Estimation of Credible Net Premiums by World Regions to Cover Catastrophe Losses

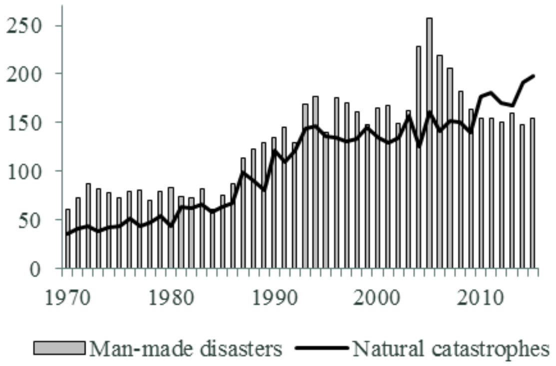
PAVLA JINDROVÁ
Institute of Mathematics and Quantitative Methods
Faculty of Economics and Administration
University of Pardubice
Studentská 95, 532 10 Pardubice
CZECH REPUBLIC
Pavla.Jindrova@upce.cz http://www.upce.cz/fes/index.html

Abstract: - The number of catastrophic events and the amount of economic losses is varying in different world regions. Part of these losses is covered by insurance. Catastrophic events in last years are associated with increases in premiums for some lines of business. The aim of this article is determination of estimates of the net premiums that would be needed to cover total or insured catastrophic losses in different world regions. For these estimates Bühlmann and Bühlmann-Straub empirical credibility models based on data from Sigma Swiss Re 2010-2016 are used. The empirical credibility models have been developed to estimate credibility premium or insurance premium for short term insurance contracts using two ingredients: past data from the risk itself and collateral data from other sources considered to be relevant. In this article we deal with application of these models based on the real data about number of catastrophic events and about the total economic and insured catastrophe losses in seven regions of the world in time period 2009-2015. Our significant results of estimated credible premiums by world regions provide information about how much money in these regions will be need to cover total or insured catastrophic losses in the next year.

Key-Words: - Empirical credibility model, economic losses, insured losses, net premium, world regions.

1 Introduction

Catastrophic events affect various regions of the world with increasing frequency and intensity. Large catastrophic events can be caused by natural phenomena or are caused by man (Fig.1). It should be noted that many events of natural character are to a large extent influenced by human activity.



Source: Sigma Swiss Re, No 1/2016, [20]

Fig.1 Number of catastrophes events 1970-2015

Such an event generally results in a large number of individual losses involving many insurance policies. An event is classified as a catastrophe and included in the *Sigma* database when insured claims, total losses or the number of casualties exceed certain thresholds, detailed in Table 1.

Table 1. The Sigma event selection criteria 2015

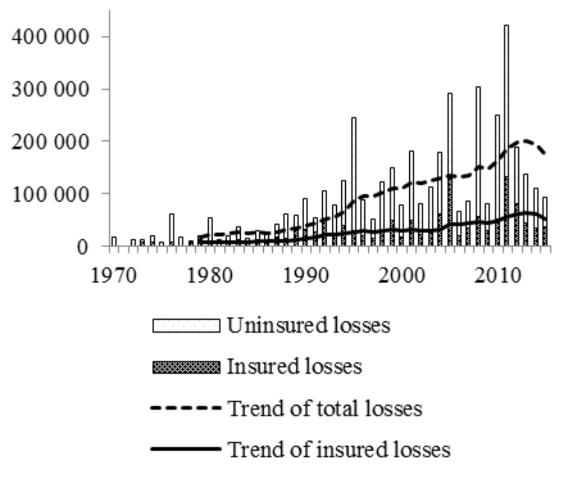
Insured losses:		
	Maritime disasters	19.7 USD million
	Aviation	39.3 USD million
	Other losses	48.8 USD million
or Total economic losses:		97.7 USD million
or Casualties:		
	Dead or missing	20
	Injured	50
	Homeless	2000

Source: Sigma Swiss Re, No 1/2016, [20] By *Sigma* [21] there were 198 natural catastrophes in 2015, and 155 man-made disaster events. The estimated total economic losses from natural catastrophes and man-made disasters across the world were USD 92 billion in 2015. This is less than the USD 113 billion total loss in 2014, and is well below the inflation-adjusted average of the previous 10 years (USD 192 billion).

