Catastrophe Bonds Structures at European Level – A Cluster Analysis Approach

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The present paper aims at examining several characteristics of the catastrophe bonds (CB) market by focusing on emblematic transactions with the objective of stressing the choices of the European-based (re)insurance groups in terms of the CB tranches structure. For the purpose of highlighting the common individualities regarding the configuration of the catastrophe bonds, there are recognized homogenous groups in terms of covered perils and size of the each CB tranche, while emphasizing some stringent aspects linked to their trigger mechanism (like the basis risk), their rating, or tenor. The research identifies several profiles regarding the structural characteristics of the CB during the entire analysed period (1999-2014) and the main periods of development of the market. Accommodating categorical and continuous data, the structural patterns are determined and analysed by applying the two-step cluster methodology.

Keywords: *catastrophe bonds structure, alternative risk transfer mechanisms, two-step cluster analysis, (re)insurance European market*

JEL Classifications: *G22, G23, G32*

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I. Introduction

The catastrophe bonds (cat bonds – CB) are recognized as an important segment of the alternative risk transfer solutions (ART), a viable risk management mechanism for the (re)insurance industry and an effective alternative investment, especially in times of crisis. Within this context, there is a flourishing body of interdisciplinary literature that focuses on the research of these innovative financial instruments and the current paper aims to complement it by analysing empirically the connections between the various structural elements, while highlighting a series of aspects related to well-known strategic considerations when issuing cat bonds, by focusing on transactions developed by E.U. headquartered (re)insurance companies.

II. Theoretical Premises: Brief Insights on Structural Components, Basis and Moral Hazard Risk and Rating

The trigger mechanism – basis risk and moral hazard

The trigger mechanism and basis risk (along with moral hazard and transparency for investors) represent a key aspect of the securitization design when structuring and issuing cat bonds. The trigger mechanism defines the payment and exhaustion circumstances, being individualized the following types: purely parametric trigger, parametric index trigger, modelled loss triggers, pure industry loss triggers, modified industry loss triggers and indemnity triggers. Regarding basis risk, one of the most suggestive definitions is offered by GIRO (2008:3): *"The residual risk that remains with (re)insurer in respect of perils and territories covered by the selected protection strategy"*. More specifically, Ross & Williams (2009:49) explain basis risk with reference to *"the difference in the pay-outs between a sponsor's own losses and a risk transfer mechanism structured to hedge against those losses"*. In this respect, the specialized literature acknowledges, with respect to the choice of the trigger mechanisms, a trade-off between the basis risk supported by the cedent, on the one side, and the transparency to investors (with respect to the adverse selection and moral hazard aspects), on the other side (Doherty & Richter, 2002; Adena et al., 2009). The indemnity trigger-based transactions have the lowest level of basis risk and transparency towards investors as these ones reflect the cedent's actual losses. However, while advancing through industry loss (pure or modified) and modelled loss to parametric (pure or index) triggers both the level of basis risk and that of transparency increases, the parametric triggers being recognized as those with the highest level of cedent's basis risk and the lowest level of investor's moral hazard risk (Finken & Laux, 2009; Hagedorn et al., 2009).

The size, the peril, the covered territory and the tenor

Taking into account the evolution of the cat bond issued volume especially after 2005, the resilience of the market during the 2008-2009 period, as well as the recent performance (2010-2014 period), there is evidence and confirmation that cat bonds have become an important risk management strategic choice at the level of the (re)insurance industry, as previously noted within the specialized literature (Cummins, & Barrieu, 2013).). Within this context, *the size of the cat bonds*, beyond being a barometer of the activity within this market, may be employed to gauge on the importance in employing of these financial innovations as complementary risk management tools by the (re)insurance companies. *The peril and the covered territory* stand for to key elements when analysing the cat bonds transactions from the perspective of the choices of the cedent companies towards considering the transfer of catastrophe risks from one or multiple territories, covering single or multiple types of perils, or hedging only peak perils (generally considered those occurring in the USA), non-peak perils or both. At the level of the tranches of the cat bonds, the analysis of covered insurance risk is of interest as each class can refer to a different type of covered peril and/or territory (Krutov, 2010). *The tenor* has been one of the features of the cat bonds that has evolved over the years, while nowadays the majority of the transactions having an average maturity of three years, reflecting the choice of the cedent's towards multiple-year deals associated to less price volatility (Cummins & Barrieu, 2013; Lakdawalla & Zanjani, 2012).

