CATASTROPHIC RISK MODELLING – RESIDENTIAL AND NON-RESIDENTIAL EXPOSURE

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Abstract

Catastrophic risk modeling has been an integral part of the insurance industry over the last decade, given the experience of a growing number of catastrophic events worldwide. Whether we are talking about probabilistic or deterministic models, catastrophic risk modeling shows a high degree of quality of results due to recent technological advances and a short response time. However, for certain geographical areas or certain events, there is the problem of using incorrect or incomplete data sets that can lead to corrupt, incorrect results that can mislead the true extent of the financial losses caused by natural disasters. The present paper aims to present the results of the exposure of insurable buildings in Romania following the occurrence of an earthquake based on a specialized modeling, used internationally. Despite some historical data on the non-residential fund in Romania estimated by extrapolation, the results obtained by modeling IF Elements are useful in the context of preparing a response to a similar event Vrancea 1977 at national level. The national disaster response plan that includes the financing of the insurance market, of the uninsured owners but also of the institutions of the statute can start from the estimates made in the present research. The research can be detailed and validated by using other modeling products or by increasing the quality of input data used (related to residential exposure, but especially non-residential) in Romania.

Keywords: AAL, IF Elements, valoare rezidenţială, expunere nerezidenţială, modelare riscuri catastrofale

JEL classification: 22 .

Introduction

Both natural disasters - earthquakes, hurricanes, landslides or floods - and man-made disasters can jeopardize the financial stability of any company. Catastrophic risk modeling refers to mathematical representations of the physical characteristics of natural disasters, terrorism, pandemics, events with extreme accidents and cyber incidents using computer applications. In the case of rare events, with significant consequences, recourse to the history of losses has proved uncertain in assessing potential future losses. Risk management

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companies have developed probabilistic models that help organizations prepare for the financial impact of disasters - before they occur. After a series of catastrophic events that impacted the population of some countries and even the industry that was intended to provide financial coverage, the importance of catastrophic risk modeling became inevitable.

Hurricane Andrew - more than $ 16 billion in insured damage - caused the insolvency of at least 11 insurers. Two consecutive years of record hurricane activity in 2004 and 2005, including Katrina, underscored the need to identify tools to predict (ex-ante) damage caused by catastrophic events. , New Zealand, Thailand and the United States recorded $ 110 billion in insurable damages - but this time the insurance market was less affected - no insolvency was caused - some experts explained that it was the result of the implementation of models of catastrophic risks (AIR Worldwide, 2017).

Although hurricane model reviews have attracted the attention of insurers and risk professionals more often, earthquake models have also evolved in the last decade. The latest US earthquake model updates (Marsh, 2015), launched in 2009 by AIR and RMS, were driven by the launch of the US National Seismic Hazard Mapping Project (NSHMP), a national scientific consensus on earthquake risk.

1.Catastrophic risk modelling

Catastrophic risk modeling is an integral part of the insurance industry, despite the skepticism shown by others at the launch of the first model in 1987 by Applied Insurance Research (AIR) (Obersteadt, 2018). At the time, the simulations were based on historical databases on natural hazards and geographic information systems (GIS).

According to Ciumaş, catastrophic risk modeling uses data and analysis to create predictive models of risk and potential damage caused by natural disasters, extreme weather events, terrorism and pandemics (Ciumaş, 2013). Catastrophic event modeling, regardless of their manufacturer, includes at least one of the following four core modules: event, hazard or intensity, vulnerability, and financial (AIR WorldWide, 2017).

- The **Event module** combines different catastrophic events and estimates the potential damages, based on the history of data collected from historical, geological, geographical or even psychological sources;
- The **Hazard module** evaluates the probability of a specific event occurring for a specific geographic area.
- The **Vulnerability module** estimates the damage caused by a certain risk to buildings and other properties, adjusted according to the local architecture or the provisions of the construction codes;
- The **Financial Module** estimates the cost of repairing the damage caused by the given events and establishes the person responsible for covering the costs.

