Milliman Research Report

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Application of Credibility Theory to Group Life Pricing

An Introduction

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1. Introduction

This paper is based on the Master Thesis 'Credibility in der Kollektiv-Lebensversicherung' which is referred to in the Appendix. The Master Thesis was authored by Manuel Tschupp, with the assistance and the support of AXA Winterthur and the Swiss Federal Institute of Technology (ETH) Zurich. Following his Master Thesis internship in 2007, Manuel was subsequently employed by AXA Winterthur between 2008 and 2011 in the group life pricing department, before joining Milliman as an actuarial consultant in July 2011. The Master Thesis is available on the ETH website (see Appendix for details on all sources).

Credibility theory, a branch of Bayesian statistics, is increasingly being used to handle risk-adjusted pricing. However, the most popular credibility models should not be applied to group life insurance business in their classical way due to the possible inadequacy of model assumptions. This paper addresses the question of how modern credibility theory may be used in an appropriate way to determine risk-adjusted premiums in group life pricing. It highlights the basic concepts and their broad applications.

The risks considered in this paper are disability and mortality, whereas savings and expense elements of a contract are deliberately neglected. Premiums are per group contract, where a single contract (e.g., with a company, or a pension fund) may contain from one single life insured up to several thousand.

Risk differentiation of premiums is necessary for a portfolio of group life contracts — for business in force, as well as for new business — as typically their pricing is a recurring process on an annual basis and their duration is one year up to a maximum of a few years. The need for this risk differentiation is primarily *adverse selection*. That is, if

- **Insurer A** grants reductions on risk premiums for contracts that systematically produce fewer insurance claims, but applies premium increases for those that systematically perform worse, and

- **Insurer B**'s premiums do not take into account these different risk characteristics,

then there is a natural drift of 'bad risk contracts' into the portfolio of insurer B, whilst 'good risk contracts' leave its portfolio in favour of insurer A. For a number of reasons this process may lead insurer B to severe problems.

Consequently, the risk premium of a group life contract should depend on the individual risk characteristic of the associated group of insured lives which can be measured by their corresponding risk experience. Usually there are two possible data sources:

The global risk experience. It is statistically observable that, for instance, the disability claims experience is significantly correlated to the industry the lives are employed in (e.g., construction, public sector, IT, etc.). Due to the amount of available statistical data, the global risk experience is a stable but quite generic information source.

The individual risk experience. The observed claims experience that has arisen in a given group might be seen as the best possible measure for an individual risk judgment. But on the other hand it could be very volatile, and for small groups there might be no such claims data at all.

The fundamental paradigm underlying credibility theory is to combine those two (or more) sources of information in a way which gives weight to their statistical significance — in other words, their 'credibility'. The degree to which the individual risk experience affects the combined risk judgment is therefore determined individually for each contract.

Bühlmann and Straub introduced a model in 1970 which is still the most widely used and most important credibility model for insurance practice. Nevertheless, in group life business and particularly for disability risks, the Bühlmann-Straub model should not be applied directly in the classical way as for several reasons the mathematical requirements of the model are not met. For example, non-homogeneous effects in time, such as the influence of economic circumstances, or IBNR[1] claims, lead to systematic dependencies within claims observations.

The techniques, presented here, allow the Bühlmann-Straub Model to be used as a risk-differentiation system for non-differentiated risk premiums. Such premiums are based on the age, gender and risk coverage and/or other criteria of the insured lives in the contract, but they do not explicitly take risk characteristics of the group as a whole into account.

We consider different risk measures, based on the number of claims, total claims amount, or a combination of both. We also present suggestions on how to treat business in force, as well as new business, with or without individual risk experience. A lack of experience is common with start-up companies or companies where there is insufficient entity-specific underwriting data and/or lack of data mining possibilities.

This paper is structured as follows:

Section 2 provides basic concepts of a risk-differentiation system, where there is a special focus on its desirable properties and mathematical construction.

Section 3 outlines the use of credibility theory in group life business. The desirable properties of risk adjustments, as well as the corresponding two-layer approach, are also discussed. Further, this section is concerned with the generic application of a credibility model and takes different claims measures into account.

Section 4 presents concepts on the actual application of the proposed concepts in insurance practice. The treatment of business in force and new business under the usual circumstances is described.

Section 5 leaves the reader with some final thoughts.

[1] IBNR is an acronym for ‘incurred but not yet reported’.

2. Basic concepts

In this section, we give a brief overview of relevant concepts related to risk-adjusted premiums in order to provide context for the key themes of the paper.

2.1 Desirable properties of the risk-differentiation system

There are different ways that risk adjustments can be applied to risk premiums. However, particularly from a business perspective there are some desired key properties that should be met by a risk-differentiation system:

Transparency. The way the risk adjustment affects the risk premium should be clear. The intuitive interpretation of a change in the risk characteristic should be reflected in the actual impact on the premium.