The rating

In terms of rating, the majority of the cat bond tranches are assessed as being non-investment grade reflecting generally the probability that the bond will be triggered (Cummins, 2008). From the perspective of this research, the analysis will try to identify potential connections between the rating of the analysed cat bond tranches and the covered perils or the trigger mechanism.

The analysis is following another research (Constantin, 2014) which analysed the CB structures by focusing on deals developed by European headquartered companies (primarily, (re)insurance groups). The research involved clustering the deals through hierarchical and k-means methods based on their size/volume and then concluding on the risk management approach (tactical or strategic) based on an innovative index grounded on three pillars (tenor, trigger and, covered peril and area). While focusing on the same deals, in order to reveal further insights, the present research examines the transactions at the level of the tranches of each CB and considers individually each component. Furthermore, in order to account for the typology of the chosen variables (both categorical and continuous), there was employed another cluster methodology, mainly the two-step cluster analysis.

Research objective and hypotheses

The objective of the paper consists in examining the structural elements and the relationship among these ones at the level of the catastrophe bonds tranches, while also emphasizing a series of features related to basis risk, moral hazard and rating. The main developed hypotheses are as follows:

(1) We expect to find large statistically significant associations between the profiles (in terms of peril and size) of the identified clusters and the other considered elements (trigger, territory, rating, tenor)

(2) Considering the novelty of the cat bonds market and the homogeneity of the sample (a selection of cat bonds developed by E.U. headquartered reinsurance groups), we expect to find few statistically significant clusters

(3) We predict a change of the structural approach of the cat bonds tranches from one stage of development of these financial products to another that reflects the various strategic choices of the (re)insurance companies on this market

III. Analysis of the Cat Bonds Structures – Insights at the Level of the Tranches

Data

The research consisted in identifying homogeneous groups of CB tranches in terms of two important structural elements: the size of each tranche and the covered peril. The data was collected from the well-known blog http://www.artemis.bm/, dedicated to the alternative risk transfer solutions (http://www.artemis.bm/deal_directory/).

The *size of each tranche* was chosen as a reflection of the contribution to the cedent's overall involvement in the cat bond market and of the importance of that tranche for the overall sample. The *peril* variable revealed the transfer of multiple or single catastrophes (wind – including hurricanes, typhoons, or European windstorms or earthquake).

The sample consists in a selection of 73 publicly revealed CB tranches developed between 1999 and 2014 by some of the most important European headquartered (re)insurance companies/groups (Achmea Reinsurance Company N.V., AGF, Allianz, Amlin AG, Assicurazioni Generali S.p.A., Axa, Brit Insurance, Groupama, Hannover Re, Munich Re, SCOR, and Sorema). For each tranche, besides the tranche and the covered peril, there were considered the following structural features:

(i) the trigger mechanism – the six main types of trigger mechanisms were combined following a taxonomy that includes four categories: *parametric, modelled loss, industry loss and indemnity* [6]. This variable is analysed within the analysis in order to reflect several core aspects related to these financial instruments: the cedent's basis risk and the moral hazard and the transparency from the investor's perspective.

(ii) the covered territory – related to the covered peril, this variable was analysed separately in order to better reflect the characteristics from the perspective of the CB tranches developed, as cedents, by E.U. based reinsurance companies (Europe, Japan, Multiple, or U.S.A.)

(iii) the rating – this variable was included in order to reflect the connections between the structural features and the credit quality of each tranche. Considering the various rating tiers published by the largest rating agencies (Moody's, S&P, and Fitch Ratings) and based on the tranches included in the sample, there were considered the following categories: investment grade (IG), non-investment grade (NI) with a series of tiers (non-investment grade speculative – NIG_S and non-investment grade highly speculative – NIG_HS) and not-rated (NR).

(iv) the tenor – also an important structural element, this variable was considered in order to reflect the potential relationships between the maturity of the CB tranches, the clustering results and the other above mentioned elements.

A summary of the descriptive statistics of the six variables used within the analysis is available at the authors, on request.

Two-Step Cluster Analysis

In terms of methodology, there was employed the two-step cluster analysis to accommodate the mixed composition of the selected data (the size – continuous variable and the peril – nominal variable), while also considering the advantage of determining the optimal number of clusters (Dossa et al., 2011).

