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NATURAL CATASTROPHE RISK MANAGEMENT

REVIEW ARTICLE

Abstract

Insurance and reinsurance are among the key forms of financial protection against catastrophic events. In modern times, probabilistic models have become increasingly important for assessing the risk of natural disasters, and are used to create insurance and reinsurance services intended to protect citizens, legal entities, as well as the state budget and local governments. Alternative forms of natural catastrophe reinsurance related to the securities market can also significantly help improve the market for (re) insurance against natural catastrophes.

Keywords: *natural catastrophe, disaster resistance concept, risk management, natural catastrophe insurance and reinsurance, probabilistic risk assessment, Nat CAT XL, Cat Bonds*

I. Introduction

Natural catastrophes are caused by the forces of nature i.e. by the effects of primary and secondary perils,[3] which expose the state to significant economic

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[3] Typical examples of primary perils are tropical cyclones, earthquakes and winter storms associated with the most severe global natural disasters causing large-scale damages. Secondary perils, such as floods, thunderstorms, snow and ice storms, droughts, fires, etc. occur more often than primary perils and cause less damage than those caused by primary perils, but such damages are also catastrophic. Secondary

losses and cause the suffering of thousands of people, and sometimes tens or even hundreds of thousands of people lose their jobs and homes. Since disasters present a broad range of human, social, financial, economic and environmental impacts, with potentially long-lasting, multi-generational effects, financial management of these impacts is a key challenge for individuals, businesses, and governments. Insurance and reinsurance, supported by a comprehensive risk assessment approach, are among the key forms of financial protection against catastrophic events.

In recent decades, there has been an upward trend in economic losses from natural disasters. The period of two consecutive years with the highest amounts of damage caused by natural disasters in the world was 2017/2018, when the damage from natural catastrophes covered by insurance amounted to as much as 219 billion USD,[4] with more than a half due to secondary peril events. However, there is a big gap between actual damages and the part of those damages that are covered by insurance. For example, it is estimated that of the total amount of damage from natural disasters in 2017 and 2018, as much as about 280 billion USD[5] remained uncovered.

Examples of insufficient coverage of damages caused by natural disasters also occur in these regions. Thus, after heavy rainfalls caused by the field of low pressure ("Yvette") formed over the Adriatic Sea, in the disastrous floods that affected Serbia, Bosnia and Herzegovina and Croatia in 2014, most of the damage was not covered by insurance. According to estimates, out of the total amount of damages caused by that event in Serbia, which is estimated at around 1.7 billion EUR, only 2% to 3% were covered by insurance.

The most common explanations for underinsurance of a significant part of damage from natural disasters are the following: (1) insufficient knowledge of citizens, but also of the state, about insurance against natural disasters, (2) lack of awareness of potential policyholders about risk, because they still largely think of insurance as an additional cost, (3) the perception of citizens and legal entities that the state has an obligation to cover the damage caused by a natural catastrophe, etc. On the other hand, insurers are reluctant to provide coverage where risk assessment is difficult and, being traditionally conservative, they offer a smaller scope of catastrophe cover.

However, the existing gap in insurance protection can also be seen as an opportunity for insurers to increase their sales volume that helps handle financial difficulties caused by natural disasters. Recognizing insurance as one of the key means of financial protection against catastrophic events, the UN, the World Bank,

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perils often occur as a consequence of primary catastrophe risks (for example, fire after an earthquake), but naturally, secondary perils may occur independently from primary perils.

[4] The biggest natural catastrophes in 2017 were caused by hurricanes Harvey, Irma and Maria, and in 2018 by typhoon Jebi and the Camp Fire.

[5] Swiss Re Institute, "Natural Catastrophes and Man-Made Disasters in 2018: Secondary Perils on the Frontline", *Sigma* 2/2019, Swiss Re Institute, 2019, pp. 8.

GEF, SECO, G7 and many other international institutions have launched a number of initiatives and projects in recent years. The aim of these initiatives is to provide protection against natural catastrophes at the international, national, regional, or individual level.

II. Managing Natural Catastrophe Risks

The extent of damage caused by a natural disaster depends on the intensity of natural forces, but also on human factors (e.g. construction of buildings, infrastructure, etc.), and the readiness of the community in the area affected by the disaster to effectively respond.