Catastrophic risk modeling can start from a probabilistic model or a deterministic model. In the case of a probabilistic model, the result is either a probability loss distribution or a set of events that could be used to create a loss distribution; the maximum probable losses ('PML') and the average annual losses ('AAL') are calculated from the distribution of losses. Approaching a deterministic model involves calculating the losses caused by a specific event; for example, Hurricane Katrina or "a tsunami affecting the Fukushima plant" could be analyzed in relation to the existing risk portfolio.

After 2011, there was a significant advance in catastrophic risk modeling. Today, technological advances - more powerful computers, mobile communications, artificial intelligence have allowed existing models to reach the high resolution required to provide forecasts specific to small locations. However, higher resolutions bring higher uncertainty and sensitivity in custom modeled results. On the other hand, general modeling has gained ground because it uses more diverse visual components and the results are more accessible to model users. They also allow for more efficient validation and verification of the model.

Beyond technological advances, customized estimates, the variety of existing models, a persistent problem in modeling catastrophic risks arises from the quality of input data used.

Although data quality is usually much better today than it was a decade ago, many organizations continue to send inaccurate or incomplete data. An example in this sense is the situation of the non-residential fund in Romania, which created difficulties for the present research approach.

However, the responsibility for ensuring the quality of the data lies with the property owners, including the state authorities. The main qualitative gaps in input data in catastrophic risk modeling come from the primary attributes or modifiers of their properties (Marsh, 2015):

- Geocoding - address information (including latitude / longitude).
- Occupation.
- Type of construction.
- Year of construction.

Unfortunately, some organizations continue to underestimate the substantial effect that poor data can have on insurance programs - and are unwilling to devote time or money to improving data quality. Such an error in estimating the financial impact may be useful, as incorrect projections of underlying losses from catastrophic risk models may result in an additional premium spent on insurance that is not required. By investing in data quality, state-owned companies or institutions can help ensure a more efficient use of limited capital. Brokers or risk experts may be involved in this process to improve existing historical data - with the support of construction and engineering experts. In general, this will translate into less uncertainty in disaster risk models, lower AAL estimates and premium savings.

1.1Utility of catastrophic risks modelling

The purpose of disaster risk modeling is to give companies the opportunity to anticipate the likelihood and severity of potential future disasters before they occur so that they can adequately prepare for their financial impact. Disaster risk models can be used to address a range of questions, including the location, size and frequency of potential future catastrophic events. Insurance companies and reinsurers use catastrophic risk models to estimate potential loss and provide them with the tools and information they need to manage that risk. In the case of the insurance industry, the result of modeling is a source of information used to develop and implement a wide range of activities: setting appropriate insurance rates; adapting the underwriting policy, analyzing the effects of different contractual clauses; making sound decisions about reinsurance and optimizing existing portfolios. In addition to estimating possible future property damage and loss, the models can be used to estimate human damage (injuries or deaths) as well as the number of claims.

In addition, European insurers use catastrophic risk models to estimate the regulatory capital required under Solvency II. Catastrophic risk models are used to obtain the probability distribution of catastrophic losses - a component of several Solvency II internal capital models.

In addition to insurers, catastrophic risk modeling is also useful for rating agencies such as A. M. Best and Standard & Poor's. They use catastrophic risk modeling to assess the financial stability of insurers who assume the risk of catastrophe. Reinsurers and reinsurance brokers use catastrophic risk modeling in pricing and structuring reinsurance treaties.

Investors in catastrophic risk bonds and investment banks also use the results of catastrophic risk modeling in pricing and structuring a catastrophic risk bond.

The current goal of modelers is to reach resolutions large enough to ensure that the prices of an insurance policy are tailored to the specific characteristics of an individual property. Continuous advances in computing capabilities and data collection tools have the potential to fill model gaps and provide real-time modeling. This could bring the skills of modelers to understand and quantify disaster risk at new levels. It is also likely that the complexity and flexibility of the models used by the insurance market will continue to increase.