The insurance industry covered almost USD 37 billion – less than half – of the total losses from natural and man-made disasters in 2015, and well below the inflation adjusted previous 10-year annual average of USD 62 billion. Natural catastrophes resulted in claims of USD 28 billion, the lowest since 2009 and again much lower than the previous 10-year inflation-adjusted annual average (USD 55 billion). Large man-made disasters led to claims of USD 9 billion, up from USD 7 billion in 2014.

The occurrences of catastrophic events are becoming more frequent (Fig. 1) and also grow indemnity of insurance and reinsurance companies at these events (Fig. 2).

Fig. 2 shows also the difference between insured and total losses over time period 1970-2015, termed the insurance protection or funding gap. It is the amount of financial loss generated by catastrophes not covered by insurance. In this figure it is evident growing trend both total and insured catastrophe losses in time period 1970-2015, determined by 10-years moving averages. The rate of growth of total losses has outpaced the growth of insured losses.

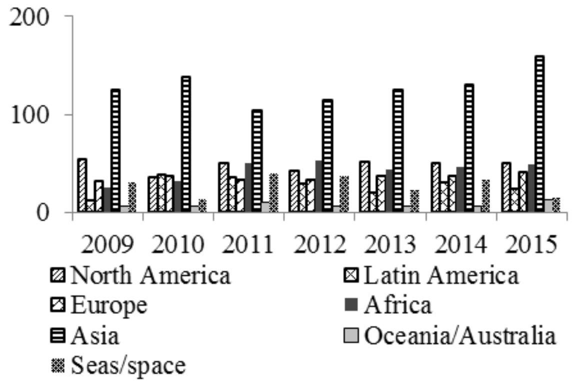


Source: Sigma Swiss Re, No 1/2016

Fig. 2. Insured and uninsured losses in 1970-2015 in USD million in 2015 prices

Catastrophic events affect various regions of the world with increasing frequency and intensity. Large catastrophic events can be caused by natural phenomena or are caused by man.

The number of catastrophic events is also varying in different regions of the world. The catastrophic events by Sigma Swiss Re are monitored for seven regions - North America, Latin America, Europe, Africa, Asia, Oceania/Australia and Seas/space. Number of catastrophe events by regions in 2009-2015 present Fig. 3 and Table 2.



Source: Own processing by Sigma Swiss Re, 2010-2016

Fig. 3. Number of catastrophe events by regions for 2009-2015

In Table 2 we can see the number of catastrophe events by regions for the period 2009-2015. We can see that the values are great in Asia for all years and the highest value is in 2015, ie. 159 catastrophe events.

Table 2. Number of catastrophe events by regions for 2009-2015

	2009	2010	2011	2012	2013	2014	2015
North America	54	36	50	43	52	51	51
Latin America	13	39	36	30	20	31	25
Europe	32	37	34	33	38	37	41
Africa	26	32	51	53	44	47	49
Asia	125	139	104	115	125	130	159
Oceania/ Australia	7	7	10	7	6	7	13
Seas / space	31	14	40	37	23	33	15

Source: Own processing by Sigma Swiss Re, 2010-2016

On the other side, we can see the smallest number of catastrophe events is in Oceania/Australia.

The worldwide insurance industry has been rocked by the increasing catastrophes in recent years and increased demand for catastrophe cover (e.g., per occurrence excess of loss reinsurance), leading to a capacity shortage in catastrophe reinsurance. Catastrophe events in last years are associated with increases in premiums for some lines of business.

Regional differences can be observed not only in the number of catastrophic events, but also in the values of economic losses.

In Table 3 we can see values of total economic losses by region in 2009-2015 in USD billion and we can compare the differences among regions.