Catastrophic damages caused by natural disasters and subsequent crises can happen at any time, anywhere in the world. As a guide for protection, crisis management, and limiting of the amount of damage that can potentially occur, the Concept of Resistance to Natural Disasters has been developed. This concept includes synchronized **preparation** for catastrophic events (through the analysis of types and severity of potential events and preparation for those events), **prevention** (through preventive activities to mitigate the consequences of natural disasters as much as possible), **protection** (life, health and property protection activities), **response** to natural catastrophes (activities to limit the amount of damage after a disaster), and finally, financial protection measures and **reconstruction** after catastrophic events, in order to restore a normal level of activity.[6]

In recent decades, countries facing the risks of natural catastrophes of the modern era have made increasing efforts to improve resilience to catastrophic events. However, the poorer countries, which have poor infrastructure and a slow public sector, are unable to establish an adequate concept of resilience to natural disasters. In this regard, long-term consequences of the vulnerability of poorer countries are inevitable, and statistics send a clear message: in poorer countries, more people die from natural disasters than in rich countries, both in absolute numbers and in relative terms, observed by the share of casualties in the total population. This is explained by the fact that in poor parts of the world, extreme weather conditions, such as floods and droughts, pose a greater danger to human life, economy, and living conditions of entire communities.

Risk mitigation is one of the most important tools that the state can use in managing the risk of natural catastrophes for, although the state must do everything it can to reduce the consequences of natural disasters (for example, by banning construction in flood zones), still, having made its best efforts toward prevention, it must also have the ability to transfer a part of the risk.

[6] Munich Re, "Natural Catastrophes 2016 Analyses, Assessments, Positions", Topics Geo-2017 Issue, Munich Re, 2017, pp. 12–13.

Many underdeveloped and developing countries have limited financial capacity to respond to natural disasters, for the following reasons: (1) they have little fiscal space for discretionary spending, (2) they have limited capacity to raise funds immediately after natural disasters, and (3) have relatively low credit potential. Such countries rely heavily on external assistance and disaster relief loans. However, such an *ex-post* policy can be inefficient, with unpredictable results, and also costly if the country borrows.

One of the best ways to mitigate the risk of natural disasters is insurance or reinsurance. This fact, even formally, is confirmed at the highest level, among other things, by the Paris Agreement[7] and Sendai Framework for Disaster Risk Reduction 2015–2030[8] which highlighted investment in disaster risk transfer and insurance at the global, national, and local levels as key priorities.

III. Catastrophe Risk Assessment

Risk management in catastrophe insurance is carried out through three basic principles: aggregation of individual risks, segregation of individual risks into special groups, and control of moral hazard. Given the high severity of catastrophe claims, they generally require high capital of insurers offering catastrophe insurance services so that it can ensure a high survival rate. Reinsurance i.e. transfer of excess risk above the capacity of the insurer to the reinsurer, stands out as a very important form of risk management.

When insuring standard risks (which are not catastrophe risks) that are not correlated, the total aggregate risk is lower than the sum of individual risks, because these risks are not realized in the same place and at the same time (thus ensuring the spread of risk). On the other hand, with the catastrophic risks, the advantages of classical risk aggregation are lost, because individual risks are dependent (mutually correlated) and the total aggregate risk increases. This further means that insurers who provide coverage for one type of natural disaster through a risk pool, must meet very high capital requirements if they do not have adequate reinsurance. To ensure this, they must increase the insurance premium for a particular type of natural disaster and, if this increase is considerable, prospective policyholders may give up the purchase of that service. However, it is still possible for insurers to make catastrophic risks insurable. The most common way is to bundle insurance of several types of natural disasters. For example, floods and earthquakes can be covered by a single insurance contract (insurance policy), and as long as these individual types of

[7] United Nations, Framework Convention on Climate Change, Decision 1/CP.21, Adoption of the Paris Agreement, 2016.

[8] United Nations Office for Disaster Risk Reduction, "Sendai Framework for Disaster Risk Reduction 2015–2030", *Third UN World Conference on Disaster Risk Reduction in Sendai*, Japan, 2015.

natural disasters are not correlated, risk pool has less risk aggregation than each of these individual types. In addition, risk spread is achieved by catastrophe insurance services provided in different geographical areas.

