PREMIUM ESTIMATION OF GENERAL INSURANCE CONTRACTS USING BUHLMANN CREDIBILITY MODEL

Abstract:

Insurance coverage is reliant on appropriate premium determination, a focus addressed in this study through the application credibility theory. The aim was to compute short-term insurance premiums by leveraging authentic data from general insurance contracts as published in the IRA annual reports spanning from 2013 to 2021. The study employed the Buhlmann credibility model to derive net credible premiums for 13 non-life insurance contracts, assuming constant changes in business volumes. The estimation of credibility premiums was conducted by initially calculating within and between-portfolio variance with an aim of determining these premiums through linear estimation approach with the help of the credibility premium formula. The results revealed consistent credibility factors across all contracts, although other influencing factors were neglected. Therefore, it was highly recommended that an appropriate credibility model alongside other factors that influence premium estimation be considered to enhance the accuracy of premium estimates. Moreover, embracing heterogeneity over homogeneity is advised to better reflect individual risk profiles. The research underscores the importance of effective premium determination in insurance firms, as premiums constitute their primary revenue. Stakeholders, including insurers and regulators, are encouraged to integrate this approach and other relevant factors to enhance pricing accuracy and overall sector practices.

Keywords: Homogeneity, Credibility premium formula, within portfolio variance, between portfolio variance

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1. Introduction

Insurance is a financial service that facilitates the transfer of risk from the insured to the insurer [1]. It cushions the insured against risk by providing indemnity payments after the occurrence of the specified event. Therefore, in return, the insured is obliged to pay premiums [2]

The basic idea behind the existence of insurance is the "pooling of risks," as highlighted by [3] and [1]. According to this principle, individuals who have the "same" exposure to a particular risk join together to form a "community-at-risk" in order to bear the perceived risk. Furthermore, Smith and Kane [6], in their groundbreaking work, suggested that with a pool of a large number of numerous risks, insurers are able to estimate premiums more accurately with the help of the expected value concept.

According to [7], insurance contracts are categorized into two: Life Assurance, which typically provides coverage for an extended period, often until the insured's death, and general insurance, which provides coverage for shorter periods. This study focused on general insurance.

In addition to risk management, non-life insurance acts as financiers to banks, which then lend the same funds to businesses and individuals, contributing to economic growth [8]. Therefore, to enable these companies to fulfill all their obligations, they must strike a balance between charging premiums that are suitable (competitive) and affordable (reasonable). Excessively low premiums may lead to insufficient funds, hindering financial obligations, while excessively high premiums may limit accessibility to insurance products and thus impede economic growth **[4]**.

Therefore, insurance premiums serve as the backbone of the insurance sector representing the revenue collected by insurers to cover potential losses from insured events. Accurately determining premiums is of utmost importance, since it ensures the financial stability of insurance companies while providing adequate coverage for the policyholders.

Credibility theory plays a crucial role in this process by offering a systematic framework for assessing risk and setting premiums. It takes into account both the historical data and individual experience, allowing insurers to tailor premiums to the specific risk profile of each policyholder or group. By incorporating credibility theory into premium determination practices, insurers can enhance the accuracy and fairness of pricing while maintaining competitiveness in the market.

Against this backdrop, our study aims to shed light on how credibility theory can be effectively utilized in computing short-term insurance premiums. By leveraging authentic data from general insurance contracts spanning nearly a decade, we seek to uncover insights that not only advance academic understanding but also offer practical implications for industry practitioners. Through the rigorous application of the Buhlmann credibility model and the derivation of net credible premiums for non-life insurance contracts, our research contributes to bridging the gap between theory and practice in the field of insurance premium determination.

Furthermore, the findings of this study hold significant importance for various stakeholders across the insurance landscape. Insurers and the regulatory body stand to benefit from invaluable insights that can refine pricing strategies and enhance regulatory practices. Additionally, consumers will gain a deeper understanding of insurance fundamentals, empowering them to make informed decisions about their insurance needs. Moreover, the scholarly community will find value in this study as it not only serves as a foundation for future research but also fosters discourse on critical aspects of the insurance industry.

2. Related studies

In the general insurance industry, premium estimation methodologies have been a subject of extensive research. Among these methodologies, the credibility theory approach, particularly the Buhlmann credibility model, has garnered significant attention. This review synthesizes key findings from recent studies regarding the application and effectiveness of the Buhlmann credibility model in estimating insurance premiums.