Table 3. Total economic losses by region in 2009-2015 in USD billion

	2009	2010	2011	2012	2013	2014	2015
North America	20.1	20.6	63.5	118.5	32.0	28.6	28.6
Latin America	0.6	53.4	5.6	4.2	9.0	8.2	7.5
Europe	20.1	35.2	8.7	26.8	33.0	15.9	12.6
Africa	0.5	0.3	1.6	1.5	1.0	1.5	1.2
Asia	16.7	78.8	260.1	30.5	62.0	51.7	37.7
Oceania/ Australia	2.1	13.1	27.8	1.1	3.0	2.3	3.0
Seas / space	2.0	20.6	3.6	3.1	1.0	1.7	1.1

Source: Own processing by Sigma Swiss Re, 2010-2016

Part of these losses is covered by insurance. The share of insured losses on total losses again varies by region (see Table 4). The values of insurance catastrophic losses by region are in USD billion. In Table 3 and Table 4 we can see significant differences among regions, as well as differences among years in individual regions.

The greatest differences are in Asia region again. The smallest value of total economic losses and insurance losses is in Africa.

The collected premiums used to cover the insured losses not only in the region of insured, but if necessary, in other regions of the world. It is caused by the globalization of the insurance and reinsurance market.

Table 4. Insurance losses by region in 2009-2015 in USD billion

	2009	2010	2011	2012	2013	2014	2015
North America	12.7	15.3	39.8	64.6	19.0	17.5	17.3
Latin America	0.1	9.0	0.6	0.9	2.0	2.3	3.2
Europe	7.7	6.3	4.3	5.5	15.0	6.6	6.2
Africa	0.2	0.1	0.3	0.2	1.0	0.8	0.0
Asia	2.4	2.2	49.2	3.4	6.0	5.2	7.0
Oceania/ Australia	1.3	8.9	19.1	0.3	1.0	1.0	2.1
Seas / space	2.0	1.6	2.4	2.4	1.0	1.3	0.9

Source: Own processing by Sigma Swiss Re, 2010-2016

The article will therefore focus on estimating the amount of net premiums that would be needed to cover the total catastrophic losses in each region. For this purpose we will use empirical credibility models. In the second part of this article we focused on the introduction of the credibility theory. The next part presents applications of using Bühlmann and Bühlmann-Straub empirical credibility models in real data in seven regions of the world and you can also find the results of these models there.

2 Problem Formulation

Credibility theory is a technique, or set of techniques, for calculating premiums for short term insurance contracts. The technique calculates a premium for a risk (in our case for a region) using two ingredients: past data from the risk itself and collateral data, i.e. data from other sources considered to be relevant, in our cases from other regions. The essential features of a credibility premium are that it is a linear function of the past data from the risk itself and that it allows for the premium to be regularly updated as more data are collected in the future [1, 2, 13, 14, 16, 19].

A credibility premium represents a compromise between the two above mentioned sources of information. The credibility formula for estimation of pure premium P_c in the next year is [6, 7, 8]:

$$P_c = Z\, P_r + (1 - Z)\,\mu \qquad (1)$$

where P_r is estimation based on own past data in risk, or region, μ is estimation based on collateral data and Z is a number between zero and one, known as the *credibility factor*.

Credibility factor Z is a measure of how much reliance the company is prepared to place on the own data [8, 9, 10, 11].

3 Problem Solution

Empirical Bayes credibility theory is the collective name for the vast literature which has developed since Bühlmann [2] and Bühlmann and Straub [3].

3.1 Application of Bühlmann credibility model

The form of empirical Bayes credibility premium as a result of Bühlmann credibility model has been derived in [2] as

$$E(m(\theta)/\mathbf{x}) = Z\,\bar{x} + (1 - Z)E(m(\theta)) \qquad (2)$$

with factor credibility Z defined by

$$Z = \frac{n}{n + \dfrac{E(s^2(\theta))}{D(m(\theta))}} \qquad (3)$$

In empirical Bayes credibility model we use the available data (values of total economic losses by regions taken from Table 3) to estimate the quantities $E(m(\theta))$, $D(m(\theta))$, $E(s^2(\theta))$, and hence obtain a Bühlman type credibility premium estimate [2] for a particular risk.