Monitoring. It should be easy to verify whether the risk-differentiation system produces the required total risk premium across the portfolio. Further risk analysis of subsets of the portfolio, as well as new business, should be possible.

Flexibility. The assignment of a new individual risk adjustment (e.g., based on the underwriting of a new business contract during the year) in line with the existing risk differentiation in the portfolio should be easy. The construction of an individual risk adjustment allows the separate identification and amendment of different parameters that affect it (e.g., statistical significance of observations, speed at which a client reports new claims, timeliness of underwriting data).

Compatibility. The risk-differentiation system should be compatible with a large spectrum of different applications. Business in force, where there might be manual interventions in the risk judgment during a given year, as well as new business with or without individual risk experience, should be taken into account.

By respecting these properties, regular and ad-hoc intervention during the year for actuarial or management reasons are easily possible, either for individual contracts or for a whole portfolio.

2.2 Construction of the risk-differentiation system

At some point a group life insurer has to compute a *non-differentiated risk premium* that covers at least the best estimate average expected total claims amount of a contract for a single year. Such a premium may consider biometric parameters such as the age and gender of each life, their chosen insured risks, and include a risk margin, but it does not take into account the risk characteristic of the specific group of insured lives as a whole.[2]

We consider the disability and mortality risks separately and denote the corresponding non-differentiated risk premiums of a contract by Π^{disab} and Π^{mort}.

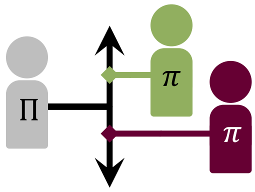
[2] The determination of the non-differentiated risk premium is not addressed in this paper.

As a key property, and in compliance with the well-known law of large numbers, the non-differentiated total risk premium is supposed to accurately compensate for the overall risk in the portfolio (with some statistical deviation, which is allowed for by the risk margin). In other words, if the insurer's pricing regime would just be based on non-differentiated risk premiums, then premiums would be expected, on average, to cover the cost of claims. But due to the effects of adverse selection (see Section 1) one has to apply risk adjustments, which results in *differentiated risk premiums,* denoted by π^{disab} and π^{mort}.

The question is how the non-differentiated risk premium, the differentiated risk premium and the corresponding risk adjustment should be related. To meet the desired properties of the previous subsection, a multiplicative approach is desirable, as demonstrated below.

If we define the risk adjustments to be $\xi^{\text{disab}}, \xi^{\text{mort}} > 0$ then

$$\pi^{\text{disab}} = \xi^{\text{disab}} \cdot \Pi^{\text{disab}} \qquad \text{and} \qquad \pi^{\text{mort}} = \xi^{\text{mort}} \cdot \Pi^{\text{mort}}.$$



That is, a contract where the insured group of lives is judged to be an average disability risk will be priced using a risk adjustment of $\xi^{\text{disab}} = 100\%$ such that neither a decrease nor an increase in the non-differentiated risk premium would be applied.

With this approach the risk-differentiation system is very *transparent*. The risk adjustment ξ is an intuitive representation of the risk characteristics of the contract, and no knowledge about the premium or any other parameter is necessary:

- A group that is judged to be 'twice as bad' as the average, e.g., is expected to produce twice as many claims or twice the claims amount, will be allotted $\xi = 2$. Therefore its premium will be twice the amount that is required for a group with the same composition, but with average risk.

- A first group (with risk adjustment ξ_{A}) that is judged to be 'half as bad' as a second one (with risk adjustment ξ_{B}) will pay half of its premium, i.e., $\xi_{\text{A}} = 0.5 \cdot \xi_{\text{B}}$ and thus $\pi_{\text{A}} = 0.5 \cdot \pi_{\text{B}}$, since $\Pi_{\text{A}} = \Pi_{\text{B}}$.

- A group that grows in volume, e.g., a 20% increase in sum assured from year 1 to year 2, but whose risk characteristics are considered to remain the same, will pay $\pi_2 = 1.2 \cdot \pi_1$ whilst the risk adjustment will remain $\xi_2 = \xi_1$ (as $\Pi_2 = 1.2 \cdot \Pi_1$).

Monitoring the risk-differentiation system is possible by analysing the risk adjustments ξ in the portfolio. It provides answers to questions along the lines of:

- To what extent does the risk-differentiation system affect the total risk premium in the portfolio? This question is related to the overall average risk in the portfolio. It could be measured by some weighted mean of the risk adjustments.

- What does the distribution of risk characteristics in the portfolio look like? What about risk homogeneity within the portfolio or specific parts of it?

- What type of business (a certain industry, large companies, certain products) tends to be a better risk than average?

- Will a potential new business contract lower or raise the risk quality of the insurer's portfolio?

Sections 3 and 4 will clarify that the suggested risk-differentiation system fulfils the additional properties of flexibility and compatibility.