In the 2013 study (Ciumaş, 2013) related to estimating an insured value for earthquake risk in Romania, the authors use 3 different indicators: market value, replacement cost and real value. Thus, the authors of the study estimated that the national insured value to be approximately 13 billion euros, with an average annual insured value of 408 million euros. That research was based on a probabilistic model without having the advantage of using international models, used by the market, with access to an international historical database.

In the following part of this study we will present two international models, well known to the insurance and reinsurance market, developed by companies specialized in catastrophic risk estimation and we will estimate with the help of one of them the estimated value of the insurable exposure at national level.

1.2.Modelling hypothesis

In conducting this paper, the authors used several specific hypotheses such as the value of insured residential buildings, the uninsured value of residential buildings, uninsured residential content, insured residential exposure, non-residential exposure.

The **value of the insured residential buildings** is the value of the PAID portfolio as of March 31, 2019. For this paper, the authors used the assumptions of the consortium and the updated replacement costs used by PAID Romania.

Exposure data of uninsured residential buildings were compiled based on statistical data available on the website of the National Institute of Statistics (INSSE) - the total number of dwellings as of December 31, 2018 was structured separately for each county, rural and urban. In addition, the data is divided into individual bands corresponding to changes in the building code. The total number of dwellings as of December 31, 2018 is 9,031,317, of which 55% are located in urban areas and 45% in rural areas. The number of risks provided by PAID on March 31, 2019 is 1,706,343, of which 75% are located in urban areas and 25% in rural areas.

Uninsured exposure is the difference between the total country-wide exposure and the exposure currently provided by PAID. The same assumptions about building mapping and modeled replacement costs are used, but there is a higher proportion of old buildings and low quality construction due to the higher proportion of rural risks.

The **value of insurable residential buildings** represents all insured and uninsured housing units in Romania (for example, the combination of the two previous categories). Regarding the residential buildings insured on an optional basis, based on the data of the insured market, the losses exceeding the PAID limits, covered by the insurance companies, were quantified.

The **value of the insured residential content** was estimated based on the modeling of the data reported by the insurance companies - here is estimated the total value of the insured goods from the insured dwellings (residential buildings). This value is calculated based on the additional content clauses accepted in the insurance by the owners of the insured buildings.

Uninsured residential content can be estimated, per county, as the difference between the total number of dwellings and the number of dwellings with insured content. For the purpose of modeling, each county is assigned an average insured amount based on the exposure of the insured content. The national average insured amount is EUR 5120. It is assumed that each existing home includes content that may suffer damage caused by natural hazards, which will lead to an increase in the claim for individual compensation.

Insurable non-residential exposure is a combination of properties insured by the internal market, optional reinsurers, international insurers, as well as uninsured properties owned by legal entities, municipalities or the state. The overall insured replacement value is based on the non-residential part of the AIR insurance industry exposure data. These AIR data include commercial, industrial, agricultural and municipal risks and are based on INSSE statistical data. It is assumed that the geographical distribution of the insurable replacement value is the same as the geographical distribution of the exposure provided by the internal market. This assumption is based on the very high degree of correlation between the GDP values per county (used as a representative amount of insurable values) and the insured values per county. Insured non-residential exposure represents losses of property damage (construction and contents) insured by the internal insurance market. The modeled LMMs do not include potential losses covered by optional reinsurers and international insurers through policies issued outside Romania. This part of the loss can be quite substantial, but it is difficult to quantify. This loss is the one that can substantially change the maximum amount to be insured, but the difficulties registered in the evaluation of the value of these buildings without residential purpose prevent the analysis of this segment, at the date of the accomplishment of the present work.

3.Used models

To estimate the insured value we took into account two valuation scenarios used internationally IF Elements and RMS Risklink, of the two calculations were detailed for IF Elements.

3.1. RMS Risklink model

For over 30 years, RMS has focused its efforts in the field of catastrophic risks, supporting organizations to make decisions related to the protection of people, property or even the environment. The combination of academic experience and technological advances has led to the emergence of solutions such as RMS Risk Intelligence that allow customers to better assess risk and reduce uncertainty in their activities.