Derived relations necessary for estimates are:

$$est\ E(m(\theta)) = \overline{X} \qquad (4)$$

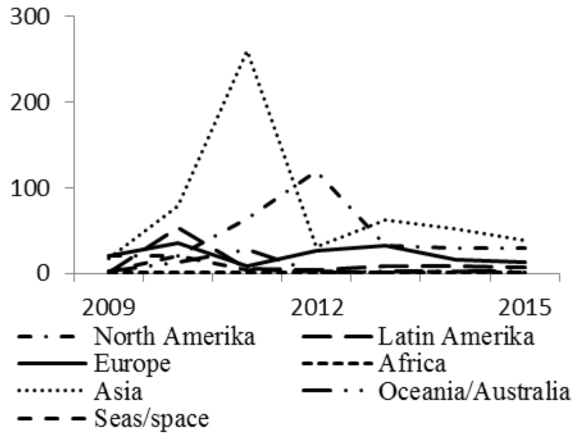
$$estE(s^2(\theta)) = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{n-1}\sum_{j=1}^{n}\left(X_{ij} - \overline{X}_i\right)^2 \qquad (5)$$

$$estD(m(\theta)) = \frac{1}{N-1}\sum_{i'=1}^{N}\left(\overline{X}_i - \overline{X}\right)^2 - \frac{1}{N\,n}\sum_{i=1}^{N}\frac{1}{n-1}\sum_{j=1}^{n}\left(X_{ij} - \overline{X}_i\right)^2 \qquad (6)$$

The derivation of these relations can be found in Bühlmann [2] and Waters [19].

Table 3 and Fig. 4 give present the total economic losses (in USD billion) to each of seven regions of the world over seven years.

Fig. 4 shows times series plot of total economic losses by regions in 2009-2015 in USD billion. We can see the highest value in 2011 in Asia region, the second highest value in 2012 in North America and the third highest value in 2013 in Asia again. We can see the differences among regions in these values.



Source: Own processing by Sigma Swiss Re, 2010-2016

Fig. 4 Times series plot of total economic losses by regions in 2009-2015 in USD billion

Table 5. Results of Bühlmann credibility model for data about total economic losses

	$\overline{X_i}$	Credibility premium
North America	44.54	39.66
Latin America	12.63	15.38
Europe	21.76	22.33
Africa	1.08	6.60
Asia	76.80	64.21
Oceania / Australia	7.48	11.47
Seas/space	4.73	9.38

Source: Own calculations

Using the Bühlmann credibility model we have calculated the credibility factor and credibility premium for the next year for each of the seven regions. For each of the regions we calculate means $\overline{X}_i = \sum_{j=1}^{n} X_{ij} / n$. These values contains second column in Table 5.

Using expressions (4) - (6) we have estimated $E(m(\theta))$, $E(s^2(\theta))$, $D(m(\theta))$:

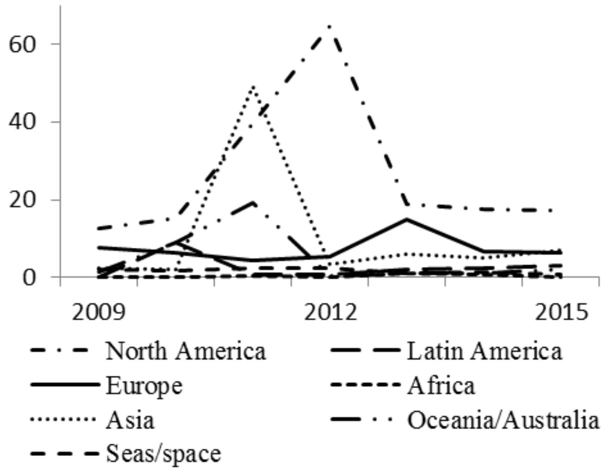
$$estE(m(\theta)) = 24.1481;$$
$$estE(s^2(\theta)) = 1259.777;$$
$$estD(m(\theta)) = 572.2954.$$

Therefore using (3) we have calculated the credibility factor Z which is the same for each region:

$$Z = 0{,}7608.$$

The credibility premium for total economic losses for each of seven regions in USD billion by (2) is in the last column of Table 5.

In the second step we used the same method for data processing of insured catastrophe losses in time period 2009-2015. Table 4 and Fig. 5 present these losses (in USD billion) in each of seven regions.



