insurance of entire portfolios is an essential precondition for efficient capacity utilization. To enable insurers to calculate premiums for portfolios of risks on a probabilistic basis, the Munich Reinsurance Company as well as other firms have therefore developed appropriate working tools in the form of portfolio analysis programs for use on PCs.

2 THE PC PROGRAM "EARTHQUAKE RISK"

The dBase program "Earthquake Risk" developed by the Munich Reinsurance Company combines earthquake exposure data and information on the insured risks to produce figures indicating the probable size of the total loss likely to affect a portfolio within any given period of time. Figure 1 is a schematic representation of the program's structure. The input data consist of

1. the earthquake catalogue of the country or region concerned and the geometry of the seismic source zones,

2. the mean expected loss percentages per degree of intensity on the Mercalli Scale, and

3. the insured risk portfolio.

As regards the exact nature of these data and the method of their processing, the following points should be noted:

ad 1) The translation of raw earthquake data

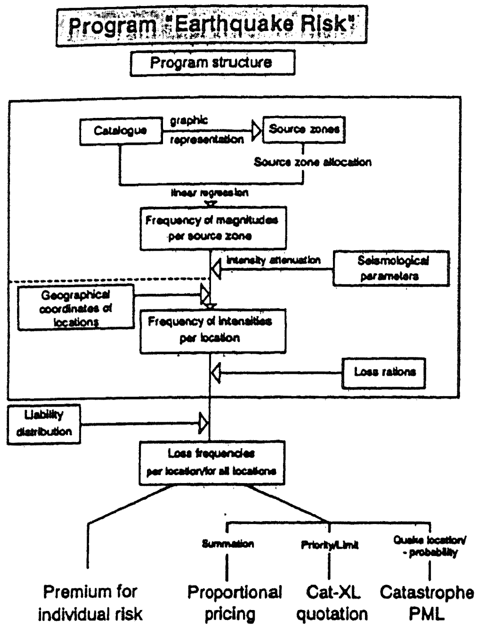

Figure 1. PC program "Eartquake Risk" - program structure.

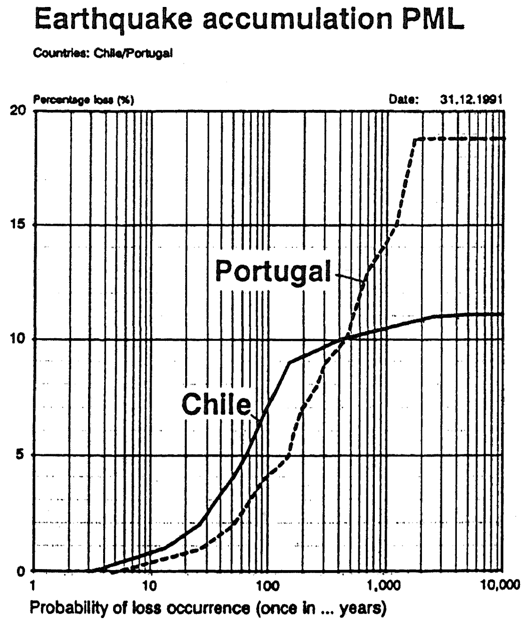

Figure 2. Example risk curves for Portugal and Chile.

into the local hazard follows the classical approach of Cornell (1968). The subsoil conditions are allowed for by adding a variable to the intensity calculated for firm ground according to the intensity attenuation function.

ad 2) The loss percentages can be shown for any class of risk defined by any combination of criteria (e.g. type of construction, building/contents/ business interruption and residential/commercial/ industrial). To determine the effects of deductibles and limits of liability, the distribution of losses around the mean value is taken into account.

ad 3) The program was designed in the first place to deal with large portfolios. The standard case is therefore that the risks in the insured portfolio are grouped together by zones and risk categories. Greater detail is, however, also possible, even to the extent of individual risk input.

3 APPLICATIONS

The program delivers a graph in which the expected loss in percent is plotted against the annual probability of occurrence, or against the so-called return period (see figure 2). The file of data that this graph represents can be used for the following applications:

1. Calculation of the average loss to be expected for any given probability of occurrence. The probable maximum loss determined with the aid of this graph forms the basis for decisions by the insurer on the total amount of capacity available, the risk that can be retained for the insurer's own account and the size of the required reserves, as well as the amount of reinsurance coverage needed to protect the retention in the event of catastrophes involving a large number of risks simultaneously.