Through the multiple solutions developed, RMS has managed to model over 18 million fires in the RMS Wildfire model, to provide 1000 risk models that can be used worldwide, 60 trillion data that it uses for results.

The RiskLink model identifies areas with unexpected concentrations or aggregations of risk and quantifies the potential for catastrophic risk for various business lines. The model works with a wide range of risks and geographical regions. Moreover, the model provides support for the short-term and strategic decisions of the insurance or reinsurance company. RiskLink identifies the most profitable risks and risk management strategies to improve the damage rate.

The RiskLink model has a number of advantages for customers in that:
• Meets sizing needs, either for a single user or to support a global enterprise;
• Quantifies risk at different levels with major probabilistic and financial results;
• Eliminates human errors and streamlines workflows by automatically sending data between RiskLink® and a company's internal applications;
• Improves modeling analysis with separately authorized software and data products, from event response processes to improving data correlations.

3.2. Impact Factor Elements – IF Elements model

Aon Benfield's Center of Excellence allows companies to analyze the financial implications of catastrophic events in order to predict the impact of risks and a better understanding of the risks per se. The offer of Aon Benfield (Impact Forecasting Elements - IF Elements) consists of a sophisticated tool for quantifying and managing the risks faced by companies, including insurance companies. The AON tool (IF Elements model) includes over 100 probabilistic and scenario models covering 10 types of risk and over 60 countries. This tool provides risk information for the highest risk areas in the world, as well as for emerging markets, in order to identify effective reinsurance programs and sound capital management, based on more accurate model results. The IF Elements model benefits from the continuous contribution of world academic research for the fine calibration of parameters. IF Elements has been used for multiple purposes - from using an insurer's loss data to generate more accurate results for a specific line of business, to modifying an existing event to explore loss sensitivity according to new regulatory requirements or impact assessment brought by a new risk.

The ELEMENTS loss calculation platform provides transparency, so that each stage of the calculation process is clearly defined and can be easily explained to stakeholders, regulators and rating agencies, while helping to quantify uncertainty in different components of the model. IF Elements allows for more accurate underwriting and risk assessment for natural and man-made hazards. The data helps insurers and their customers understand the impact of disaster risk on individual locations and then, in turn, estimate what the premium addition will be.

In the case of Romania, the IF Elements platform offers probabilistic modeling for earthquake risk.

4.The results of the study

Taking into account the AON IF model and the data from the PAID portfolio of March 31, 2019, the following results related to the residential value (expressed in euros) in Romania were obtained, as a result of an earthquake, as can be seen in Table 1 .

Table 1 - Residential value modeling in Romania

Scenario	Residential value insured by PAID (Euro)	Residential value non-insured (Euro)	Insurable residential value (Euro)
Replacement cost	57,266,683,155	230,337,433,790	287,604,116,945
Return period 200 years	1,069,525,834	4,628,493,764	5,683,475,715
Estimated loss Vrancea 1977	1,049,381,212	4,813,013,224	5,862,394,436

Source: IF Elements model

Starting from the statistical data available on the website of the National Institute of Statistics (INSSE), the model can provide an estimate of the replacement cost for the value of residential buildings in Romania. Starting from the degree of PAID coverage at national level, it is possible to estimate the replacement cost for the cost of insured residences (19.91% of total dwellings), uninsured and their total, respectively.

According to the IF Elements model, the insured residential value in case of an earthquake similar to the one in 1977 represents 18.81% of the insurable residential value in Romania, which is not a favorable element considering the mandatory aspect of the Romanian home insurance policy. Insurable residential value of 5.68 billion Euros can represent an important operational objective to be achieved in the next period for the local insurance industry but also for the authorities with an interest for an event with such important social repercussions for the population.