In addition to the positive effects, which are achieved by bundling several types of natural disasters to one insurance service, catastrophe insurance has best effects when there is segregation between high and low risk policyholders. Through this technique, insurers reduce the expected damages, as a result of two processes. Firstly, if in the underwriting process the insurer divides policyholders in its portfolio into high-risk and low-risk, the variance of the portfolio results will be lower than the variance of the portfolio in which the policyholders were not divided according to exposure. This reduction in variability reduces the risk of losses on the part of the insurer. Secondly, by dividing policyholders according to exposure, insurers assess the premium more adequately, so that it better reflects the contribution of each individual policyholder to the risk pool. Such an approach has numerous advantages, whereas insured persons become aware of the costs of their risky behaviour.

The third way in which insurers reduce the level of catastrophic risks (damages) to which they may be exposed is by controlling moral hazard, i.e. changes in the insured's behaviour towards the property that is the subject of insurance (because he transferred his personal risk to the insurance company). For example, the insured person may be less interested in protecting his or her household when a flood is imminent, because he or she knows that the insurer will compensate the damage.

Insurers apply various techniques to reduce the effects of moral hazard, and the most common is the use of deductible. Unlike insurance against events associated with relatively small damages, where beneficial effects are achieved by applying a nominal (fixed) deductible, catastrophe insurance is more effective when contracting a percentage deductible. This technique implies that the insurer and the insured have a proportional share in the damage and that the insured has a special interest in behaving in a way that will reduce the potential damage from the catastrophic event. In addition, a significant technique for reducing moral hazard is the introduction of certain exclusions from insurance (for example, in flood insurance, exclusion of facilities located near riverbeds or water basins).[9]

IV. Models for Determining Catastrophe Insurance and Reinsurance Premium

There is no single methodology for determining the insurance premium against natural disasters, but is generally required to be estimated on the basis of

[9] Jelena Doganjić, Živorad Ristić, "Catastrophe Insurance – Contemporary Trends", *Insurance in the Post-Crisis Era*, University of Belgrade, Faculty of Economics Publishing Centre, 2018, pp. 275–290.

all expected future costs related to the transfer of damage risk to the insurer or reinsurer, with the fulfilment of profitability conditions.

Given the complexity of catastrophe insurance, the calculation of the risk premium for this insurance is less and less performed by traditional deterministic methods, because they are insufficient and not adjusted to this type of risk. In the absence of representative statistics, available statistics are often used in practice but with certain reservations, limitations, and deviations. Such data are based on the intuition or knowledge of experts. Applying fuzzy system theory, satisfactory solutions can be obtained in cases where there is a problem of uncertainty, unreliability, ambiguity, and vagueness.[10] In the segment of insurance risk assessment, it is used when there are no clear, precise, or sufficient data necessary for reliable risk quantification. Fuzzy systems and fuzzy technologies represent a mathematical approach based on which certain inaccurate information can be mathematically modelled, which is the basis for computer information processing using numerous models and types of software tools.[11] The development of technologies enables the formation of more advanced, hybrid models, as well as the application of simulations in certain phases of modelling.

Simulations in the modelling process enable the analysis of the effects of the application of different insurance conditions (e.g. deductible and coverage limits), as well as the analysis of the sensitivity of the results to the application of different parameters of frequency distribution and claim severity.[12]

In contemporary conditions, the catastrophe insurance premium is estimated by modelling – using stochastic methods, i.e. by applying probability theory, using statistical distributions, which approximate claims experience. Some of the continuous distributions, with a heavy tail, are often used to model the claim severity.

The probability distribution of losses, also called exceedance probability curve, is referred to as the probability that a certain amount of damage will be exceeded in a certain period. For example, for simulation period of 10.000 years, the highest causing loss will have 1/10.000 exceedance probability or 0.01%. The second highest loss will have exceedance probability of 1%, etc. These probabilities can also be expressed through return periods. Thus, the amount of damage corresponding to a return period of 100 years has 1% probability to be exceeded during the year. The return period of e.g. 100 years does not mean that if, for example, a flood occurs with that return period, the next flood will happen in about hundred years' time.

[10] For more details about this area see Lotfi A. Zadeh, "Fuzzy sets", *Information and Control,* (8), 1965, pp. 338–353 and Hans-Jiirgen Zimmermann, *Fuzzy Set Theory and its Applications*, 4th Edition, Springer, 2001.

[11] Vladimir Gajović, Marija Paunović, "Applying Fuzzy Mathematics to Risk Assessment in Insurance Industry", *Insurance Trends*, vol. 1, 2018, pp. 23–38.