This method was also considered because though it assumes the continuous variables follow a normal distribution and the categorical a multinomial one, the procedure performs quite reasonably even when this condition are not respected (Dossa et al., 2011; Norušis, 2011; Chan, 2005). The analysis was developed by employing the two-step cluster methodology with the SPSS IBM software package.

This methodology, developed by Chiu et al. (2001) (cited, also, in Mooi & Sarstedt, 2011) implies, intuitively, two steps: (i) a pre-clustering stage there is employed a sequential clustering procedure through which, while analysing each record, there is decided whether the current observation pertains to the already formed clusters, or it should be included in a new one and (ii) after performing the pre-clustering procedure, the already formed clustered are grouped in order to attain the desired number of clusters through the agglomerative hierarchical clustering technique (SPSS Inc., 2001; IBM SPSS 20 Help/Tutorial. Help a).

Considering that the research is developed through both categorical and continuous variables, there was used, as distance measure based on probability – the Log-likelihood, while following Chiu et al. (2001), as cited in Michailidou et al. (2009), and the Two Step Cluster Algorithms presented in the SPSS IBM 20 Help/Tutorial and other SPSS IBM documents (Chiu et al., 2001; Michailidou et al. 2009; IBM SPSS 20 Help/Tutorial. Help b). In order to determine the number of clusters, there was employed BIC – the Bayesian information criterion, determined for each number of clusters within a specified array (IBM SPSS 20 Help/Tutorial. Help c).

The decision regarding the appropriateness of the solutions was also based through considering the Akaike's information criterion – AIC, while also examining the silhouette measure (a coefficient that regard both the cohesion and separation with respect to the formed clusters). Closer to one is this coefficient, the better is the solution as a reflection of the small distances between elements within a cluster (cohesion) and of the large distances between cases that pertain to different clusters (separation).

Once the clustered were identified, the analysis was directed towards examining the stability of the solutions through one-way ANOVA analysis and chi-square tests. Afterwards, there was examined the relationship between the traits of the formed clusters based on the size and the covered perils of the CB tranches and the other nominal (the trigger mechanism, the covered territory, and the rating) and continuous variables (the tenor). While for the continuous variable there was considered the one-way ANOVA analysis, for the nominal ones there was implemented the chi-square test. With respect to the chi-square test, there was considered the Koehler & Larntz (1980) rule of thumb (a number of observations of at least ten, the square of this number at least ten times the number of categories, while the number of categories is no less than three) (Koehler & Larntz, 1980), in favour of the more conservative one of Cochran (1954).

The analysis was conducted both from a static perspective, for the overall sample (1999-2014 period), and from a dynamic one, considering three periods that characterise this market: the evolutionary period (1999-2004), the "take-off" period (2002-2007), and the mainstream period (2008-2014). While the two first periods are inspired from a seminal paper that investigates the CB market (Cummins & Weiss, 2009), the last one reflects the consolidation of the market of these instruments while also considering the resilience of these instruments even during the most recent economic crisis. Considering the sample dimension, the dynamic analysis was considered, on the one side, for the evolutionary and "take-off" period, combined, and, on the other side for the mainstream period, while also revealing a number of comprehensions concerning the CB structural aspects in normal and turbulent times on the financial markets. Furthermore, starting the mainstream period with the 2008-2009 years was also based on the fact that within this period the cat bond market proved its true resilience within the turbulent times on the financial markets: while in 2007 the cat bond market evolution proved to be an exception within the stormy environment of the financial crisis, the collapse of Lehman Brothers in 2008 resulted in a decrease of the activity on this market but, at the same time, proved that with the appropriate structural changes this securitization segment can resist and further recover and develop as the recent period proves. From this, one can infer that the proper knowledge of the sources of risk did not cause inadequacies or even worse outcomes (Marinoiu, 2009). Moreover, as catastrophe bonds were becoming more and more to be considered an environmental and climate change related risk management tool, one can infer that this was also a driver of their success, considering that the specialized literature links corporate social responsible accomplishments to competitiveness (Iamandi, 2013). Therefore, the mainstream period starts with 2008-2009 period as this, in our opinion, along gaining the critical mass, stable and efficient risk management tools should be characterized by mature structural features.