Source: Own processing by Sigma Swiss Re, 2010-2016

Fig. 5 Times series plot of insured catastrophe losses by regions in 2009-2015 in USD billion

Using the Bühlmann credibility model we have calculated the credibility factor and credibility premium for these data about insured catastrophe losses for the next year for each of the seven regions. For each of the regions we calculate means $\overline{X}_i = \sum_{j=1}^{n} X_{ij} / n$.These values are contained in the second column in Table 6.

Using expressions (4) - (6) we have estimated $E(m(\theta))$, $E(s^2(\theta))$, $D(m(\theta))$:

$$estE(m(\theta)) = 7.7408;$$
$$estE(s^2(\theta)) = 103.1477;$$
$$estD(m(\theta)) = 67.1490.$$

Table 6. Results of Bühlmann credibility model for data about insured catastrophe losses

	$\overline{X}_i$	Credibility premium
North America	26.59	23.20
Latin America	2.58	3.51
Europe	7.38	7.44
Africa	0.38	1.71
Asia	10.79	10.24
Oceania / Australia	4.81	5.34
Seas/space	1.66	2.75

Source: Own calculations

Therefore using (3) we have calculated the credibility factor Z which is the same for each region:

$$Z = 0.8200.$$

The credibility premium for insured catastrophe losses for each of seven regions in USD billion by (2) is in the last column of Table 6.

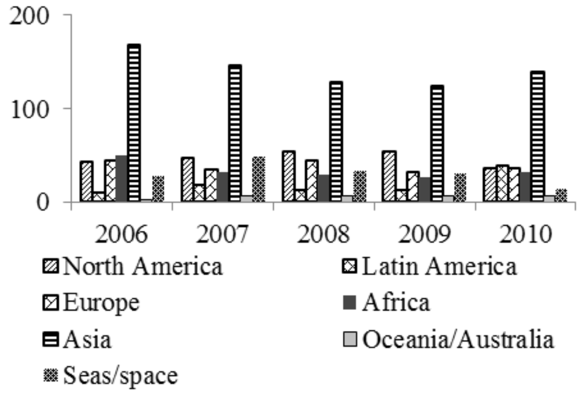
3.2 Application of Bühlmann - Straub credibility model

Contrary to the Bühlmann model in section 3.1 Bühlmann-Straub credibility model accounts for the varying annual volume of business, as is for example observed number of claims. In the first step we have applied this model on total economic losses (Table 3 and Fig. 5) with acceptation of the number of catastrophe events (Table 2).

Let region, for which the estimates of total economic losses are computed, is one of N regions. Insured losses in previous n years are known for all these regions.

Let P_{ij} is a variable, describing number of catastrophic events of the i-th observed region (i = 1,…, N; N = 7) in the j-th year (j = 1, …, n; n = 7).

Let Y_{ij} is the size of total economic catastrophe losses for each region i = 1, …, N and each year j = 1, …, n.



Source: Own processing by Sigma Swiss Re, 2010-2016

Fig. 5. Total economic losses by regions in 2009-2015 in USD billion

According to [4, 5, 6, 12, 14, 17, 18, 19] for the estimation of credible net premium for the i-th risk, the following formula is used

$$E(m(\theta)/X) = Z_i\overline{X}_i + (1-Z_i)E(m(\theta)) = Z_i\overline{X}_i + (1-Z_i)\overline{X} \quad (7)$$

Credibility factor for the i-th risk is calculated in form [3, 18]:

$$Z_i = \frac{P_i}{P_i + \dfrac{E(s^2(\theta))}{D(m(\theta))}} \quad (8)$$

The rules for estimating the parameters $E(m(\theta)), E(s^2(\theta)), D(m(\theta))$ are by [3, 18]:

$$estE(m(\theta)) = \overline{X} \quad (9)$$

$$estE(s^2(\theta)) = \frac{1}{N(n-1)}\sum_{i=1}^{N}\sum_{j=1}^{n}P_{ij}\left(X_{ij}-\overline{X}_i\right)^2 \quad (10)$$