3. Application of credibility theory

In this section we discuss the application of credibility theory in the context of Section 2. To aid readability and reduce complexity, we furthermore restrict our considerations to either the disability or the mortality risk without loss of generality. All concepts can be applied to both risks in an analogous way. Nevertheless, if possible within the framework of the product under consideration, and with regard to the available data, disability and mortality risks should be considered separately due to independence and homogeneity assumptions within the model.

3.1 Desirable properties of the risk adjustment

In addition to the outlined desirable properties of a risk-differentiation system, as described in Section 2, there are specific qualities one would expect from the risk adjustment ξ in the given context.

In essence, ξ should depend on the given group's individual risk characteristics which, in practice, are measured by the individual and global risk experience. It is reasonable to assume that such risk experience should be available for most contracts in the portfolio and for new business as well — that is, it should rely on:

- A statistical observation during a fixed time period, the so called *observation period*
- Some *claims observation* for a contract in a particular year of the observation period
- Some *volume measure* for the contract in that year

Subsection 3.3 includes possible definitions for these terms.

In the Introduction section, the individual and the global risk experience were described as the two usual information sources to determine a combined risk judgment. As an intuitive property, one would then wish the risk judgment of a contract with large volume to be mainly based on its individual risk experience. In fact, as illustrated in Figure 1:

The greater the volume of a contract, the more weight should be given to its individual risk experience and the less weight to the corresponding global risk experience.

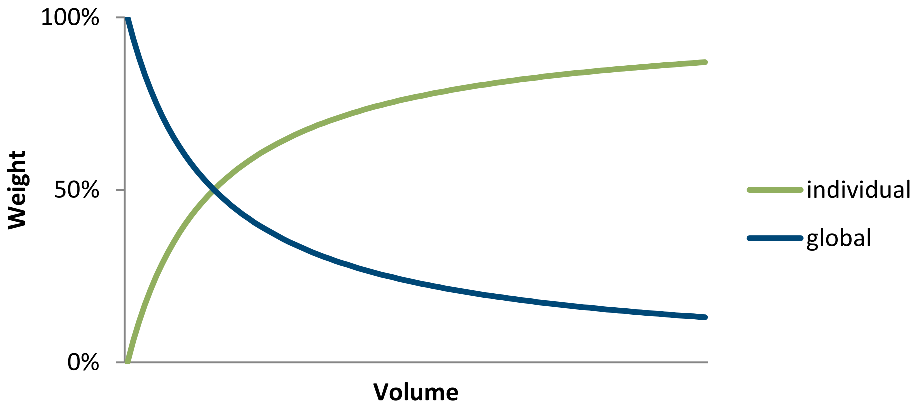


Figure 1: Weight of the global and individual risk experience

On the other hand, the risk premiums of small contracts should also be differentiated to some extent, though the individual risk experience is not statistically significant. This requires the provision of risk groups (see Subsections 3.2 and 4.1).

Furthermore, group life business can be heavily affected by non-homogeneous effects over time:

- First, there is a time delay between the occurrence of a claim (e.g., the first day of a work incapacity that leads to disability and thus to an insurance benefit, or the time of death of an insured) and the availability of the information to the insurer, be it due to medical assessment, delayed declaration by the customer, processing speed of the insurer or any other reason. This gives rise to IBNR claims, and the delay can be up to several years. Figure 2 illustrates this effect for disability risk.

- Second, economic cycles might systematically provoke more or fewer claims observations for some years within the observation period. For example, the financial crisis caused a peak in the number of disability claims observations in some countries. Such economic cycles may affect certain subsets of the portfolio differently (e.g., dependent on the industry the insured lives are employed in). Therefore, it is important to explore subsets with similar sensitivity to such effects separately, rather than treating the insurer's entire portfolio as a whole.

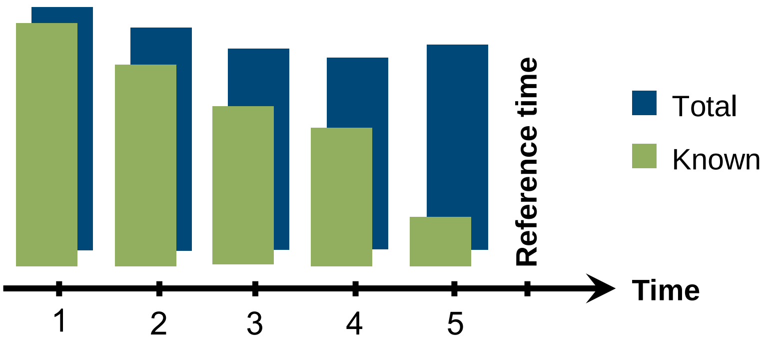


Figure 2: Number of disability claims per occurrence year[3]

The bottom line is that the year of occurrence of a claim, related to the date of its statistical analysis, is important information. As an example, a risk-differentiation system that only considers the total number of claims in an observation period, rather than the actual number per year, would therefore systematically underestimate the risk of a contract where there are only the most recent years of data available.

As a final desirable property, the application of risk adjustments should be generic and independent of the insurance product, as long as it is applied to the actual risk premium (or to parameters that affect the risk premium proportionally, e.g., sums at risk) within the multiplicative approach.