[12] Jelena Kočović, Marija Koprivica, "An Internal Model for Measuring Premium Risk When Determining Solvency of Non-Life Insurers", *Economic Annals*, Vol. LXIII, No.217, Faculty of Economics, Belgrade, 2018, pp. 109.

Namely, this means that in any year, there is 1% probability that such damage will happen, regardless of when the last similar event occurred.

Convex exceedance probability curve in lower return periods (of high exceedance probability) indicates that the average annual loss – AAL is highly dependent on the values in lower return periods. Such curve is typical for more frequent catastrophic losses such as, for example, storms or floods. Conversely, concave curve in lower return periods indicates that average annual loss is more dependant than losses in higher return periods. Such shape of a curve is typical for less frequent catastrophic losses such as, for example, earthquakes.

Loss probability distributions can be formed for any geographical region, for a specific portfolio of buildings, or for a single building.

Due to the number and complexity of risk factors, when forming the premium tariff for natural catastrophes, the following problems must be solved:

- among numerous possible risk factors, the most important should be chosen to become an integral part of the tariff
- subgroups of risk factors should be identified within each risk factor
- it is necessary to form an adequate model of premium calculation for risk factors and their subgroups.[13]

Given the principle of personalization of insurance risk, on the one hand, and the requirement for risk aggregation, on the other hand, probability distributions are most often determined for homogeneous risk groups, for which the insurance premium is subsequently determined.

Table 1 Example of risk factors that can be used to determine the premium in insurance against earthquake and flood.[14]

Risk factor	Example	Earthquake	Flood
Geographical location – area	CRESTA of high or low resolution	Yes	Yes[15]
Geographical location – detailed	Precise latitude and longitude coordinates of the analysed location	No	Yes
Type of building	▪ Residential ▪ Office	Yes	Yes
Construction class	▪ Wood construction ▪ Masonry construction ▪ Reinforced concrete ▪ …	Yes	Yes

[13] Jelena Doganjić, Živorad Ristić, "Differentiation Premiums as a Precondition for Protection against Premium Instability and Negative Risk Selection", *Insurance Trends 4/2011*, 2011, pp. 27–31.

[14] Jelena Doganjić, Živorad Ristić, "Catastrophe Insurance - Contemporary Trends", *Insurance in the Post-Crisis Era*, University of Belgrade, Faculty of Economics Publishing Centre, 2018, pp. 286.

[15] It is applied, although more detailed geographic location would be more desirable.

Risk factor	Example	Earthquake	Flood
Storeys	▪ 1-2 ▪ 3-5 ▪ 6+	Yes	No or rare
Year of construction	▪ 1941–1962 ▪ 1963–2006 ▪ > 2006	Yes	No
Apartment /office location	▪ ground floor ▪ first floor ▪ other floors	No	Yes
Basement premises	▪ Building has a basement ▪ Building has no basement	No	Yes
Ground floor evaluation	▪ < 0.50m ▪ 0.50m - 1.00m ▪ > 1.00m	No	Yes

However, when determining the insurance premium for catastrophic risks, we must not ignore the fact that the usability of historical data on catastrophic events is limited, given their small scope (catastrophes rarely occur), and given that the portfolio of buildings is constantly changing. The number and value of insured buildings, materials from which they are built, construction methods, repair costs, etc. are also changing. Consequently, historical data are not suitable for a direct assessment of expected claims and insurance premiums.

In response to these problems, probabilistic risk assessment models, such as professional software packages like RMS, AIR, ERN, ARA, Risk Frontiers, RED, etc., are gaining an increasingly important role in insurance of catastrophic events, and some insurers or larger brokerages independently develop their own models of insurance against catastrophic risks. These models (software) are the result of the work of multidisciplinary teams consisting of experts in the field of meteorology, climatology, seismology, geophysics, hydrology, actuarial science, economics, etc., who apply the latest scientific knowledge in risk assessment.