Discussion of the Main Research Findings

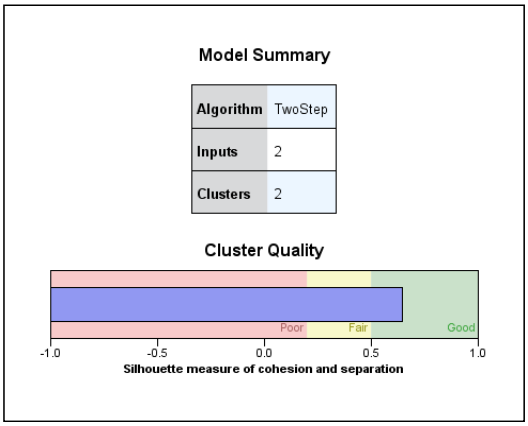
Static analysis

After employing the two-step cluster analysis for the overall period – the static approach, the research findings showed that the suitable solution, based both on BIC and AIC, was a two-segment one, while the silhouette measure above 0.5 (0.6), confirmed a good quality regarding both the cohesion and the separation (displayed in Fig. 1).

In terms of validity of the cluster solutions, both the one-way ANOVA (for the continuous variable – size) and the cross-tabulation analysis (chi-square for the categorical variable – peril) revealed the statistical significance of the results. For the one-way ANOVA, there was previously checked the assumption homogeneity of variance which, following the Levene's test, was not fulfilled ($p\text{-value}<0.05$). Therefore, instead of using the Fisher F test, there were employed both the Welch and Brown-Forsythe ones which confirmed that the means are significantly different (p-value<0.05) – table available at the authors on request. As far as the results of the cross-tabulation are concerned (table available at the authors on request), the first cluster comprises, mainly, multiple peril tranches, while the second cluster is composed, almost entirely, by classes of Cat bonds that cover hurricanes, European storms or typhoons. The three tranches covering earthquake considered in the analysis are, also, distributed in cluster 2. The chi-square test (χ^2=73, with p-value<0.05, while applying the Koehler & Larntz (1980) rule of thumb for acceptance) confirmed that the peril pattern is different in the first and in the second cluster as there is a significant association between the peril of the cases and the cluster they pertain to.

Figure 1

Cluster Solution for the Overall Period – Summary and Quality

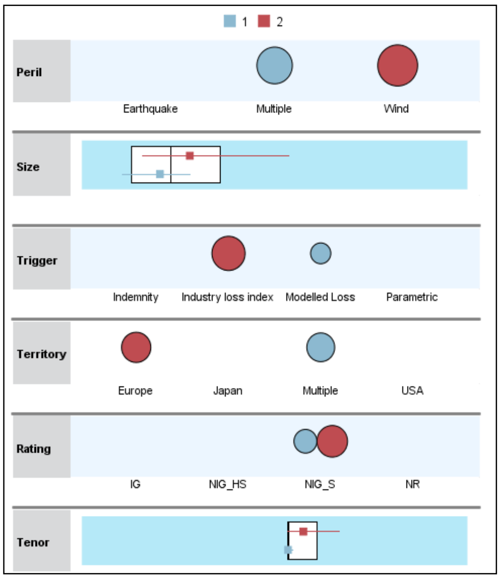


Source: authors' contribution (developed in SPSS IBM)

The analysis also implied the comparison of the two clusters (Fig. 2) both in terms of the variables that served to form the clusters (size and peril) and in terms of the evaluation ones (trigger, territory, rating, and tenor).

Figure 2

Cluster Solution for the Overall Period – Cluster Comparison



Source: authors' contribution (developed in SPSS IBM)

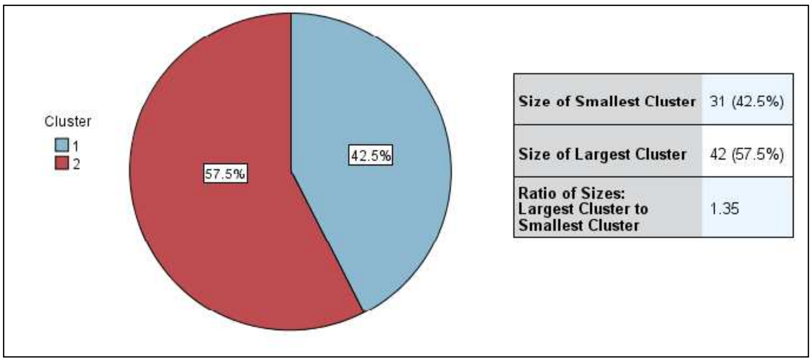
Considering also the validity of the solution, it seems that the analysed tranches pertain to the following patterns in terms of size and peril: Cluster 1 (Lower size – multiple perils) and Cluster 2 (Higher size – single perils): ***(1) Cluster 1 (Lower size – multiple perils)*** is characterized by smaller size/volume of the tranches (average=88.77 and median=88.98), mostly modelled loss and industry loss index triggers (32.3%), the tranches refer mainly to multiple territories (61.3%), with the majority of ratings pertaining to the non-investment grade – speculative tier (41.94%), and a slightly lower tenor (mean=3.04 and median=3) and ***(2) Cluster 2 (Higher size – single perils)*** comprises tranches with a rather larger size/volume (average=145.97 and median=119.2), with mainly industry loss index triggers (64.29%), European oriented classes in terms of the covered territories, with the majority of ratings pertaining also to the non-investment grade –