[3] The graph shows the number of disability claims for a given sub-portfolio in the year of occurrence. The green bars show the number of claims as known by the reference time. The blue bars are the number of disability claims that have arisen, but were not known to the insurer by the reference time (e.g. they are known today, some years after the reference time). All amounts are for illustrative purposes only and not based upon actual data.

3.2 Two-layer approach

The fundamental paradigm of credibility theory is to combine a global and an individual risk experience in a way that gives appropriate weight to their statistical significance. Therefore, if the statistical significance of a contract's individual risk experience can be inferred from its volume, then 'small' contracts tend to be mainly judged upon the corresponding global risk experience.

As this risk experience is *global*, many contracts have the same common source of information, and thus their risk adjustments are similar. But the global risk experience is not necessarily meant to be the same throughout the whole portfolio. Hence, a straightforward way to differentiate the risk premiums of small contracts according to their risk characteristic is to differentiate the global risk experience. This can be realised by partitioning the portfolio into some large subsets, the so-called *risk groups*, where each risk group has its own global risk experience.

The concept of risk groups leads to the following challenges:

- In which suitable way should the portfolio be partitioned, and to which risk group should future new business be allocated? The total number of risk groups, their volume, available risk information for each group, and their homogeneity are all crucial to the risk-differentiation system.

- Once the risk groups have been decided upon, how are the corresponding global risk experience measured and the risk judgment of each risk group determined?

- As there are several risk groups with different global risk experience, how do the global and individual risk experiences of a single contract interact to lead to the combined risk judgment of the contract? The mechanism used should also meet the desired properties that were described in Subsection 3.1.

The first and the second issues above are discussed in the later Subsection 4.1. For the time being, let us focus on the fundamental question of the third bullet point. The idea there is to think of the risk-differentiation system in two layers:

- **Global layer.** In the first layer, a given contract is allotted to one of the risk groups with reference to a defined criterion. Each risk group has a fixed *risk level* which is interpreted as the risk judgment of the risk group in relation to the whole portfolio. Thus, a risk level of 80% would mean that an average contract in the risk group is expected, for example, to produce 20% fewer claims than an average contract in the whole portfolio.

- **Individual layer.** In the second layer, the given contract is judged in relation to its corresponding risk group, rather than in relation to the whole portfolio. Thus a corresponding *risk level* of 110% would mean that the contract is expected, for example, to produce 10% more claims than an average contract in the same risk group.

Hence, in this two-layer approach, for each contract there are two risk judgments in series, one to determine the risk level of the contract's risk group in relation to the whole portfolio and the other to compute the risk level of the contract in relation to its risk group. If one thinks of both risk judgments in terms of the aforementioned multiplicative approach (Subsection 2.2), one now can compute the risk adjustment ξ of the given contract by multiplying those two risk levels, e.g., $\xi = 80\% \cdot 110\% = 88\%$.

Figure 3 illustrates the two-layer approach, where the given contract was assigned to Risk Group 2 and was judged to be a slightly better risk than an average contract in the same risk group.

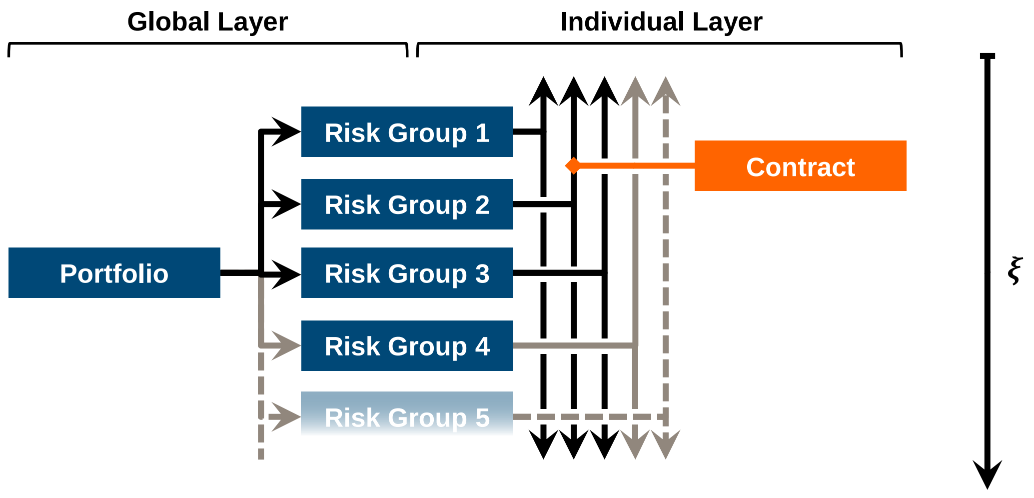


Figure 3: Two-layer approach

3.3 Generic credibility model

In the preceding sections it was outlined what a risk-differentiation system in group life pricing could look like, and how risk judgments would be applied within the framework of a two-layer approach. We now need a system to express these risk judgments in terms of risk levels, i.e. concrete numbers, to finally determine the risk adjustment ξ.