2. Calculation of the average price for the entire portfolio that the insurer needs to obtain in order to cover his risk. This is expressed as the premium rate per year in relation to the overall value of the portfolio. It is calculated by integration over the data of the entire file or, in other words, by adding together the products of the losses incurred per event and the corresponding probabilities of occurrence. Apart from calculation of the probable maximum loss, one of the most important criteria for determining how much capacity can be made available is the comparison of the technically required premium with the price actually paid.

3. Calculation of the average price per location in the insured portfolio. This will not be discussed here, because the following remarks will concentrate on the synoptical analysis of portfolios.

4 SUMMARY OF THE RESULTS OBTAINED TO DATE

The "Earthquake Risk" program has been used so far for the following countries and regions: Israel, Jordan, Japan, New Zealand, the Philippines, Puerto Rico, Jamaica, Mexico, Colombia, Venezuela, Chile, Canada, California, the "Pacific

Northwest" (the region of Puget Sound/USA and Vancouver/Canada) and Portugal. The areas treated cover a wide range of configurations, as regards both seismicity and portfolio structure. On the basis of a purely empirical analysis of the calculations carried out so far, an attempt has been made to determine whether any systematic trends are observable. The reference parameters used were as follows:

- The average annual loss (to be abbreviated henceforth as AAL). In accordance with the description given earlier this can be understood as an overall measure of the seismic risk given in a particular region. "Risk" in this context is defined as the product of the seismic exposure on the one hand and the susceptibility of the insured risks to losses on the other.

- The 1000-year loss, abbreviated in the following as PML_{1000}. This value is used uniformly to represent a very large loss. The reason why not the actual maximum loss is taken here is that the return periods for the largest losses in the different areas vary between 300 and 150,000 years, which means that they would not be comparable.

- The ratio between PML_{1000} and AAL. This ratio reflects the proportions of the overall risk accounted for by rare versus frequent losses; the lower the figure - where the average annual loss is high compared with the size of the 1000-year loss - the greater the contribution of frequent small losses is to the risk as a whole.

For illustrative purposes, figure 2 shows two curves comparing Portugal with Chile. The steepness of the curves is determined generally by the seismicity of the country or region concerned and the geographical distribution of the insured risks in relation to the seismic source zones. The plateaus on the right-hand side of each curve result from the size of the maximum loss in each case, which cannot be exceeded in view of the given seismological conditions. The extent of large losses is determined quite decisively by the concentration of the risks. In most of the countries and regions mentioned above, between 65% and 85% of liabili ties are located within the largest city of the area concerned. Exceptions in this respect are California (where less than 50% of liabilities are in Los Angeles), Mexico (approx. 50% of liabilities in the Distrito Federal), Japan (approx. 30% in the Bay of Tokyo), New Zealand (approx. 50% in the area of Auckland) and Colombia (approx. 35 % in the area of Bogotà). For this reason in these countries the maximum loss is relatively low in relation to the total amount of insured property throughout the country as a whole; in no case does it exceed 10%. In this figure, only the direct effects of earthquakes are taken into account, however; the additional damage caused by fires following an earthquake - which may be considerable - is not included. In order to avoid confusing the picture by incorporating too many influencing factors, these areas will not be considered any further here but will form the subject of a later investigation.

If the above parameters are examined in relation to each other, the following observations result:

1. PML_{1000} vs. AAL: In figure 3 the average annual loss is plotted against the 1000-year loss. Although there is some indication of a positive correlation between these two quantities, the range of fluctuation is so broad that no real conclusion can be drawn from the size of the 1000-year loss for a particular region as to the size of the average annual loss for the same region. This was also observed by Taylor et al. (1990) on the basis of a comparison between areas of differing seismicity in California. In the case of the regions represented in figure 3, for 1000-year losses in the range of 8 to 9% the average annual loss varies between 0.5% and 2.5%. The reason for this lies in the different starting points and slopes of the risk curves, as shown in figure 2. As already mentioned, these differences mean in practice nothing else than differences in the extent to which rare and frequent loss events contribute to the overall loss expectancy. These contributions are reflected in the ratios between PML_{1000} and AAL, which vary for the countries and regions studied between extremes of 20 for Mexico (Zona del Valle) and 163 for Eastern Canada. The greater the ratio, the more important are the rare, large losses within the context of the overall risk.