Trufin & Loisel [9] investigated ultimate ruin probabilities for large initial capital, focusing on light-tailed claim amounts. They computed credibility-adjusted premiums using the Buhlmann credibility model. Their findings highlighted the effectiveness of the Buhlmann credibility model in computing credibility-adjusted premiums for light-tailed claim amounts, particularly for large initial capital.

Jindrova & Kopecka [10] applied Empirical Bayes credibility to analyze economic catastrophic losses by region, utilizing data from 2009 to 2015 on catastrophic events and total economic losses. They emphasized the impact of increasing frequency and intensity of catastrophic events on economic losses and insurance premiums.

Benetti [11] compared the outcomes of credibility models and regression models using real data for extreme losses of natural hazards in the Czech Republic. Their study concluded that the Buhlmann credibility models generate sufficient reserves to cover associated risks compared to regression models, particularly for extreme losses of natural hazards.

Chukwudum [12] demonstrated the application of the Buhlmann credibility theory model in estimating credibility premiums, emphasizing the integration of business volume data for improved estimates. Her study suggested that integrating business volume data into the estimation process improves credibility premium estimates.

Karina et al.[14] investigated the Buhlmann credibility model's application in predicting claim frequency, particularly with heterogeneous Weibull count distributions. They underscored limitations in relying on the Poisson assumption in the Buhlmann credibility model, particularly in cases of heterogeneous Weibull count distributions.

Rokicki & Ostaszewski [13] adjusted initial cost estimates for public infrastructure projects by incorporating additional risks and uncertainty using the actuarial credibility approach and machine learning algorithms such as LASSO and OLS. They consistently found that the actuarial credibility approach outperformed machine learning algorithms in adjusting initial cost estimates for public infrastructure projects, highlighting the robustness of the credibility theory approach.

Research gap

The research gap identified in this study highlights the underutilization and lack of clarity surrounding the Buhlmann credibility model, particularly within my country's insurance industry. While the model has been previously applied in studies, primarily focusing on medical insurance and often using simulated data, its practical application in other non-life insurance contracts, remains limited. Furthermore, most of existing studies lacked clarity in detailing the methodology employed, particularly in obtaining credibility factors.

3. Methodology

This section summarizes a detailed description of data's type, sources and size used in the review process. Furthermore, the section digs into a thorough examination of the Buhlmann credibility paradigm

3.1 Research design

The study design outlines crucial processes such as model description, data collection, and preprocessing which are essential for the model execution. The Buhlmann credibility model was chosen due to its suitability in handling general insurance contracts and effectively combining individual and group experience data.

The data collection was executed through secondary means, sourcing information from IRA annual reports spanning nine years 2013 to 2021. The IRA data encapsulated aggregate claims for 13 non-life insurance contracts. The selected contracts included Aviation, Engineering, Fire Domestic, Fire Industrial, Liability, Marine, Motor private, Motor Commercial, Personal Accident, Theft, Workmen's compensation, Medical and Miscellaneous insurance.

The data underwent thorough scrutiny to address outliers, thus enhancing overall consistency and reliability. Outliers, defined as values lying outside the range of -3 to +3 according to the empirical rule, were carefully identified and remedied. The selection of secondary data was underpinned by its cost-effectiveness and time efficiency, thereby streamlining the analysis process. The aggregate claims data in thousands of shillings is given below

Table 1 Aggregate claim Amounts in thousands shillings by year

Risk	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	15144	5915	12888	69815	48571	28336	9285	43775	3515
2	301706	366679	469159	448796	431756	411244	595785	705840	592670
3	337000	289864	483315	523792	309981	477500	414559	385069	421323
4	803448	801192	1179620	988870	1100373	1141362	825219	1145668	979632
5	253807	316224	432374	661618	340822	597548	399152	464619	636608
6	560436	566269	631540	500636	725376	669398	669464	597154	1043536
7	8784204	1.1E+07	1.3E+07	1.5E+07	1.4E+07	1.4E+07	1.7E+07	1.6E+07	18015197
8	9271908	1.1E+07	1.3E+07	1.3E+07	1.3E+07	1.4E+07	1.5E+07	1.5E+07	17884591
9	884041	1296968	672750	1237378	1081310	747352	464566	496935	1063712
10	1143607	1238056	771202	1194596	969900	1304641	887812	727749	860395
11	2024589	2649305	2671450	2987439	3126587	2374487	1548271	1961545	1752873
12	9260252	1.3E+07	1.5E+07	1.8E+07	2.1E+07	2.1E+07	2E+07	2.1E+07	23273005
13	529996	668871	852009	430640	653554	740981	781086	729921	647599

where;