$$estD(m(\theta)) = \frac{1}{P^*}\left\{\begin{array}{l}\dfrac{1}{Nn-1}\sum_{i=1}^{N}\sum_{j=1}^{n}P_{ij}\left(X_{ij}-\overline{X}\right)^2 \\ -\dfrac{1}{N(n-1)}\sum_{i=1}^{N}\sum_{j=1}^{n}P_{ij}\left(X_{ij}-\overline{X}_i\right)^2\end{array}\right\} \quad (11)$$

when it is mean, that

$$\overline{X}_i = \frac{1}{P_i}\sum_{j=1}^{n}P_{ij}X_{ij} = \frac{1}{P_i}\sum_{i=1}^{n}Y_{ij} \quad (12)$$

$$\overline{X} = \frac{1}{P}\sum_{i=1}^{N}\sum_{j=1}^{n}P_{ij}X_{ij} = \frac{1}{P}\sum_{i=1}^{N}P_i\overline{X}_i \quad (13)$$

$$P^* = \frac{1}{Nn-1}\sum_{i=1}^{N}P_i\cdot\left(1-\frac{P_i}{P}\right) \quad (14)$$

The value of credibility factor shows the rate of reliability of own data for each region.

The estimates of parameters $E(m(\theta))$, $D(m(\theta))$, $E(s^2(\theta))$ are the same for all the regions. Credibility factor Z_i differs for each region. The higher is the value of risk rate P_i, the higher is the value of credibility factor Z_i.

In the first step Bühlmann-Straub model was applied to compute credible net premium for seven regions of the world based on total economic catastrophe losses in time period 2009-2015 published in Sigma Swiss Re [21] (Table 3).

Total amount of total economic losses Y_i, where $Y_i = \sum_{j=1}^{n}Y_{ij}$, by each region i in the time 2009-2015, total number of catastrophic events P_i, where $P_i = \sum_{j=1}^{n}P_{ij}$ by each region in the whole period, and average total economic catastrophe losses per catastrophe events $\overline{X}_i$ for each region were computed according to (12). These characteristics present Table 6.

Table 6. Computed characteristics of the regions for total economic losses

	P_i	Y_i	$\overline{X}_i$
North America	337	311.80	0.9252
Latin America	194	88.39	0.4556
Europe	252	152.31	0.6044
Africa	302	7.58	0.0251
Asia	897	537.63	0.5993
Oceania / Australia	57	52.39	0.9192
Seas/space	193	33.14	0.1717

Source: Own calculations

Computed values in Table 6 have used to estimate parameters of the Bühlmann-Straub credibility model according to (9)-(11):

$estE(m(\theta)) = 0.5301;$

$estE(s^2(\theta)) = 18.4931;$

$estD(m(\theta)) = 0.0343.$

According to (8), values of credibility factors Z_i are computed for each region. It is necessary to find these values to be able to estimate credible net premium per region according to (7). The values of credibility factors and values of credible net premiums by regions are contained in Table 7.

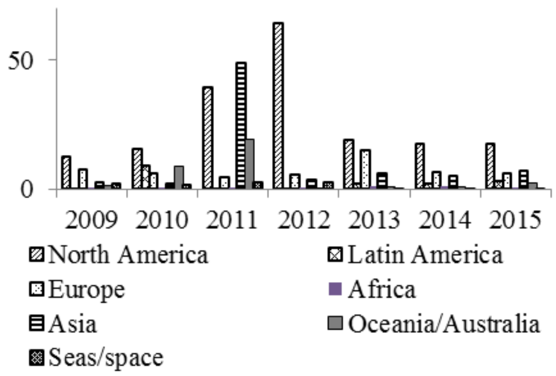
Table 7. Credibility factor Z_i and estimates of net credible premium per region in 2016

	Z_i	Net credible premium
North America	0.3846	0.6821
Latin America	0.2646	0.5104
Europe	0.3185	0.5538
Africa	0.3589	0.3488
Asia	0.6245	0.5734
Oceania / Australia	0.0956	0.5673
Seas/space	0.2636	0.4357

Source: Own calculations

Estimates of credible net premiums by regions provide information about how much money in the region will be needed to cover total economic catastrophe losses in the next year per one catastrophe event.

In the second step we have applied this model on insured catastrophe losses (Table 4 and Fig. 6) with consideration of the number of catastrophe events (Table 2).