speculative tier (54.76%), and a slightly higher tenor (mean=3.16 and median=3.17).

Once checked the validity of the cluster solution, there was further analysed the distribution of the elements in each cluster, in terms of number of cases and frequency (Fig. 3). As can be notices, the sizes of the two clusters are rather balanced (with a 1.35 ratio of sizes), cluster 2 having a greater number of elements (42 out of 73).

Figure 3

Cluster Solution for the Overall Period – Cluster Sizes



Source: authors' contribution (developed in SPSS IBM)

Further, in order to check the association between the nominal variables (trigger, territory, and rating) and the patterns of the two formed clusters there was employed the crosstabs analysis (table available at the authors on request) along with the chi-square test. For all three variables, the chi-square test confirmed that there is association between each of them and the two Cat bond trances profiles (trigger: χ^2=20.5, with p-value<0.05; territory: χ^2=20.06, with p-value<0.05, and rating: χ^2=8.99, with p-value<0.05; while applying the Koehler & Larntz (1980) rule of thumb for acceptance). For the tenor, the one-way ANOVA analysis was run in order to check the performance of this variable in formally differentiating between the two clusters, concluding that the means are not significantly dissimilar. In addition, with respect to the stage of development of the Cat bond market and the allocation of the tranches within the two clusters, it seems that within Cluster 2 there are mainly transactions from the "take-off" and "mainstream" period (only one tranche from the evolutionary period), in Cluster 1 there are present tranches of CB from all the three periods. Once established the statistical significance of the association between the three categorical variables and the patterns concerning the two clusters, the research was complemented with several measure of the association in order to determine the magnitude of that association – *Phi, Cramer's V, and the Contingency Coefficient.* As can be noticed in Table 1, there is a rather strong, statistically significant, association between each of the three variables and the clusters' profiles.

Table 1

Association Tests

Test	***Trigger***		***Territory***		***Rating***	
	Value	Approx. Sig.	Value	Approx. Sig.	Value	Approx. Sig.
Phi	0.530	0.000	0.524	.000	0.351	0.029
Cramer's V	0.530	0.000	0.524	.000	0.351	0.029
Contingency Coefficient	0.468	0.000	0.464	.000	0.331	0.029
N of Valid Cases	73					

Source: authors' contribution (developed in SPSS IBM

Dynamic analysis

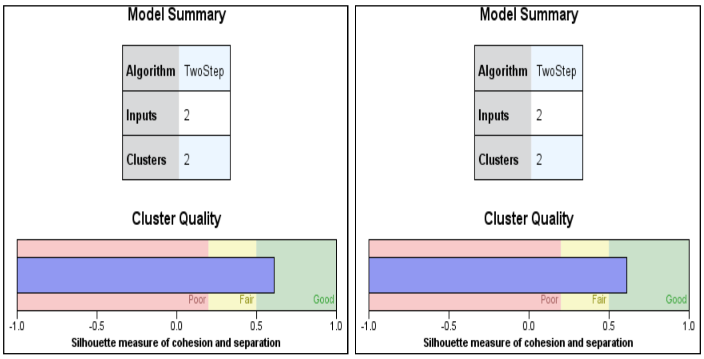
When analysing from a dynamic perspective, at the level of the evolutionary and "take-off" period, on one side, and the mainstream period, on the other side, the achieved findings revealed, as for the case of the static analysis, a two-cluster solution (with a silhouette coefficient of 0.6, which settled the good quality of the solution in terms of cohesion and separation). These results are displayed in Fig. 4.

As far as the validity of the cluster analysis results is concerned, after employing the one-way ANOVA and the cross-tabulation analysis, it resulted in a statistical significance of the solutions.

