EFFECTIVENESS OF USING CREDIBILITY MODELLING IN THE INSURANCE INDUSTRY - A CZECH CASE STUDY

Karina Benetti

Abstract

Credibility theory is one of the actuarial approaches used to calculate premiums. This article aims to evaluate the effectiveness of using the theory of credibility to predict the development of premiums by comparing the results of calculating premium credibility based on actual data collected from Czech non-life insurance from 2006 to 2018 with the actual results for non-life insurance in the Czech Republic. The Czech insurance market is strongly influenced by natural risks, which in many cases have high losses. The data are taken from the Czech non-life insurance market concerning the number of the three Czech most risky areas and the number of extreme claims. Concerning the number of extreme claims, the results of this contribution can be a good guide for the Czech insurance industry in extreme claims during natural disasters. This paper evaluates how credibility theory methods are effective for insurance companies in estimating the development of premiums.

Key words: Bühlmann and Bühlmann-Straub credibility, credibility premium, credibility theory, extreme losses, effectiveness

JEL Code: C13; C52; C58

Introduction

This paper builds on previous research from 2019 (Benetti et al., 2019) and 2021 (Benetti, 2021). The study from 2019 focused on calculating the premium credibility based on accurate data collected by the non-life Czech insurance industry. This research used a modified model based on the Bühlmann and Bühlmann-Straub models to project the premiums based on the past /posterior data of extreme losses by natural hazards collected from the Czech insurance market from 2006 to 2018. The research from 2020 was focused on comparing the results of the calculation of the credibility premium based on accurate data collected from the non-life Czech insurance industry with the results of the prediction of premium development using the regression model and the actual results for the insurance market in non-life insurance in the Czech Republic.

In the Czech Republic, insurance companies (Act No. 277/2009 Coll.) Must, among other things, create technical provisions to maintain their financial health. In non-life insurance, the most problematic provisions include the equalization reserve and the provision for claims.

Among the standard methods that insurance companies use to calculate them are the following methods (Cipra, 1999): i. development triangle, ii. Chain Ladder, iii. Inflation-adjusted Chain Ladder, iv. separation method, v. average cost method and then vi. Bornheutter-Ferguson method.

Another option is to use credibility theory. Bayes first developed the credibility theory in 1763. Many researchers have been working to develop the theories and the models used to reach a more accurate method of calculating the risk premium that should be collected by the insurers based on conditional probability.

Later, Bühlmann and Bühlmann-Straub's credibility approaches are considered the recent development of the Bayesian credibility theory; these models apply the most excellent accuracy theory. Bühlmann introduced his model in 1967. This work was followed by Bühlmann-Straub (1970), who continued the earlier work of Bühlmann and introduced a multivariate generalization of the credibility model for claim reserving.

The Czech Republic has faced high losses caused by natural storms and floods over recent years; the Czech insurance market has experienced extreme losses of natural hazards that would affect the calculation of premiums to cover the expected liabilities in such risks. Thanks to changing climatic conditions, we can expect that the Czech insurance market will have to cope with the event of other climate changes and thus the more frequent implementation of risks such as storms, drought and other risks already mentioned. Therefore, it is the prediction of the development of written premiums that is crucial for maintaining the financial health of non-life insurance companies, which cover natural hazards. Since credibility theory provides an actuarial approach to deal with these extreme losses, it will be essential to explore the effectiveness of credibility models in such risks. Both Bühlmann and Bühlmann-Straub models introduced the credibility models that can help calculate the premiums required to cover such losses.

The paper aims to compare the effectiveness of using credibility theory to estimate the number estimating insurance premiums' payment.

1 Methodology

1.1 Review of the selected literature

Linda and Kubanová (2012) used actual data from five insurance companies to calculate premiums for motor third-party liability insurance based on Bühlmann-Straub credibility as a methodology to improve the quality of net premium estimation.

Pacáková (2013) applied Bayesian credibility analysis to estimate parameters for several statistical distributions given prior distribution. Furthermore, estimate the credibility premium or credibility number of claims in insurance.

Jindrová (2014), demonstrated a classical Bayesian approach to estimate the probability of realizing the risk of death and permanent disability due to an accident for different age groups of men and women within the Slovak insurance market.

Seinerová (2015) illustrated and applied of Bühlmann Straub model to estimate the credibility costs by combining individual and collective experience throughout the credibility factor as a confidence level. This model is used for health care insurance.

Jindrová and Seinerová (2015), applied the Bühlmann Straub model to measure the cost of healthcare insurance and the corresponding credibility factor and concluded that for large companies, the estimation of the healthcare cost is reliable, while for small-sized companies, it's meaningless without the referral to data from the whole market. In addition, Bayesian analysis is considered a useful technique for healthcare insurance.