Source: Own processing by Sigma Swiss Re, 2010-2016

Fig. 6. Insured catastrophe losses by regions in 2009-2015 in USD billion

Total amount of insured losses Y_i, where $Y_i = \sum_{j=1}^{n} Y_{ij}$, insured by each region i in the time 2009-2015, total number of catastrophic events P_i, where $P_i = \sum_{j=1}^{n} P_{ij}$ by each region in the whole period, and average insured catastrophe losses per insurance events $\overline{X}_i$ for each region were computed according to (12). These characteristics present Table 8.

Table 8. Computed characteristics of the regions for insurance losses

	P_i	Y_i	$\overline{X}_i$
North America	337	186.16	0.5524
Latin America	194	18.06	0.0931
Europe	252	51.64	0.2049
Africa	302	2.67	0.0088
Asia	897	75.53	0.0842
Oceania / Australia	57	33.66	0.5906
Seas/space	193	11.59	0.0600

Source: Own calculations

Computed values in Table 8 have used to estimate parameters of the Bühlmann-Straub credibility model according to (9)-(11):

$$estE(m(\theta)) = 0.1699;$$
$$estE(s^2(\theta)) = 2.4757;$$
$$estD(m(\theta)) = 0.0366.$$

According to (8), values of credibility factors Z_i are computed for each region. It is necessary to find these values to be able to estimate credible net premium per region according to (7).

Values of credibility factors Z_i (second column) and values of credible net premiums by regions (last column) are contained in Table 9. In this table we can compare values of credibility factors Z_i. We can see the highest value of this factor is for Asia region and the smallest value is for Oceania/Australia. We can also compare the values of net insurance premium. The highest value is in North America and the smallest value is in Africa.

Table 9. Credibility factor Z_i and estimates of net insurance premium per region in 2016

	Z_i	Net insurance premium
North America	0.8327	0.4884
Latin America	0.7413	0.1130
Europe	0.7882	0.1975
Africa	0.8168	0.0383
Asia	0.9298	0.0902
Oceania / Australia	0.4570	0.3622
Seas/space	0.7403	0.0886

Source: Own calculations

Estimates of credible net premiums by regions provide information about how much money in the region will be needed to cover insured catastrophe losses in the next year.

4 Conclusion

The catastrophe events have an enormous impact on our society. This impact is deep and long. Not only we need to investigate the causes of such events and develop plans to protect against them, but we will have to resolve the following huge financial losses as well.

The merits of these credibility models for calculating premiums for a risk (in our case for a region) are using two ingredients: past data from the risk itself and collateral data, i.e. data from other sources considered to be relevant, in our cases from other regions.

Results of application Bühlmann credibility empirical model in Table 5 provide an estimate of the total amount of credible premium in the regions of the world in the sum of USD 169.03 billion in 2016. The highest estimation is in Asia (64.21 USD billion).

Results of application Bühlmann-Straub credibility empirical model in Table 7 provide an estimate of net credible premium by regions of the world in USD billion in 2016. The highest estimation is in North America (0.6821 USD billion).

Development of the financial consequences of natural and man-made catastrophes have a major impact on the global insurance market and forcing the insurance and reinsurance companies to seek for new approaches and ways to cover these risks [15].

Results of application Bühlmann credibility empirical model in Table 6 provide an estimate of the total insured amount of credible premium in the regions of the world in the sum of USD 54.19 billion in 2016. The highest estimation is in North America (23.2 USD billion).

Results of application Bühlmann-Straub credibility empirical model in Table 9 provide an estimate of net insurance premium by regions of the world in USD billion in 2016. The highest estimation is in North America (0.4884 USD billion).

Raises the concern that the capacity of the world's insurance and reinsurance markets in the future will not be sufficient to cover these risks and aims to seek alternative options for their transfer.

References:

[1] P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*, New York: Taylor & Francis Group, 2007.

[2] H. Bühlmann, Experience rating and credibility. *ASTIN* Bull. 4, 1967, pp. 199-207.