As a rule, these models contain the following elements: Exposure Database, Event Generators, Damage Severity Assessment Module, Physical Damage Assessment Module, and Module for Assessment of Damages Covered by Insurance:

- **Exposure database** contains information of building location, types (construction class, height of a building, year of construction, existence of a basement, etc.) and their replacement value;
- **Event generators** are catalogues of simulated events which include frequency, strength, location, and other characteristics of the whole array of probable catastrophic events. These catalogues contain tens of thousands of computer-simulated catastrophic events, representing a wide range of possible occurrences;

- **Damage severity assessment module** simulates the realization of a catastrophic event, for each location that is expected to be affected, and simulates the severity of the hazard. For example, for an earthquake, the severity of the hazard is expressed by the scale of expected earthquakes and/or by the number and intensity of fires that may accompany the earthquake;
- **Physical damage assessment module** simulates the degree of damage for each possibly affected building in the analysed location, by applying the intensity of the simulated events to the portfolio (buildings) exposed to these events. The degree of expected damage to the buildings of different construction types and purpose is expressed through simulated distributions of damage probabilities;
- Within the **Module for assessment of damages covered by insurance**, a simulation of the potential amount of claims is performed according to the conditions given in the insurance contract - part of the total damage estimated by the module of physical damage, which is covered by insurance.

The result of these software packages is a simulation of claims for ten or even tens of thousands of stochastic years, for the analysed portfolio. These data, along with the exposure database, represent the input parameters for determining the insurance premium.

The following table shows an example of the results of the stochastic model - Occurrence Exceeding Probability curve (OEP) and for cumulative annual damage amounts, for all loss events (Aggregate exceeding probability - AEP).

Table 2 Example of stochastic model outputs

Probability	Amount of individual damage
0.01%	**170.952**
0.01%	**151.691**
0.01%	141.571
0.01%	133.451
0.01%	**122.701**
0.01%	117.579
0.01%	112.923
0.01%	108.707
0.01%	104.891
0.01%	**101.167**
0.01%	99.001

Return period	Exceedance probability	Amount of individual damage	Cumulative amount of damage
10000	0,01%	**170.952**	178.140
5000	0,02%	**151.691**	159.838
2000	0,05%	**122.701**	130.936
1000	0,10%	**101.167**	109.357
500	0,20%	81.644	90.336
250	0,40%	61.882	70.270
100	1,00%	41.887	50.470
50	2,00%	29.353	37.623
25	4,00%	18.941	26.176
20	5,00%	16.429	25.800
10	10,00%	9.306	15.002

Probability	Amount of individual damage
...	...
...	...

Return period	Exceedance probability	Amount of individual damage	Cumulative amount of damage
5	20,00%	5.466	10.211
2	50,00%	1.554	3.123

Source: Authors – based on the practice in using stochastic models

The expected average annual loss (AAL), which is obtained based on the exceedance probability curve, is usually taken as a measure of risk, for the observed number of simulations. Furthermore, the risk premium rate, before the safety allowance, can be determined as a quotient of the expected average annual loss and the value of the building from the exposure database. The safety allowance, in case of deviation from the expected value of the average loss, is calculated in practice using the standard deviation model, the variance model or, most often, using the expected loss model. When determining the total insurance premium, expected costs and expected profit should be both taken into account.[16]

V. Types of Catastrophe Insurance

Adequate insurance protection mitigates the impact of natural catastrophes (1) by lowering insurance premium to encourage policyholders to take preventive measures (insurers determine the premium according to the amount of risk, and offer a lower premium when the policyholder implements risk minimisation measures) and (2) by paying out indemnity after catastrophes, providing financial protection for those affected, so that the recovery of damaged property can begin without delay.

The insurance markets can make an important contribution to the management of disaster risks by providing a source of funding for recovery and reconstruction. The damages paid out by insurers to the insured injured persons in the aftermath of a disaster event reduce the financial burden on households, businesses, and governments.

Types of catastrophe insurance may be mainly divided as follows:

- Insurance covering one catastrophe risk or insurance covering several catastrophe risks;
- Voluntary or compulsory (mandatory) catastrophe insurance and
- Standard coverage against catastrophe risks, micro disaster insurance, or budget protection insurance.