Gao (2016) illustrated modelling claim reserving using Bayesian analysis, which this study classified into two sessions. The first session introduced the Bayesian methodology for claim reserving. The second session proposed a compound model as a probabilistic approach and the Bayesian expansion models by applying Monte Carlo simulation for claim reserving.

Jindrová and Kopeck (2016), considered Bühlmann and Bühlmann-Straub's empirical credibility to estimate the credibility premiums and net premiums for catastrophic claim amounts and economic losses for different regions. They applied Bühlmann and Bühlmann-Straub's credibility for short-term insurance considering two types of data i.e., past data from risk itself and collateral data from other relevant sources.

In 2019 ElSayed and Soliman (2019) applied the Bühlmann and Bühlmann-Straub credibility models in six branches of non-life insurance in Egypt from 2006 to 2015. They adopted the model of allocating the number of claims and the number of observed extreme losses to predict credible net premiums for the coming year and used a standard model in the six non-life insurance sectors in Egypt between 2006 and 2015. demonstrated by extreme

events, use the modified Bühlmann and Bühlmann-Straub credibility models, where the tail behaviour of receivables is considered to predict credible premiums.

The ElSayed and Soliman model (2019) was then used to estimate premiums in non-life insurance in the Czech insurance market (Benetti et al., 2019).

The study from 2021 (Benetti) was focused on comparing the results of the calculation of the credibility premium based on accurate data collected from the non-life Czech insurance industry with the results of the prediction of premium development using the regression model and the actual results for the insurance market in non-life insurance in the Czech Republic.

1.2 Data and methodology

Data for the Czech insurance market used in this paper are incurred claims from the three most important areas: damages caused by the weight of snow, damages caused by floods and damages caused by gales and hailstorms and the number of extreme losses from each area for the period from 2006 to 2018. Czech Insurance Association reports these data.

In this research, we compare the results of a previous study from 2019 (credibility theory) with the results of regression models and actual data from the Czech Insurance Association from 2019.

The models that will be used in this paper are applied by using the R Package, an open-source environment for mathematical and statistical computations and Statgraphics Centurion. The actuary package is also used to apply the modified Bühlmann and Bühlmann-Straub credibility models. This section will present the data used in this research. It will illustrate the results that are reached by applying the modified credibility models in different types of risks, such as natural hazards and the expected net premium that should be collected to cover the extreme losses resulting from these risks.

The natural hazards data is collected, as mentioned before, from the Czech insurance market and published by the Czech Insurance Association from 2006 to 2018. Table 1 illustrates the amount of extreme claims for three main types: damage caused by the weight of snow, damage caused by the floods, and damage caused by gales and hailstorms.

Tab. 1: The amount of extreme claims (in thousands CZK)

Damages	2006	2007	2008	2009	2010	2011	2012
Damages caused by weight of snow	2 564 492	20 603	2 403	309 790	1 212 759	271 774	148 399
Damages caused by floods	1 340 848	386 892	5 070	1 508 902	3 994 437	336 827	353 794
Damages caused by gales and hailstorms	685 606	3 134 566	1 250 653	1 936 736	2 706 853	1 045 302	1 740 007
Sum	4 590 946	3 542 061	1 258 126	3 755 428	7 914 049	1 653 903	2 242 200
Damages	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
Damages caused by weight of snow	124 402	22 070	20 704	19 976	105 474	13 591	
Damages caused by floods	7 457 780	1 013 006	68 245	355 609	170 619	186 373	
Damages caused by gales and hailstorms	1 733 727	931 355	1 181 358	1 535 267	2 511 817	1 056 526	
Sum	9 315 909	1 966 431	1 270 307	1 910 852	2 787 910	1 256 490	

Source: author's from (CIA, 2019)

Table 1 shows the number of claims in the Czech insurance market. This table shows that the most significant damage happened in 2013, and floods caused it during the period under review. Table 2 shows the number of extreme losses for each risk type.

Tab. 2: Number of extreme losses

	2006	2007	2008	2009	2010	2011	2012
Damages caused by weight of snow	0	0	0	0	1	0	0
Damages caused by floods	0	0	0	1	1	0	0
Damages caused by gales and hailstorms	0	1	1	0	1	0	0
Sum	0	1	1	1	3	0	0
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	
Damages caused by weight of snow	0	0	0	0	0	0	
Damages caused by floods	1	0	0	0	0	0	
Damages caused by gales and hailstorms	2	0	0	0	0	1	
Sum	3	0	0	0	0	1	

Source: author's from (CIA, 2019)

2 Results

2.1 Descriptive statistical analysis

First, a descriptive statistical analysis is conducted to understand the different statistical characteristics of each type of risk that will be analyzed. Tab. 3 summarize the statistical characteristics of each insurance area.