For the evolutionary and take-off period, the Levene's test revealed that the homogeneity of variance was not violated as the p-value>0.05. Therefore, there was employed the Fisher F test (ANOVA) that revealed that the means are virtually different (p-value=0.054). For the mainstream period, the Levene's test suggested that the homogeneity of variance condition is violated and, instead of using Fisher F test, the robust tests of equality of means (Welch and Brown-Forsythe) should be used. These ones confirmed that the means are significantly different (p-value<0.05) – table available at the authors on request.

Figure 4

Cluster Solution for the Evolutionary and "Take-off" Periods and for the Mainstream Period



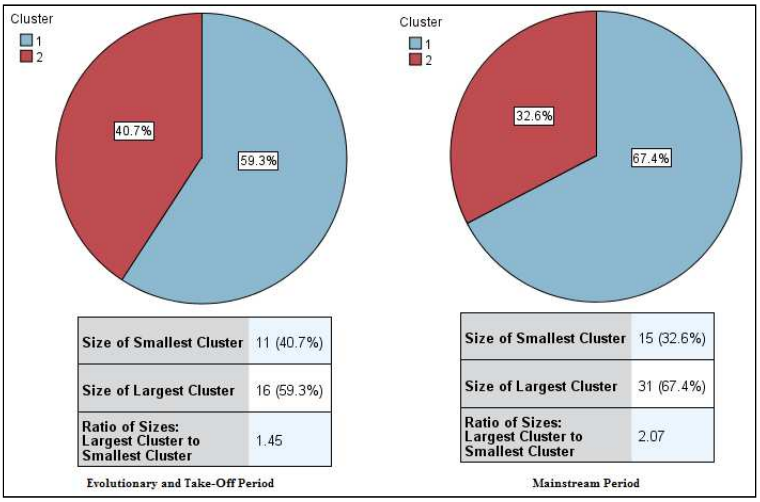
Source: authors' contribution (developed in SPSS IBM)

With regard to the cross-tabulation analysis, the chi-square test (p-value<0.05, while applying the Koehler & Larntz (1980) rule of thumb for acceptance) confirmed that, for the two investigated periods, there is a significant association between the peril of the cases and the cluster they pertain to. The following patterns emerge (table available at the authors on request.): ***(a) For the first analysed period*** (evolutionary and "take-off"): Cluster 1 comprises only multiple peril tranches and Cluster 2 encompasses of Cat bonds tranches that cover hurricanes, European storms or typhoons. The only earthquake-covering tranche pertains to Cluster 2 and ***(b) For the second analysed period*** (mainstream): Cluster 1 encompasses mainly Cat bonds tranches that cover hurricanes, European storms or typhoons and the only two Cat bond tranches that cover earthquake, while Cluster 2 is formed entirely by tranches that cover multiple perils

However, there seems that the dynamic analysis, as well as the static one, also reveals a two-cluster solution in which one cluster is made entirely of multiple peril tranches, while the other comprises single peril tranches.

Figure 5

Cluster Solution for the Evolutionary and "Take-Off Period" & Mainstream Period – Cluster Sizes



Evolutionary and Take-Off Period	
Size of Smallest Cluster	11 (40.7%)
Size of Largest Cluster	16 (59.3%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	1.45

Mainstream Period	
Size of Smallest Cluster	15 (32.6%)
Size of Largest Cluster	31 (67.4%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	2.07

Source: authors' contribution (developed in SPSS IBM)