Natural catastrophe insurance usually covers several perils (e.g. floods and earthquakes or some other combination). By combining different perils into one

[16] Jelena Doganjić, "Premium Adequacy Risk Management in Non-Life Insurance", Faculty of Economics of the Unviersity of Priština, *Ekonomski pogledi* 1/2015, Kosovska Mitrovica, ISSN 1450-7951, 2015, pp. 85–98.

insurance service, insurers increase the risk spread. However, there are also cases when catastrophe insurance covers only one peril (e.g. floods). In addition, these risks depend on a large number of parameters and are determined for each receptor separately. [17] Numerous models of multicriteria risk analysis have been proposed and developed, which can be adjusted and used for analysis and simulation of catastrophic risks.[18]

Voluntary catastrophe insurance, as insurance against one or more perils, is usually offered together with other insurances or as their supplement. With such an offer, insurers try to avoid unfavourable risk selection, namely, event when the insurance covering a natural disaster is bought only by insured persons located in high-risk zones, exposed to natural catastrophes. An example is the homeowners insurance against fire and allied perils which, in addition to covering standard risks (fire, explosion, storm, etc.), covers e.g. the risk of flood.

Mandatory insurance against natural disasters is a mechanism that, among other things, aims to reduce strain on the state budget when a natural disaster occurs. Numerous challenges are associated with the development of compulsory catastrophe insurance (usually through the funds of several insurers or the state). A particular challenge is to define the appropriate role of the public sector, as such a model must reconcile the interests of both private and public sectors, and must include a win-win situation. Typical examples of compulsory catastrophe insurance are the covers provided by the Turkish Catastrophe Insurance Pool (TCIP), with about 9.5 million homes insured against earthquakes in 2020,[19] and Insurance Pool against Natural Disasters of Romania (*PAID*), with more than 1.7 million homes insured against flood, earthquake, and landslide.[20]

Catastrophe insurance also differs in the manner in which it is sold: as standard insurance - when the value of insured buildings is covered; or as micro-insurance - when affordable protection is provided at usually a smaller scope; or sold as budget protection. Standard catastrophe insurance is insurance that covers damages caused by the actuation of a natural disaster up to the insured amount (which depends on the value of the insured item), but not above the limit allowed by the insurer. Micro disaster insurance is insurance with low amounts of insurance indemnity (e.g. 1 to 2 thousand Euros or some other, relatively low value). The target group for this type

[17] M. Kerkez, V. Gajovic, G. Puzić (2017). "Flood risk assessment model using the fuzzy analytic hierarchy process", Progress in Economic Sciences, Instytut Ekonomiczny Państwowa Wyższa Szkoła Zawodowa im. Stanisława Staszica w Pile, 4, pp. 271–282.

[18] Gajović, V., Kerkez, M., Kočović, J. "Modeling and simulation of logistic processes: risk assessment with a fuzzy logic technique", *SAGE Journal*. Simulation: Transactions of the Society for Modeling and Simulation International, Vol. 94(6), 2018, pp. 507–518.

[19] *https://dask.gov.tr/tcip/zorunlu-deprem-sigortasi-istatistikler.html* – accessed on 08-04- 2021.

[20] The Insurance Pool against Natural Disasters, "Raportul privind solvabilitatea si situatia financiara 2020", PAID, 2021, pp. 3.

of insurance are usually low-income households, i.e. moderately poor households (those above the poverty line, but prone to slip below the poverty line in case of unexpected expenditures). The target group of micro disaster insurance services may also be small and medium-sized enterprises.

Budget protection of the state or local self-governments from damages caused by natural disasters is insurance intended to protect the budget against unforeseen payments as an aid to companies, citizens, farmers, and other affected persons, or due to unplanned repairs of damaged infrastructure after catastrophic events.

VI. Types of Catastrophe Reinsurance

The international reinsurance market, both traditional and alternative, supported by recent developments and innovations, can contribute to risk management by strengthening the capacity of insurers and providing professional support in quantifying the catastrophe risks. The global nature of the international reinsurance market allows part of the damage caused by natural disasters to be compensated on the international market, thus reducing the pressure on a country's financial system. The pooling of risks by reinsurers allows for further diversification, in addition to the diversification of risk realised by primary insurers, providing an additional layer of risk absorption capacity at a lower cost than can be achieved by insurance companies individually.[21] As previously explained in this paper, if the risks are concentrated in high exposure to a single extreme event or a series of such events, the primary insurer needs to have a large capital to cover high volatility of potential claims. However, if the risks are diversified through reinsurance, then the insurer needs less capital to cover exposures to extreme events. Reinsurers can also buy retrocession for their exposures, usually covering extreme risks, that is, events that potentially have a low frequency but an extremely high severity.