Tab. 3: Descriptive analysis for claim amounts per risk area

Risk Area	Mean	Median	Standard deviation	Skewness	Kurtosis
Damages caused by weight of snow	372 034 000	105 474 000	734 193 000	3.96215	5.39114
Damages caused by floods	1 321 420 000	355 609 000	2 132 260 000	3.57881	1.12532
Damages caused by gales and hailstorm	1 649 980 000	1 535 270 000	748 197 000	4.38144	-0.25874

Source: (Benetti et al., 2019)

Tab. 3 displays the amount of claims for the following risk areas: damages caused by the weight of snow, damages caused by floods and the last risk area was damages caused by gales and hailstorms. For damages caused by the weight of snow is mean in the amount of 372 034 000 CZK, for damages caused by floods is 1 321 420 000 CZK and for damages caused by gales and hailstorms, the mean is 1 649 980 000 CZK.

2.2 Credibility models

This article does not deal with the actual modelling of premium values using credibility models but is based on already published results (Benetti et al., 2019). For this reason, only the resulting values of the net premium estimate will be given here; see the tab. 4.

Table 4 shows the projected net premiums for each risk type that should be collected in each type by the insurance market to cover any extreme events that may occur in 2019. The estimates for net insurance premiums for damages were calculated for the Czech insurance market are 1 486 558 000 CZK for damages caused by the weight of the snow, 4 178 870 000 CZK for damage caused by floods, and finally, 1 961 127 000 CZK for damages caused by gales and hailstorm.

Data are now available on the Czech insurance market on whether these modified credibility models are suitable for estimating net insurance premiums. According to the results of the Czech Insurance Association, the results for 2019 were as follows: damages caused by the weight of the snow was 192 305 000 CZK, damages caused by floods were in the amount of 288 816 000 and damages caused by gales and hailstorm was in the amount of 2 292 976 000 CZK.

Tab. 4: Credibility factors and estimates of net insurance premiums per risk area in 2019 (in thousands CZK)

Risk area	Credibility factor (Z_i)	Net Insurance Premium
Damages caused by the weight of snow	0.7940475	1 486 558
Damages caused by floods	0.9204231	4 178 870
Damages caused by gales and hailstorm	0.9585628	1 961 127

Source: authors' calculations based on the result from R Package

It is now possible to compare the results of the credibility models with the actual values – see Table 5.

Tab. 5: Comparison of predicted values using credibility modelling with real values

Risk Area	Credibility Modelling (%)
Damages caused by the weight of snow	773
Damages caused by floods	1 446
Damages caused by gales and hailstorm	85.5

Source: authors'

From the results given in the table above, if the model values compared to actual values are above 100%, the insurance company would use the model to create sufficient reserves in premiums. Still, if these values are higher than 100%, it is considering whether it does not make too large reserves and does not have large amounts of funds stored in them unnecessarily. The law directly states that the person responsible for the company's financial health must also be an excellent financial manager (but the law no longer states what we can imagine under that). So, the question here is whether the modelled reserve – 1,446% is no longer exaggerated, and the insurance company should instead maintain a lower reserve, e.g., 400%, and invest any other available funds.

For insurance companies – to maintain their financial health, it is not appropriate to keep reserves below 100% - this is contrary to legal regulations. Insurance companies must make such estimates of the future development of insurance benefits that they meet their obligations. From this point of view, forecasts of the growth of premiums using credibility modelling seem to be entirely appropriate, except for the estimate in the risk area – damages caused by gales and hailstorms.

3 Discussion

The future development of net premium can be modelled using various statistical modelling tools. Net insurance premiums were estimated using the Bühlmann-Straub Credibility Model. These results were then compared with actual values.

It is evident that if the insurers used the Bühlmann-Strabu Credibility Model to estimate net premium, they would be able – except for risk area damages caused by gales and hailstorms – to create sufficient reserves to cover the risks. But, of course, by law, they must make compulsory reserves, which are calculated based on well-defined procedures, whereby insurance companies must count on maximum damage. Therefore, this model does not calculate as much damage as possible. Still, the expected net premium is estimated to cover

the insurance company's costs with the appropriate type of risk – except risk area damages caused by gales and hailstorms. Therefore, the Bühlmann-Straub Credibility Model can serve insurance companies as a complementary model to estimate the net premium.