The actual credibility model is set up to provide such a risk level in a generic way. Therefore, we consider an *individual entity*, where there is individual risk experience available, and a *global entity*, where there is global risk experience available[4]. The output of the credibility model is a credibility estimator that is used as risk level of the individual entity in relation to the risk level of the global entity within the multiplicative approach.

In Subsection 3.1 it was stated that risk experience should rely on some claims observations and some volume measure within an observation period:

- **Observation period $\boldsymbol{T}$.** Risk characteristics of a group life contract usually do not change in an abrupt manner, so neither should their risk judgment. Using observations from several years yields some stability in the risk experience. Furthermore, too short an observation period would result in too few observations to differentiate the risk judgments of the individual entities from one another. In addition, emerging data is less statistically significant because of IBNR claims, though it is needed to determine an accurate up-to-date risk judgment. In contrast, too long a period would require too much historical data. For group life business an observation period of around five elapsed years is usual.

- **Claims observation $\boldsymbol{C_{ij}}$.** For each year j of the observation period, C_{ij} quantifies the claims observation of the individual entity i. For our application it is either the known corresponding number of claims or the known corresponding total claims amount[5] at a certain point in time. As a third option, it might be the corresponding *weighted number of claims*, see Subsection 3.4. These quantities do not have to be IBNR claims adjusted.

[4] The individual entity is a subset of the global entity, e.g., consider a contract as an individual and a risk group as a global entity.

[5] A claims amount of a given claim at a certain point of time is the accumulated value of benefits paid plus the present value of expected future benefits.

- **Volume measure V_{ij}.** For each year j of the observation period, V_{ij} denotes the volume of the individual entity i. For our application it is either the corresponding number of insured lives (when C_{ij} is the number or weighted number of claims) or the corresponding total non-differentiated risk premium (when C_{ij} is the total claims amount).

On the basis of these parameters, the credibility estimator, φ_i, is defined as follows:

$$\varphi_i = \alpha_i \cdot R_i + (1 - \alpha_i) \cdot R$$

The credibility estimator, φ_i, which is a linear combination of the individual and global risk experience, is used as the risk level of the individual entity in relation to the global entity. As this is a relative judgment with respect to the global entity, the global risk experience is $R = 1$ in the above formula, i.e., the global entity has got risk level 100% in relation to itself. On the other hand, the individual risk experience R_i is quantified by

$$R_i = \frac{\sum_{j \in T} C_{ij}}{\sum_{j \in T} f_j \cdot V_{ij}},$$

where f_j are structural parameters and are explained below. Finally, there is α_i, the weight of the individual risk experience. It is determined by

$$\alpha_i = \frac{\sum_{j \in T} f_j \cdot V_{ij}}{\sum_{j \in T} f_j \cdot V_{ij} + \frac{\sigma^2}{\tau^2}},$$

where σ^2 and τ^2 are again some structural parameters. See next page for an intuitive approach.

Structural parameters are considered to be constants for the period of one year, or the period of recurring pricing. They are estimated on the basis of the insurer's whole portfolio, i.e., the business in force, and are also applied to new business coming on throughout the year:

- **Expected claims observation frequencies f_j.** The way in which these parameters are estimated is key to dealing with the non-homogeneous effects in time that were described in Subsection 3.1. As is evident from the above formula for the individual risk experience, those frequencies appear in the denominator. As the actual claims observations C_{ij} in the numerator are affected by time-inhomogeneous effects, there would be a good chance to get an unbiased R_i if the denominator is affected by the same effects and to a similar extent as the numerator. Depending on the choice of the risk groups it is reasonable to assume that this property is fulfilled within the same risk group by using the formula

  $$f_j = \frac{\sum_{i \in P} C_{ij}}{\sum_{i \in P} V_{ij}},$$

  where P represents the subset of business in force contracts that are assigned to the risk group under consideration.

- **Time inhomogeneity σ^2.** This parameter quantifies the average risk deviation over time of a contract in the same risk group. The larger the deviation, the less the statistical significance of the individual risk experience, so the less weight should be given to it.

- **Group inhomogeneity τ^2.** This parameter quantifies the average risk deviation in risk levels of the contracts in the same risk group. The larger the deviation, the less the statistical significance of the global risk experience (to judge the individual entity), so the less weight should be given to it.

The interested reader is referred to the literature indicated in the Appendix for more information on the corresponding estimators.

Insight: An intuitive approach to the credibility weight α_i

Although the stated formula for the credibility weight is a mathematical result of the underlying theory, it has an intuitive interpretation. Reconsidering its components:

- $\sum_{j \in T} f_j \cdot V_{ij}$ is the 'observation-related volume' of the individual entity.
- σ^2 is the 'uncertainty within an average individual risk experience'.
- τ^2 is the 'uncertainty within the global risk experience'.