Estimating this indicator can be useful in taking real measures to improve this situation at national and even at regional level - whether these will be found in the form of legal provisions (diversification of sales channels) or awareness campaigns for the population (such as those developed by PAID Romania, UNSAR online) or coercive measures to pay insurance premiums (given the mandatory nature, the role of local authorities is essential). If we analyze the history of the last 5 years of the PAID portfolio, which highlights a modest increase in insurance coverage (in fact catastrophic risk, defined according to Romanian law), we can say that there is a need to intensify tangible measures to boost the purchase of this product and not to relax them.

The table above gives a similar picture to the values recorded at the 1977 event - a similarity can be seen with the estimated values for insured and uninsured values, important for analyzing catastrophic events of interest for the population, state institutions or the insurance industry in the next period.

Regarding the forecast of the dimensioning of the material damages of the insurable content from the residential buildings in Romania, the following conclusions were generated, as can be observed in Table 2.

Table 2 - Content value modeling in Romania

Scenario	**Non-insured residential content (euro)**	**Facultative insured content and buildings**
Costul de înlocuire	39,446,937,480	61,982,817,186
Annual average loss	10,142,792	4,761,277
Content losses in case of Vrancea 1977	536,912,225	228,884,700

Source: IF Elements model

The estimates made using the IF Elements model started from an average coverage hypothesis per county of about 5120 euros (based on historical data of the insurance industry). Uninsured content was estimated as the difference between the total number of dwellings and the number of dwellings with insured content.

According to the AON model, the replacement cost for content was estimated, at national level, at about 39.45 million euros not covered by the insurance industry in the event of a catastrophic event, lower than in the case of goods covered by an insurance policy.

It is interesting that on an annual level, on average, in Romania there are registered about 4.76 million euros of losses related to the content of insured residential buildings but about 10.14 million euros uninsured losses. The degree of non-coverage of the content in Romania has two main causes: on the one hand, the low degree of coverage of housing insurance but also the lack of concern (due to a lack of financial education in this regard) to ensure the content of housing and not only the dwelling. Lack of complete and accurate information can lead to a higher degree of coverage for content. The solution for this situation is sustained campaigns of correct information of the different clauses provided by content and buildings insurance products.

The same negative ratio is to be seen in the case of a catastrophic event such as the one in 1977 in Vrancea - the value of uninsured assets exceeds by 134.57% that of goods that would be insured by facultative insurance products. This value of the uncovered losses representing about 70.11% of the total content damages registered in case of a similar event Vrancea 1977 is alarming taking into consideration the situation in which the population or the state would be obliged to bear all the amount that would be refused by the insurance industry. State intervention, although desirable, would be detrimental to insurance activity in general.

If the estimates for the residential sector (both buildings and property) are relatively easy to model, the same statement cannot be made about the non-residential sector. Despite the rather limited assumptions of the non - residential building fund, the IF Elements model generated a number of interesting results for the present research, as can be seen in Table 3.

Table 3 – Non-residential value modeling in Romania

Scenario	Non-residential exposure insured locally (euro)	Non-residential exposure Non-insured locally (euro)	Non-residential exposure insurable (euro)
Replacement cost	73,884,908,723	301,138,258,814	375,023,167,536
Annual average loss Pierdere medie anuală	17,660,059	93,315,116	110,975,175
Losses in case of Vrancea 1977	913,350,454	4,471,223,202	5,384,573,656

Source: IF Elements model

Insurable non-residential exposure refers to the amount of buildings (properties) insured on the internal or external market, as well as uninsured properties, owned by legal entities, municipalities or the state. At this time, it is not possible to strictly assess uninsured buildings. A comprehensive situation of the value of uninsured buildings is not easy to achieve, despite the existence of several statistical databases belonging to state institutions - such an approach is a research project in itself that can be done separately. For the purpose of this paper, the non-residential value was estimated starting from the statistical data provided by INSSE. Replacement values were calculated based on reconstruction costs. However, the replacement value initially reported by RIA is reduced by about 42%, which corresponds to the difference in average replacement cost used by RIA and PAID for residential risks.