4 Conclusions

The Bühlmann and Bühlmann-Straub approaches represent the recent Bayesian trust theory; these models use the highest accuracy theory. This study compared the results of the improved Bühlmann and Bühlmann-Straub confidence models with actual values.

This research focused on three risk areas in the Czech non-life insurance market from 2006 to 2018. Furthermore, these sectors include extreme events predicting the plausibility of net premiums for the coming year 2019 for each risk area in the Czech insurance market. In addition, this process shows how much money each branch will need to cover extreme events to manage risks.

Based on economic changes in the Czech insurance market, future research may consider fluctuations in the number of insurance claims due to extreme losses or number of changes in insurance contracts. Furthermore, it would be possible to compare the results of credibility models with the results of standard models used in insurance practice and compare them with actual values.

Acknowledgment

This paper was created with the support of specific research by EF TUL 2021–2022 (the project of Internal Grant Competition "Use of Credibility Theory").

References

Bayes, T. (1763). An Essay towards solving a Problem in the Doctrine of Chances. Phil. Trans, 1763, 53, 370–418.

Benetti, K. (2021). The Comparison of the Results of Credibility Modelling and the Regression Models with Real Data for Extreme Losses of Natural Hazards in the Czech Republic. *In Liberec Economic Forum. In, Proceedings of the 15th International Conference*, Liberec: Technical University of Liberec, 2021, pp. 519–530. ISBN 978-80-7494-578-6.

Benetti, K.; Elsayed, M.; Soliman, A. & Khalil, D. (2019). Credibility Modelling for Extreme Losses of Natural Hazards in the Czech Republic: An Actuarial Approach. *In Liberec*

Economic Forum. Proceedings of the 14th International Conference, Liberec: Technical University of Liberec, 2019, pp. 81–92. ISBN 978-80-7494-482-6. WOS: 000540987200007.

Bühlmann, H. & Straub, E. (1970). Glaubwürdigkeit für Schadensätze. *Bulletin of the Association of Swiss Actuaries,* 1970, 70(1), 111-133.

Bühlmann, H. (1967). Experience rating and credibility. *ASTIN Bull*, 1967, 4, 199-207.

CIA. (2019). *Škody z pojištění majetku* [online]. 2019 [cit. 2019-04-05]. Available at: http://www.cap.cz/statisticke-udaje/skody-z-pojisteni-majetku

Gao, G. (2016). *Three Essays on Bayesian Claims Reserving Methods in General Insurance*. The Australian National University, PhD Thesis, 2016.

Jindrová, P. & Kopeck, L. (2017). Empirical Bayes Credibility Models for Economic Catastrophic Losses by Regions. DOI: 10.1051/70901006itmconf/201, 2017.

Jindrová, P. & Kopecká, L. (2016). *Empirical Bayes Credibility Models for Economic Catastrophic Losses by Regions*. DOI: 10.1051/70901006itmconf/201.

Jindrová, P. & Seinerová, K. (2015). Bayesian estimates of health care costs in Slovakian insurance companies. *International Journal of Economics and Statistics,* 2015, 3: 174-177.

Jindrová, P. (2014). Credibility Risk Models in Accident Insurance. *In Proceedings of the 7th International Scientific Conference: Managing and Modelling of Financial Risks*, Ostrava: VŠB-TU Ostrava, pp.307-316. WOS: 000350605800037.

Jindrová, P. (2014). Credibility Risk Models in Accident Insurance. *Managing and Modelling of Financial Risks: 7th International Scientific Conference, PTS I-III* Ostrava, 307-316. WOS:000350605800037.

Linda, B. & Kubanová, J. (2012). Credibility Premium Calculation in Motor Third-Party Liability Insurance. *Proceedings of the 14th Wseas International Conference on Mathematical and Computational Methods in Science and Engineering*, Sliema, Malta. September 7-9, 2012, 259-263.

Pacáková, V. P. (2013). Credibility models for permanently updated estimates in insurance. *International Journal of Mathematical Models and Methods in Applied Sciences,* 2013, 7(3), 333-340.

Seinerová, K. (2015). Segment-specific Bayesian analysis of health insurance costs. *10th International Scientific Conference Financial Management of Firms and Financial Institutions.* Ostrava, VŠB-TU of Ostrava, Faculty of Economics, Department of Finance, 2015, 1115-1120. WOS:000376799500136.

Contact

Karina Benetti
The Technical University of Liberec, Faculty of Economics
Department of Economic Statistics
Studentska 1402/2
461 17 Liberec
Czech Republic
karina.benetti@tul.cz