2. PML_{1000}/AAL vs AAL: In order to examine whether there are systematic differences in the contributions of different loss sizes as a function of the overall risk, the ratios mentioned above were plotted in figure 4 against the annual average losses. Since the ratios already contain the quantity, namely the AAL, to which they are to be compared, such a procedure is not entirely unproblematic. Nevertheless, the negative correlation between the ratios and the overall risk observable

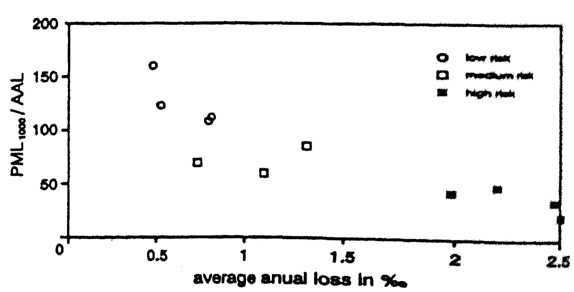

Figure 3. 1000-year loss compared to average annual loss.

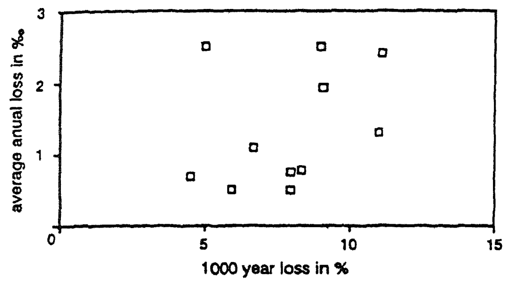

Figure 4. Ratio 1000-year loss/average annual loss compared to average annual loss

from the graph is very marked. The greater the risk, the smaller is the PML_{1000}/AAL ratio and the smaller also is the proportion of the overall risk accounted for by the 1000-year loss (which stands for the part of the curve representing the large losses).

Visually, a distinction can be drawn between two groups of countries: those with a high risk (the Philippines, Jamaica, Chile, Mexico D.F.) in the bottom right-hand corner of the graph and those with a low risk (Canada, Jordan, Portugal) in the upper left-hand corner. The middle range is occupied by Israel, Puerto Rico and Venezuela.

3. PML_{1000}/AAL vs. PML_{1000}: The grouping together of countries and regions with a relatively high or low risk shown in figure 4 is observable also if the ratios are compared with the 1000-year losses, although this seems surprising at first glance. The data as a whole do not indicate any clear trend, but the groupings marked in figure 4 by different signatures appear again here, in that the ratio between PML_{1000}/AAL and PML_{1000} is much lower in the case of the high-risk countries than in the case of the low-risk countries. If the two groups are examined separately, there may well be considerable differences in the degree of dependance of the ratio on the PML_{1000}. Further investigations are, however, necessary to confirm the truth of this supposition.

5 CONCLUSIONS

The evaluations carried out so far with the aid of the Munich Reinsurance Company's portfolio analysis program "Earthquake Risk" can be summarized as follows:

Taking the averal annual loss expectancy as a measure of the overall risk to which a region is exposed, two separate groups of countries with clearly distinct degrees of risk are observable. They are distinguished by the differing weight of loss events of different rates of frequency within the framework of the overall risk: In high-risk countries large, rare losses are relatively unimportant, the main contribution towards the total loss burden coming from more frequent events resulting in small and medium-sized losses. In low-risk countries, on the other hand, major events that occur only rarely contribute to the overall loss burden to a much greater extent. For earthquake insurers this means in practice the following:

1. Any "PML" defined as a low probability event ($p <= 0.001$/p.a.) is not appropriate as the sole determinant for premium calculation.

2. To calculate a premium that is commensurate with the risk, it is necessary to integrate over all conceivable loss events together with their corresponding probabilities.

3. As regards the contribution of large losses to overall premium requirements, systematic differences can be assumed between regions with high and low risks. In the case of low-risk regions, the greater significance of large losses, together with their rarity and the resulting uncertainty, makes it seem appropriate to demand a special premium loading. This applies particularly in the case of catastrophe reinsurance which deals exclusively with large and catastrophic losses.

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