Their impact on the weight α_i, allotted to the individual risk experience, is:

component	**change**	**impact on α_i**
$\sum_{j \in T} f_j \cdot V_{ij}$	↑	↑
$\sum_{j \in T} f_j \cdot V_{ij}$	↓	↓
σ^2	↑	↓
σ^2	↓	↑
τ^2	↑	↑
τ^2	↓	↓

The following Figure 4 illustrates these relations:

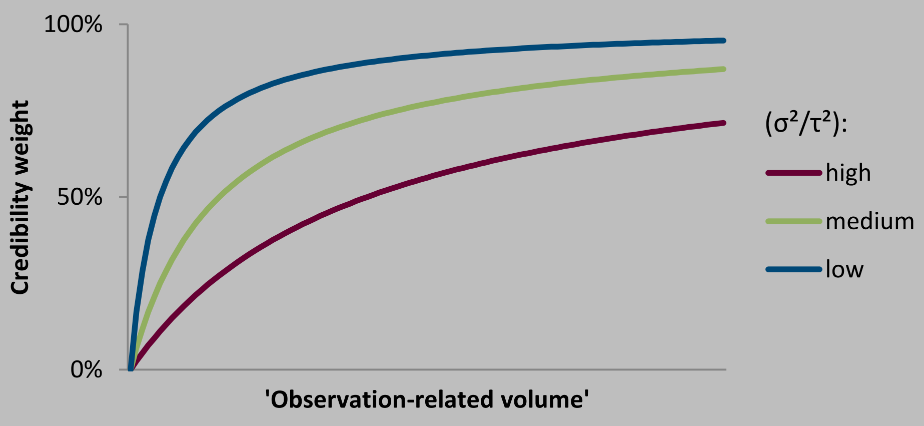


Figure 4: Credibility weight in relation to its components

3.4 Choice of the claims observations measure

In the previous subsection, the claims observation C_{ij} was defined to be the known number of claims or the known claims amount. In many cases, the observed number of claims is a more statistically significant measure for the actual risk characteristics than the corresponding claims amount.

A typical example to illustrate this is motor insurance. There a driver should be considered as bad risk, if he causes a lot of accidents, i.e., the number of claims is heavily correlated to the risk characteristics. But the corresponding claims amount is more affected by the value of the car and other circumstances of the accident and the insured coverage than by the driver's risk characteristics, and thus it might be too volatile. There is a similar reasoning for group life insurance. For example, large claims are often due to a high salary of the insured, which is often heavily correlated with the degree of education of the individual. This class of employees generally produces a large total claims amount, but a low number of claims.

Nevertheless, with disability and mortality risks in group life insurance, the claims amount is also important information about the risk characteristics of an insured group. Typically, the claims amount is directly correlated to the salary of the insured, and there is also a strong link to the age of the life. It is worth knowing whether claims in a group tend to arise in the upper or lower income group, or among younger or older subgroups, as such information is reasonably related to the risk characteristics of the whole group of insured lives.

Therefore, one could seek to combine both measures. This could either be done by computing a risk adjustment separately for each of the number of claims and the claims amount, and then combining the two risk adjustments into one single risk adjustment in an appropriate way. Alternatively, the two measures could be combined into a single measure for determining the corresponding risk adjustment. While the first method is quite straightforward, the aim of this subsection is to outline a suggestion for following the second.

It is possible to classify insured claims according to claims amounts. Once such classes have been defined, one may assign a weight to each of the classes in an appropriate way, such that each claim within class k will have weight ω_k.

In the context of Subsection 3.3, the claims observation C_{ij} of contract i and year j will then be the sum of the weights of the corresponding claims, rather than either the number of, or the total amount of known claims.

4. Pricing in practice

The scope of this section is to indicate how the concepts of Sections 2 and 3 might be used in practice when pricing insurance business. It is concerned with the recurring process of risk assessment of business in force, as well as with risk judgment of new business. As already stated, disability and mortality risks should be considered separately.

4.1 Provision of risk groups

The provision of risk groups is a recurring process, though it might be sufficient to re-check only every few years instead of annually.

As already stated, the industry in which the lives are employed constitutes a good criterion for an a priori risk judgment and thus could be used to build risk groups. There are also other parameters that could be worth taking into account. In essence, it is a question of strategy as to whether to apply a certain criterion for the construction of risk groups or not, assuming these criteria are statistically significant.[6] However, the fundamental property of all such criteria should be that they are generally available and objectively measurable for all types of business, particularly for new and in-force business.

Once the relevant criteria have been determined, the question is how to assign contracts to risk groups. The industry a company is operating in makes up a good example, as usually there are industry standard classification systems[7] that objectively link a company to an industry. The use of such a system's main branches might result in dozens of 'industry sectors'. Then it would be necessary to allot these industry sectors to risk groups.