[3] H. Bühlmann, E. Straub, Glaubwürdigkeit für Schadensätze. *Mitteilungen der Vereinigung Schweizerischer Versicherungs-mathematiker* 70, 1970, pp. 111-133.

[4] J. Gogola, Method for permanent adjustments of premium in non-life insurance (Spôsob permanentnej úpravy výšky pojistného v neživotnom poistení). *E + M Economics and Management*, 16 (4), 2013, pp. 134-141.

[5] P. Jindrová, Credibility Risk Models in Accident Insurance. In *Proceedings of the 7th International Scientific Conference: Managing and Modelling of Financial risk*, 2014, pp. 307-316.

[6] P. Jindrová, L. Kopecká, Empirical Bayes Credibility Models for Economic Catastrophic Losses by Regions. In WSEAS Proceedings *The 2016 International Conference Applied Mathematics, Computational Science and Systems Engineering (AMCSE 2016),* In *ITM Web Conferences* 9, 010016 (2017). DOI: http://dx.doi.org/10.1051/itmconf/20170901006.

[7] P. Jindrová, V. Pacáková, Bayesian Probability Models for Critical Illness Insurance. In *Recent Advances in Mathematical Methods in Applied Sciences*. Athens, 2014, pp. 218-221.

[8] P. Jindrová, V. Pacáková, Actuarial Models for Valuation of Critical Illness Insurance. *International Journal of Mathematical Models and Methods in Applied Sciences*, 9, 2015, pp. 218-222.

[9] P. Jindrová, K. Seinerová, Bayesian Estimates of the Regional Costs in Public Health System of the Czech Republic. In *Proceedings of the 12th International Scientific Conference: European Financial Systems 2015*, 2015, pp. 246-252.

[10] P. Jindrová, K. Seinerová, Bayesian Estimates of Health Care Costs in Slovakian Insurance Companies. *International Journal of Economics and Statistics*, 3, 2015, pp. 174-177.

[11] P. Jindrová, K. Seinerová, Comparison of Bayesian Estimates of Health Care Costs for Czech and Slovakian Insurance Companies, *Scientific Papers of the University of Pardubice, Series D,* 37 (2/2016), 2016, pp. 48-59.

[12] B. Linda, J. Kubanová, Credibility Premium Calculation in Motor Third-Party Liability Insurance, WSEAS conference *Advances in Mathematical and Computational Methods,* Malta, 2012, pp. 259-263.

[13] V. Pacáková, Bayesian Estimations in Insurance Theory and Practice. In Advances in Mathematical and Computational Methods: *proceedings of the 14th International Conference on Mathematical and Computational methods in Science and Engeneering*, 2012, pp. 127-131.

[14] V. Pacáková, Credibility models for permanently updated estimates in insurance. *International journal of mathematical models and methods in applied sciences*, 3(7), 2013, pp. 333-340.

[15] V. Pacáková, P. Jindrová, Simulation of the highest insured catastrophe losses using quantile function. *International Journal of Mathematics and Computers in Simulation*. NAUN, 10, 2016, pp. 242-248.

[16] V. Pacáková, B. Linda, Simulation of the extreme losses in non-life insurance *E & M EKONOMIE A MANAGEMENT*, 12(4), 2009, pp. 97-103.

[17] V. Pacáková, E. Šoltés, T. Šoltésová, Credibility Estimation of the Claim frequency. *E & M EKONOMIE A MANAGEMENT*, 12(2), 2009, pp. 122-126.

[18] E. Šoltés, V. Pacáková, T. Šoltésová, Selected credibility regression models in motor hull insurance (Vybrané kredibilné regresné modely v havarijnom poistení), *Ekonomicky casopis*, 54(2), 2006, pp. 168-182.

[19] H. R. Waters, *Credibility Theory,* Edinburgh: Heriot-Watt University, 1993.

[20] Natural catastrophes and man-made disasters in 2015: Asia suffers substantial losses. *Sigma No 1/2016*, Swiss Re Ltd, Economic Research & Consulting, Zurich (2016) [online] Available from: http://reliefweb.int/sites/reliefweb.int/files/resources/sigma1_2016_en.pdf

[21] *Sigma Swiss Re 2010-2016* [online] Available from: http://www.swissre.com/sigma/