1. Aviation
2. Engineering
3. Fire Domestic
4. Fire Industrial
5. Liability
6. Marine
7. Motor Private
8. Motor Commercial
9. Personal Accident
10. Theft
11. Workmen’s compensation
12. Medical
13. Miscellaneous

3.2 The Buhlmann Credibility Model

The Buhlmann credibility model emerged as the first credibility model in the realm of insurance pricing during the mid-20th century [5]. At its core, the model sought to refine the premium estimation process by simply integrating policyholders’ individual experiences and the broader collective risk data. To apply the model, our initial step is to calculate the average claim cost for each contract. We then proceed to compute the overall average claim cost across all 13 contracts, which play a key role in determining both the within and between variance. Lastly, we determine the credibility factor. Collectively, these steps constitute parameter estimation under the Bühlmann model and are explained below.

3.2.1 Parameter Estimation under the Buhlmann Model

Let X_{ij} denote the aggregate claims or number of claims for Risk Number i , where $i = 1,2,\dots,N$, in year j, where $j = 1,2,\dots,n = 9$. $m(\Theta_i)$, which is the credibility premium for the next immediate time period given X_{ij}^{s} , was achieved by first obtaining the estimates of $E[m(\Theta)], var[m(\Theta)]$, and $E[s^2(\Theta)]$ subject to the following assumptions ;

(a) The distribution of each X_j depends on a parameter Θ, which is fixed

(b) Given the fixed value of Θ, the X_j^s are assumed to be independent and identically distributed.

(c) The changing volumes of business are assumed to be constant throughout each contract.

Therefore, the unbiased estimators can be obtained as follows

$$E[m(\Theta)] = \bar{X} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N} \tag{1}$$

$$var[m(\Theta)] = \frac{1}{N-1}\sum_{i=1}^{N}(\bar{X}_i - \bar{X})^2 - \frac{1}{Nn}\sum_{i=1}^{N}\left[\frac{1}{n-1}\sum_{j=1}^{n}\left(X_{ij} - \bar{X}_i\right)^2\right] \tag{2}$$

$$Z = \frac{n}{n + \frac{E[s^2(\Theta)]}{var[m(\Theta)]}} \tag{3}$$

Hence, the credibility premium is given by

$$m_{n+1}(\Theta_i) = Z_i\bar{X}_i + (1 - Z_i)\bar{X} \tag{4}$$

4. Results and Discussion

This section introduces the Buhlmann credibility model for estimating credibility premiums. Furthermore, it determines the parameters $E[m(\Theta)], E[s^2(\Theta)]$, and $var[m(\Theta)]$, which will be pivotal in estimating credibility premiums for insurance contracts based on the data from Table 1. The computations involved the application of Equations (1) to (4) along with the utilization of summary statistics presented in Table 2 derived from Table 1

Table 2 Summary Statistics

Risk	$\bar{X}_i$	$\frac{1}{8}\sum_{j=1}^{9}\left(X_{ij}-\bar{X}_i\right)^2$	$\frac{1}{12}\sum_{i=1}^{13}(\bar{X}_i-\bar{X})^2$
1	26360444.44	5.28449×10^{14}	1.65141×10^{19}
2	480403888.9	1.62349×10^{16}	1.303×10^{19}
3	404711444.4	6.64553×10^{15}	1.35822×10^{19}
4	996153777.8	2.40815×10^{16}	9.57258×10^{18}
5	455863555.6	2.15604×10^{16}	1.32078×10^{19}
6	662645444.4	2.5043×10^{16}	1.17475×10^{19}
7	14036189444	8.0445×10^{18}	9.89244×10^{19}
8	13341596444	6.42305×10^{18}	8.55899×10^{19}
9	882779111.1	9.44595×10^{16}	1.0287×10^{19}
10	1010884222	4.5794×10^{16}	9.48165×10^{18}
11	2344060667	3.07341×10^{17}	3.0487×10^{18}
12	17859304988	2.07946×10^{19}	1.89591×10^{20}
13	670517444.4	1.64702×10^{16}	1.16936×10^{19}
Sum	53171470877	3.58203×10^{19}	4.8627×10^{20}
Average	4090113144	2.75541×10^{18}	4.05225×10^{19}