The allocation will be based on business in force in the insurer's portfolio. With the generic credibility model defined in Subsection 3.3 we choose the industry sectors to be the 'individual entities' and designate the whole portfolio as the 'global entity'. Each main industry i will be assigned a risk level $\iota_i \coloneqq \varphi_i$ in relation to the average risk level in the whole portfolio, which is 100%. Now all industry sectors can be plotted on a single scale of risk levels, see Figure 5 for an example excerpt:

Entities and use of result in the generic credibility model		
Individual entity i	**Global entity**	**Use estimator φ_i as**
Industry sector	Whole portfolio	ι_i

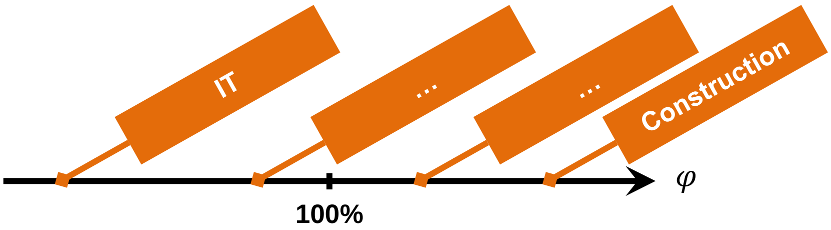


Figure 5: Risk levels of industry sectors

6 The statistical significance of a criterion for an a priori risk judgment might be determined by application of a credibility model, or other such techniques, for example generalised linear models.

7 Examples: NOGA in Switzerland, NACE in the European Community, UKSIC in UK, SIC and NAICS in the United States.

The next question is how many risk groups an insurance company should have within group life business. The more risk groups, the better the a priori risk differentiation of business. But with an increasing number of risk groups, the claims experience of the risk groups will become less statistically significant, and there might even be risk groups with no claims data at all. So a number between three and seven might be appropriate, where an odd number produces a risk group 'in the middle', i.e., whose risk level would correspond more or less to the average risk level in the whole portfolio.

In terms of the two-layer concept shown in Figure 3 in Section 3.2, risk groups can be seen as partition of the scale of risk levels in Figure 5. Thus, for a given number, n, of risk groups, there are $(n-1)$ barriers needed on the scale to actually separate the risk groups. Depending on the distribution of the industry sectors' risk levels, there are several reasonable choices of barriers. The values of the chosen barriers will be denoted by b_k, where $k = 1, \dots, n-1$, and the corresponding risk groups by G_l, $l = 1, \dots, n$. Now, as illustrated in Figure 6 for the example of three risk groups, the industry sector i is allocated to the risk group

$$\left.\begin{matrix} G_1 \\ G_l \\ G_n \end{matrix}\right\} \text{ if } \begin{cases} \iota_i < b_1 \\ b_{l-1} \leq \iota_i < b_l \text{ and } 1 < l < n \\ b_{n-1} \leq \iota_i \end{cases} .$$

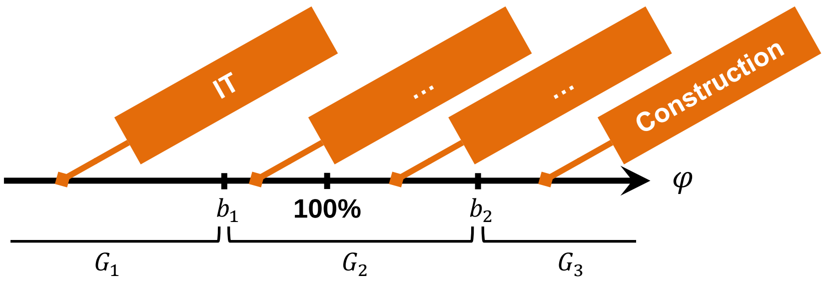


Figure 6: Allocation of three risk groups

Finally, each of the risk groups G_k, $k = 1, \dots, n$, needs to be assigned its risk level ϱ_k. Again, this is based on business in force in the insurer's portfolio, and we use the generic credibility model of Subsection 3.3. The risk groups will now act as 'individual entities', and the whole portfolio is the 'global entity'. The resulting credibility estimator yields the desired risk levels, i.e., $\varrho_i := \varphi_i$, $i = 1, \dots, n$:

Entities and use of result in the generic credibility model		
Individual entity i	**Global entity**	**Use estimator φ_i as**
Risk group	Whole portfolio	ϱ_i

4.2 Treatment of business in force

Pricing of group life contracts is an annually recurring process; thus, risk adjustments of business in force should be determined at the same frequency with updated observation data.