Commonly, traditional reinsurance treaties, which do not cover catastrophe risks, have precedence over reinsurance treaties that cover natural disasters. Namely, most often catastrophe reinsurance treaties are applied to the amount of damage remaining after the use of traditional reinsurance, such as quota share reinsurance, surplus share reinsurance, etc. However, sometimes, catastrophe reinsurance coverage is arranged and applied even without prior traditional reinsurance.[22]

Common forms of reinsurance coverage for damages resulting from natural disasters are covers provided through Nat CAT XL (Natural catastrophe excess-of-loss) treaties and Aggregate Stop Loss treaties.

[21] Organisation for Economic Co-operation and Development, "The Contribution of Reinsurance Markets to Managing Catastrophe Risk", *OECD,* 2018, pp. 3.

[22] Jelena Doganjić, "Natural Catastrophe Risk Management", *Insurance market after Covid 19*, University of Belgrade, Faculty of Economics Publishing Centre, 2020, pp. 329–344.

Nat CAT XL reinsurance is used when the potential for accumulation of claims is high and when this insurance covers aggregated / accumulated claims above the agreed deduction (layer), up to the agreed maximum limit. This type of reinsurance can be contracted for a specific loss event (per occurrence) or for a series of loss events (per aggregate). Per occurrence Nat CAT XL coverage protects the insurer against very high catastrophe losses per one occurrence, while Aggregate Nat CAT XL coverage is used for more frequent catastrophic events that have a lower severity.

For example, let us suppose that an insurer provides insurance coverage to its policyholder who has facilities in a particular area and that such insurer, for its own protection, also has reinsurance with a quota of 40%: 60%, as well as Nat CAT XL reinsurance 10,000,000 XS and 1,500. 000 for additional protection, after the application of quota share reinsurance, in the event of a natural catastrophe from an earthquake of a certain intensity. In the event that such an earthquake hits the area where the insured facilities are located, most of those facilities will suffer damage. The insurer will, within the limits of the insurance contract, compensate the damage to the insureds, and part of the damage will be reimbursed by the reinsurer, first by realizing the quota share reinsurance treaty, and then by applying the reinsurance treaty which covers the earthquake risk, up to the treaty limit.

Table no. 3 provides an example of such risk cover.

Table 3 Example of natural catastrophe risk transfer by *Nat CAT XL* contract (amounts in 000)

Number of insurance contract	**Amount of loss covered by insurer**	**Amount of loss covered by reinsurer (60%) by applying quota share reinsurance**	**Amount of loss retained by insurer after the application of quota share reinsurance contract (*Net Pre Nat CAT*)**	**Amount of loss covered by reinsurer under *Nat CAT XL* (10M XS 1.5M)**	**Amount of loss retained by insurer after the application of *Nat CAT XL (Net Post Nat CAT)***
1	10	6	4	6.500	1.500
2	1	0,6	0,4		
3	7,5	4,5	3		
…	…	…	…		
3.000	2,5	1,5	1		
Total	20.000	12.000	8.000		

Like any XL reinsurance contract, Nat CAT XL reinsurance contract can be contracted through levels (layers), which makes it easier to cede the risk to reinsurance, because reinsurers participating in the reinsurance pool can choose which level of risk they want to cover. If the insurer from the previous example buys a Nat CAT XL contract with two layers:

Layer 1: 2.500.000 XS 1.500.000 and

Layer 2: 7.500.000 XS 4.000.000,

he will receive compensation on the basis of both levels of reinsurance coverage, and the amount of damage he will retain will be equal to the agreed level of deduction (self-retention) determined by the reinsurance contract.

Table no. 4 shows the results of the above example.

Table 4 Example of natural catastrophe risk transfer by *Nat CAT XL* multi-layer contract (amounts in 000)

Number of insurance contract	Amount of loss covered by insurer	Amount of loss covered by reinsurer (60%) by applying quota share reinsurance	Amount of loss retained by insurer after the application of quota share reinsurance contract (*Net Pre Nat CAT*)	Amount of loss covered by reinsurer under *Nat CAT XL* Layer 2 (7.5M XS 4 M)	Amount of loss covered by reinsurer under *Nat CAT XL* Layer 1 (2.5M XS 1.5M)	Amount of loss retained by insurer after the application of Nat CAT XL *(Net Post Nat CAT)*
1	10	6	4	4.000	2.500	1.500
2	1	0,6	0,4			
3	7,5	4,5	3			
…	…	…	…			
3,000	2,5	1,5	1			
Total	20.000	12.000	8.000			

Aggregate stop loss reinsurance covers part of the cedant's total losses (non-catastrophic and catastrophic) over a period (of usually one year) above the agreed retention (usually agreed as a percentage of total net premium or as a pre-determined claims ratio). This coverage helps to protect against serious damage caused by catastrophic events, although it is provided based on the loss experience in a certain period (usually in a certain year), and not as a cover related to the occurrence of certain events. This type of contract is used to protect the overall results of insurance (especially large fluctuations in claims), and also after the application of other types of reinsurance contracts.