where;

$$E[m(\Theta)] = \bar{X} = \frac{\sum_{i=1}^{N}\bar{X}_i}{N} = \frac{53171470877}{13} = 4090113144$$

$$E[s^2(\Theta)] = \frac{1}{N}\sum_{i=1}^{N}\left[\frac{1}{n-1}\sum_{j=1}^{n}\left(X_{ij}-\bar{X}_i\right)^2\right]$$

$$= \frac{1}{13}\sum_{i=1}^{13}\left[\frac{1}{8}\sum_{j=1}^{9}\left(X_{ij}-\bar{X}_i\right)^2\right]$$

$$= \frac{1}{13} \times 3.58203 \times 10^{19}$$

$$= 2.75541 \times 10^{18} \approx 2.76 \times 10^{18}$$

$$var[m(\Theta)] = \frac{1}{N-1}\sum_{i=1}^{N}(\bar{X}_i-\bar{X})^2 - \frac{1}{Nn}\sum_{i=1}^{N}\left[\frac{1}{n-1}\sum_{j=1}^{n}\left(X_{ij}-\bar{X}_i\right)^2\right]$$

$$= \frac{1}{12}(4.8627 \times 10^{20}) - \frac{1}{9}E[s^2(\Theta)]$$

$$= \frac{1}{12}(4.8627 \times 10^{20}) - \frac{1}{9}(2.75541 \times 10^{18})$$

$$= 4.021634333 \times 10^{19} \approx 4.02 \times 10^{19}$$

and,

$$Z = \frac{n}{n + \frac{E[s^2(\Theta)]}{var[m(\Theta)]}} = \frac{9}{9 + \frac{2.76 \times 10^{18}}{4.02 \times 10^{19}}} = 0.992445$$

Thus the estimates of structural parameters and credibility factors are presented in Table 3

Table 3: Structural Parameters and the Credibility Factors

Parameter	Value
$E[m(\Theta)]$	4090113144
$E[s^2(\Theta)]$	2.76×10^{18}
$var[m(\Theta)]$	4.02×10^{19}
Z	0.992445

After applying the Buhlmann Credibility model and utilizing the structural parameters as components, the resulting credibility premium values for the next immediate time period are presented in Table 4

Table 4: Credibility Premium Estimates

Risk	$\bar{X}_i$	Z_i	Credibility Premium
1	26360444.44	0.992445	57063003
2	480403888.9	0.992445	507676048
3	404711444.4	0.992445	432555476
4	996153777.8	0.992445	1019529331
5	455863555.6	0.992445	483321122
6	662645444.4	0.992445	688540727
7	14036189444	0.992445	13961044619
8	13341596444	0.992445	13271699424
9	882779111.1	0.992445	907011235
10	1010884222	0.992445	1034148484
11	2344060667	0.992445	2357252483
12	17859304988	0.992445	17755275672
13	670517444.4	0.992445	696353253

Table 4 shows that the credibility factor are uniform across all contracts. This uniformity arises from the assumption made by the Buhlmann credibility model, which considers the risk volumes to be identical. Additionally, it can be observed that the credibility premiums for each contract exhibit variation. This variance is a direct reflection of the differing claims experience

Finally, it is evident that the entire dataset carries diminished weight, as indicated by the higher overall variance presented in Table 3. This underscores a stronger reliance on data from individual risk as opposed to group experience.

5. Conclusion

The primary objective of this study was to compute the average claim costs for each type of general insurance contract, establish the corresponding credibility factors for each, and derive the suitable credibility premium for each policyholder based on the aggregate claims for each contract. Throughout this research, the average claim costs, credibility factors and the credibility premiums were acquired using the Buhlmann credibility model. It is important to note that product pricing is imperative in the functioning of insurance firms because the premiums collected typically constitute their primary revenues stream. Consequently, possessing effective methods for ascertaining suitable premium levels for clients is of utmost significance.

It is therefore recommended that major stakeholders within the insurance industry (insurers and the regulator), consider adopting this approach while incorporating other factors that do influence premium estimation. By doing so, they can elevate the accuracy of general insurance product pricing, resulting in improved overall practices within the sector.

Expanding on the recommendation opens up avenues for further research by considering various factors influencing premium estimation beyond the scope of the current study. This could involve exploring the impact of additional variables such as demographic trends, economic indicators, or emerging risks on insurance pricing accuracy.

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