In terms of the two-layer concept, the generic credibility model is used to judge a contract in the insurer's portfolio in relation to the corresponding risk group. Here, the corresponding risk group $G_{g(i)} \in \{G_1, \dots, G_n\}$ to contract i is the risk group that is allotted to the industry sector the insured lives of the contract are employed in[8] (see Subsection 4.1). Hence, we use the group of lives in contract i as the 'individual entity' and its risk group $G_{g(i)}$ as 'global entity'. The resulting credibility estimator $\gamma_i \coloneqq \varphi_i$ is the risk level of contract i in relation to the risk level $\varrho_{g(i)}$ of risk group $G_{g(i)}$:

Entities and use of result in the generic credibility model		
Individual entity i	**Global entity**	**Use estimator φ_i as**
Single contract	Risk group	γ_i

The final risk adjustment ξ_i of the contract, which is used in the context of Subsection 3.2, is computed by

$$\xi_i = \varrho_{g(i)} \cdot \gamma_i \, .$$

As business in force is considered, the required data to apply the credibility model is available to the insurer for the period the lives were insured for. If this period is shorter than the observation period of the model, then the input parameters are restricted to the available observation years. Nevertheless, there is a minimum number of observation years needed to produce reliable results that are in line with the original risk adjustment. Whenever this is not fulfilled, an insurer should usually retain the original risk adjustment.

Furthermore, in practice there could be the issue that the corresponding risk group for a given contract cannot be determined. One possible approach is to use the median risk group, e.g. $G_{(n+1)/2}$ for an odd number n of risk groups, or the risk group G_k where ϱ_k is closest to 100%. A technically more sophisticated way would be to designate the group of lives in the contract as the 'individual entity' and the whole portfolio as 'global entity', and then to determine ξ_i directly:

Entities and use of result in the generic credibility model		
Individual entity i	**Global entity**	**Use estimator φ_i as**
Single contract	Whole portfolio	ξ_i

[8] The function $g: \mathbb{N} \to \{1, \dots, n\}$ maps the index of a contract to the index of the corresponding risk group.

4.3 Treatment of new business

In contrast to business in force, with new business there is usually no volume and claims data, nor any underwriting data at all, available from the insurer's own portfolio. Nevertheless, risk differentiation is important to be competitive in the market, and so a risk adjustment for a potential new business contract should be computed.

To apply the risk-differentiation system, it is necessary to demand underwriting data from the possible contractual partner and maybe even the previous or current insurer of the group. Such underwriting data should include the necessary information to determine the risk group of the contract, and to compute the risk level of the contract in relation to the risk level of the corresponding risk group. The possible contractual partner and the present insurer are generally motivated to provide this data, as:

- Accurate underwriting data (especially for 'good risks') allows a precise risk judgment and thus lowers the need for conservative pricing and possible future pricing amendments.
- The offer might be conditional on the accuracy of the data provided, and thus the contract would be void if the information turns out to be wrong.
- The present insurer might lose its correctly priced contract if the full list of claims is not provided, as then a competitor's average pricing of the group might be lower than the risk-adjusted pricing (especially for 'bad risks').

An insurer might require the risk adjustment to be in line with the risk-differentiation system that is applied to the in-force portfolio of the insurer. Therefore, the choice of an appropriate risk level $\tilde{\varrho}_{g(i)}$ of the risk group and suitable structural parameters for the credibility estimator $\gamma_i \coloneqq \varphi_i$ is important. The final risk adjustment ξ_i of the contract, which is used in the context of Subsection 3.2, would then again be computed by

$$\boxed{\xi_i = \tilde{\varrho}_{g(i)} \cdot \gamma_i \,.}$$

For new business there is no minimum number of observation years needed. For example, there will be no volume and claims data available for start-up companies, i.e., the pricing will rely on the risk experience of the corresponding risk group alone. If the risk group of the contract cannot be determined, the same approach as described in the previous section is possible.

5. Some final thoughts

Although almost all necessary steps to set up a risk-adjusted pricing model based on existing, non-differentiated risk premiums are described in this paper, there are several aspects that require careful consideration, for example:

- The matching of non-differentiated risk premiums and their risk adjustments
- The simultaneous impact of a given risk criteria on both the non-differentiated risk premiums and their risk adjustments, leading to double consideration, which might be undesirable
- The selection of relevant claims and volume measures
- The constitution of weighted claim numbers
- The creation of risk groups using the two-layer approach
- The estimation of structural parameters for the different applications of the credibility model
- The validity of the assumptions in the underlying theory as applied within a given model
- The treatment of underwriting data for new business
- The re-evaluation of risk adjustments from one year to another
- The use of risk adjustments for non-standard products
- Compliance with local insurance regulations and law

Appendix

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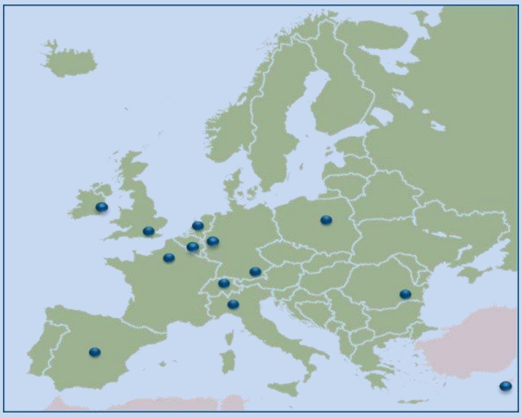

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