Alternative reinsurance contracts are among the most innovative natural catastrophe covers available on the world market today. According to Swiss Re estimates, these contracts cover about 25% of the insured catastrophic risks. However, the regulations of many countries still do not permit this type of reinsurance coverage. The most common alternative reinsurance contracts are ILS contracts (Insurance Linked Securities), and there are a number of other types of alternative reinsurance (such as collateralized reinsurance) that are also widely used in the international market.

The most common form of ILS are CAT Bonds. For buyers of these bonds, these are usually high-yield debt instruments (compared to other fixed-income bonds - because they involve the risk of catastrophic events) designed to provide money for re/insurers in the event of a natural disaster. CAT bonds allow re/insurers to receive funding from the bond only if specific conditions are met - a catastrophic event and a certain value of the agreed trigger for the payment of indemnity. If an event protected by the bond activates a payout to the re/insurer, the obligation to pay interest and repay the principal is either deferred or completely forgiven.

The transaction with the CAT bond begins with the establishment of an independent special purpose entity (SPE). A sponsor (insurer or reinsurer) wishing to provide coverage for its exposure to the risk of a catastrophic event enters into a contract with the Special Purpose Entity and pays a premium. The SPE is in charge of issuing the bond and placing it on the financial market. The funds raised through the placement of this bond are deposited in a separate account and, as a rule, should be further invested in highly liquid securities, with a stable rating. If the catastrophic event is not realized in the period defined by the contract, the bonds are paid in full. If the contracted event occurs and the triggers provided for in the contract are reached, all funds are withdrawn from the bilateral account in favour of the sponsor who uses them to pay overdue receivables. The value of the bond is accordingly adjusted. [23]If the total damage from the catastrophic event is greater than the value of the bond, investors waive their rights to collect from the bond they purchased (interest and principal). If the total loss from the insured event is less than the value of the bond, the balance after payment to the sponsor is returned to the investor.

Transactions related to CAT bonds are associated with a number of risks, such as credit risk, liquidity risk, modelling risk, etc. Nevertheless, the development of an alternative reinsurance market has had a positive impact on the availability of reinsurance coverage, facilitated the entry of additional capital, and mitigated the growth and volatility of reinsurance prices that have historically occurred after major catastrophic events,[24] which is considered an important contribution of this form of reinsurance coverage to the catastrophe risk management.

VI. Conclusion

Catastrophe risk management is a major challenge for individuals, businesses and governments, both in developed and developing countries. Insurance and re-

[23] N. Tešić, B. Paunović, P. Katanić, P, "Alternative Mechanisms of Transfering Catastrophe Risks to the Capital Market", *Insurance Market After Covid – 19*, University of Belgrade, Faculty of Economics Publishing Centre, 2020, pp. 344.

[24] Organisation for Economic Co-operation and Development, "The Contribution of Reinsurance Markets to Managing Catastrophe Risk", *OECD,* 2018, pp 16.

insurance services make an important contribution to managing the risks of natural disasters, by providing sources of funding for disaster recovery and reconstruction. The global traditional and alternative reinsurance market provides an additional source of capital to mitigate the financial impacts of natural disasters, diversify risks, and strengthen the capacity of insurers to provide affordable insurance for catastrophic risks.

Catastrophe risk management is a complex problem and involves multidisciplinary knowledge. Bearing in mind that there is no single methodology for determining the insurance premium for natural catastrophes, and that the application of traditional, deterministic methods is not appropriate, the paper discusses modern methods that could be used for determining the premium. The catastrophe insurance premium in contemporary circumstances is estimated by modelling and simulations. By stochastic methods, i.e. by applying probability theory, an approximation of claims experience is performed using statistical distributions. Different software tools play a significant role and provide valuable support to professionals in their decision-making and risk management.

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