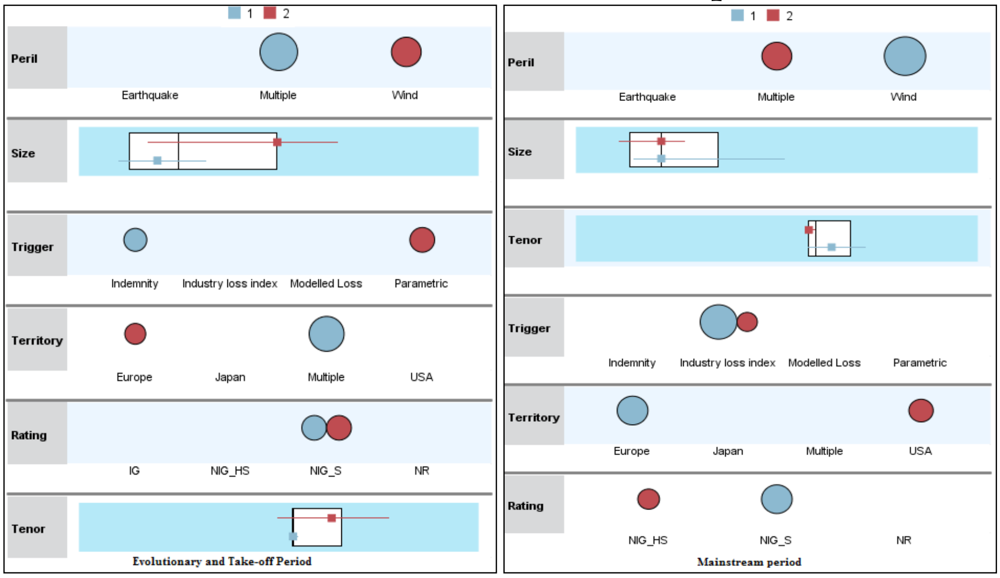
The allocation of the cases in each cluster (Fig. 5) reveals that the sizes of the two clusters, both for the first and for the second period are rather balanced (with a 1.35, respectively a 2.07 ratio of sizes), Cluster 2 having a greater number of elements (16 out of 27 for the evolutionary and "take-off" period and 31 out of 46 for the mainstream period). As for the static analysis, the research was accompanied by the comparison of the two clusters (Fig. 6) both in terms of the variables that served to form the clusters (size and peril) and in terms of the evaluation ones (trigger, territory, rating, and tenor).

For the first period (evolutionary and "take-off"), the results revealed the following patterns: ***(1) Cluster 1: Lower size – multiple perils*** – smaller size/volume of the tranches (average=78.28 and median=65.34), mostly indemnity triggers (37.5%), the tranches refer mainly to multiple territories (87.5%), with the majority of ratings pertaining to the non-investment grade – speculative tier (43.75%), and a slightly lower tenor (mean=3.08 and median=3) *and* ***Cluster 2 – Higher size – single perils*** – comprises tranches with a rather larger size/volume (average=137.77 and median=149.94), with mainly parametric triggers (63.64%), European oriented classes in terms of the covered territories, with the majority of ratings pertaining also to the non-investment grade – speculative tier (63.64%), and a slightly higher tenor (mean=3.15 and median=3.42).

For the second period (mainstream), the results revealed the following patterns: ***(1) Cluster 1 – Higher size – single perils*** – comprises tranches with a rather larger size/volume (average=148.88 and median=100.75), with mainly industry-loss triggers (74.2%), European oriented classes in terms of the covered territories, with the majority of ratings pertaining also to the non-investment grade – speculative tier (51.61%), and a slightly higher tenor (mean=3.17 and median=3.17) and ***Cluster 2: Lower size – multiple perils – smaller size/volume*** of the tranches (average=99.96 and median=100.75), mostly industry-loss triggers (46.67%), the tranches refer mainly to USA in terms of covered territory (66.67%), with the majority of ratings pertaining to the non-investment grade – highly speculative tier (53.33%), and a slightly lower tenor (mean=3 and median=3).

Figure 6

Cluster Solution for the Evolutionary and "Take-Off Period" & Mainstream Period – Cluster Comparison



Source: authors' contribution (developed in SPSS IBM)

The investigation regarding the association between the nominal variables (trigger, territory, and rating) and the patterns of the two formed clusters was performed through the crosstabs analysis (table available at the authors on request) along with the chi-square test. For two of the three variables (trigger and territory), the chi-square test confirmed that there is association between each of them and the two Cat bond tranches patterns, for both of the two considered periods. As for the static analysis, the one-way ANOVA analysis revealed that the means are not significantly different when considering the tenor.

After confirming the statistical significance of the association between the two of the categorical variables and the patterns in terms of size and peril that characterize the two identified clusters, the research was fulfilled by determining some measure of the magnitude of that association – Phi, Cramer's V, and the Contingency Coefficient. As can be noticed in Table 2, the association between trigger and territory, on one side, and the clusters' profiles is quite strong and statistically significant.

Table 2

Association Tests

Period	**Ev&Toff**		**Mainstream**	
Trigger	**Value**	**Approx. Sig.**	**Value**	**Approx. Sig.**
Phi	0.644	0.011	0.573	0.002
Cramer's V	0.644	0.011	0.573	0.002
Contingency Coefficient	0.541	0.011	0.497	0.002
N of Valid Cases	27		46	
Territory	**Value**	**Approx. Sig.**	**Value**	**Approx. Sig.**
Phi	0.884	0.000	0.594	0.001
Cramer's V	0.884	0.000	0.594	0.001
Contingency Coefficient	0.662	0.000	0.510	0.001
N of Valid Cases	27		46	
a. Not assuming the null hypothesis.				
b. Using the asymptotic standard error assuming the null hypothesis.				