Regarding the value of non-residential buildings, it can be easily noticed that the insurance coverage offered by the insurance companies in the Romanian market is relatively modest in the total insurable exposure (estimated according to the principles presented above). Starting from the cost of replacement, only 19% would be accepted by the local market, which creates an impressive demand for coverage on international markets - unfortunately, such a demand can be honored internationally at different insurance premiums, specifically levels high compared to local offers. Perhaps a greater concern in identifying insurance options under national law can be more easily supported by owners of non-residential buildings. The opportunity cost of insurance on the Romanian market is clearly favorable, compared to the international one and should be a concern for covering those catastrophic situations. Interestingly, according to IF Elements, the insurable value of the residential fund in Romania represents 75% of the insurable value of non-residential buildings - which means that the penetration of home insurance falls even below the level of about 19% nationally according to PAID Romania figures. The situation is a turning point in the event of a catastrophic event with a resonant financial impact for the population, companies and state authorities. Comparing the total insurable value (375.02 billion euros) with the value of gross written premiums at national level in 2019 (approximately 2.44 billion euros), we can conclude the need for careful negotiations with international markets in order to obtain feasible coverage for non-residential buildings, the local market is not still ready to absorb the unconscious insurance claim completely.

Regarding the value of the average annual losses, the locally insured value maintains its share in the insurable total, the percentage being similar to the insured value for residential type buildings.

An information that can prove useful for identifying solutions to cover the losses produced in case of a similar event Vrancea 1977 is related to the insurable size of losses - compared to the data generated by the IF model for the residential fund, similar results are observed for non-residential buildings. The figures are staggering in their size - if we add them up - 11.24 billion euros is a hard-to-cover amount for any of the local national markets. Even the locally insured value of about 1.96 billion euros (for residential and non-residential) in its total is rapidly approaching the total value of the insurance market at the end of 2019, which is not exactly reassuring for any of the stakeholders of this type of event. The backlog from the low quality of non-residential data may dampen the final results of locally insured exposure, but the amounts already confirmed are likely to sound the alarm once again of the need to step up education and information campaigns at all levels. administrative, professional associations, employers, the general population.

Estimating as accurately as possible the insurable exposure of residential or non-residential buildings is an important element for national governments. They are aware of the costs associated with limiting disaster risk management to disaster response. State institutions are increasingly using catastrophe-type modeling tools as they move from ex-post management to ex-ante addressing disaster risk from disasters. By modeling disasters we identify and quantify risks to populations and infrastructure, it is possible to assess mitigation strategies and develop disaster financing programs.

Conclusions

Catastrophic risk modeling has become an essential component of the insurance industry. The impressive scale of recent catastrophic events has illustrated the value of the insurance industry's focus on local risk assessment. These events demonstrated the usefulness of high-resolution models and qualitative databases to achieve a correct map of local exposures. That is why the need for dynamic and transparent modeling will become even more important.

In the context of the implementation and diversification of the technologies used, the modeling of catastrophe events will reach new levels of scenarios and simulations in real time. Big data, artificial intelligence or machine learning are just a few elements that give impetus to already specialized companies to propose new products or improve existing products. New or better tools are a step forward in preparing for events with financial, social, human impact in any economy, at any level.

Regarding the estimates regarding the maximum value of the damage caused by a catastrophic event in Romania, there is a difficulty in estimating the non-residential value. The reality is that there are enough extremely well calibrated modeling tools, but unfortunately there is not enough data to make the most of existing models. In the context of the objective of estimating the maximum possible loss in terms of material damage to buildings and content, it is difficult to validate the value of non-residential buildings. The possibility of centralizing the data related to these buildings and the analysis of the resulting figures represent a distinct approach that will be approached separately.

Even estimated, the result obtained from the insurable exposure in Romania may represent a strategic objective in the commercial approach of the home insurance line but especially in the resilience approaches that the state authorities / institutions should design to be applied when such an event will be recorded, again, in Romania.

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