Source: authors' contribution (developed in SPSS IBM)

IV.Conclusions

The first validated hypothesis refers to identifying few clusters in terms of size and peril at the level of the analysed sample. Therefore, by identifying two clusters

(Cluster 1 – Lower size – multiple perils and Cluster 2 – Higher size – single perils – more specifically, wind related natural catastrophes), both through the static analysis, as well as through the dynamic analysis, beyond confirming the expectation, this result confirms that the (re)insurance companies headquartered in E.U. have rather well delineated homogenous strategies in terms of structuring of the cat bonds tranches. Furthermore, the majority of tranches in the second cluster (higher size) cover only European wind or also include European wind (considered non-peak risks). Therefore, it seems there is a propensity of these companies towards using the cat bond market not only for diversifying the hedging of peak risks through non-peak risks, but actually as a complementary solution to the classic methods of managing natural catastrophes that distress socially and economically the European continent.

The hypothesis regarding large statistically significant associations between the profiles (in terms of peril and size) *of the identified clusters and the other considered elements* (trigger, territory, rating, tenor), *though only partially, it was also confirmed.* Specifically, for the static analysis, the results revealed rather high association coefficients between trigger, territory, and rating and the pattern of each cluster, reflecting that there is a statistically significant link as follows: (1) lower-sized, multiple-peril tranches generally are characterized by modelled loss and industry loss index triggers, cover multiple territories and the majority of ratings pertain to the non-investment grade – speculative tier and (2) higher-sized, single perils tranches employ mostly industry loss index triggers, mostly covering catastrophes occurring only within the European continent, the majority of ratings being characterized as belong to the non-investment grade – speculative tier. In addition, the outcomes of the static analysis prove that the tranches are quite homogenous in terms of rating - as a snapshot of the analysed period.

For the dynamic period, only the trigger and territory variables proved to be statistically associated with the two profiles. For the evolutionary and "take-off" period there seems that: (1) lower sized, multiple-peril tranches are associated to indemnity triggers, while covering multiple territories and (2) higher-sized, single-peril tranches are related mainly to parametric triggers and European territories. For the mainstream period, /the results suggest that: (1) lower-sized, multiple-peril tranches are linked mostly to industry-loss triggers while the tranches refer mainly to USA in terms of covered territory and (2) higher-sized, single-peril tranches are associated mainly with industry-loss triggers, while covering mostly natural catastrophes that occur in European territories.

The last hypothesis, concerning *the change of the structural approach of the cat bonds tranches from one stage of development (evolutionary and "take-off") of these financial products to another (mainstream period), was mostly confirmed*, reflecting the various strategic choices of the (re)insurance companies on this market. Specifically, though the profiles of the two clusters follow the same pattern (lower size – multiple perils versus higher size – single peril – mostly wind) for both periods, in terms of the average size of the tranches there seems to be an increase from one period to another, which could reflect the tendency of the cedents' of employing more this market as complementary solution for managing natural catastrophes. Furthermore, it is interesting to notice that both during in times of normality, as well in times of crisis and recovery on the financial markets, these instruments seem to have a stable pattern size-peril.

In terms of the covered territory, at the level of the lower-sized multiple-peril cluster there seems to be a shift from multiple covered territories to a single, peak territory (USA). However, for the higher-sized single-peril cluster, the majority of the tranches reflect the tendency of covering European territories.

While for the first considered period the majority of the indemnity triggers are two extremes in terms of basis risk and moral hazard (parametric – high basis risk and low moral hazard risk for the higher-sized single-peril cluster and indemnity – low basis risk and high moral hazard risk for the lower-sized multiple-peril cluster), for the second one, there seems to be a propensity towards industry loss index triggers at the level of the cat bond tranches, reflecting the strategy of choosing a more balanced trade-off between basis risk and transparency toward investors. Overall, the static research results, which stand for an outline of the examined tranches over the analysed period, show that in terms of the trigger, both at the level of the first cluster (modelled loss) and at the level of the second one (industry loss index) there is a propensity towards middle choices in terms of the trade-off basis risk-moral hazard.

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V. References

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