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Corso di Laurea in Laurea Magistrale in Scienze Statistiche e Attuariali

Tesi di Laurea Magistrale

Application of GLM Advancements to Non Life Insurance Pricing

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The data scientist is a person who is better at statistics than any software engineer and better at software engineering than any statistician.

Josh Wills

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Qua potrei ringraziare:

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- DEAMS per la formazione e l'apertura alla collaborazione col mondo aziendale

Abstract

This is my abstract …

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1
Non-Life Insurance Pricing

In this chapter I am going to provide an overview on how non-life insurance works from an actuarial point of view with a specific focus on the pricing needs.

1.1 What a Non Life Insurance is

The Italian Civil Code provides the following definition of insurance contract:

Definition 1.1 (Insurance Contract, Art. 1882, Italian Civil Code)**.** The insurance is the contract with which an insurer, in exchange of the payment of a certain premium, obliged himself, within the agreed limits:

1. to pay an indemnity to the insured equivalent to the damage caused by an accident;
2. or to pay an income or a capital if a life-related event occurs.

This definition identifies two parties: the *Insurer* and the *Policyholder*. The policyholder pays to the Insurer a certain *Premium* at the beginning of the insurance coverage and the insurer will pay a benefit if a certain event (*Claim*) occurs. This event could happen zero, one or more than one times, so it is possible to have more than one claim.

Usually, in non-life insurance, the benefit is a capital that could be predetermined (e.g. in motor theft insurance, where the benefit is usually the value of the insured vehicle) or defined by the entity of the claims (e.g. in motor third party liability insurance, it depends on the damage the policyholder has provided to a third party). Regarding the "agreed limits", another peculiarity of non-life insurances is that the coverage period is defined as a fixed amount of time, usually corresponding to 1 year.

Starting from this legal definition, we can formalize a non-life insurance contract as follows. Let's:

- $]t_1, t_2]$, with $t_1 < t_2$, be the coverage period;
- $P > 0$ be the premium payed by the policyholder to the insurer;
- $N \in \mathbb{N}$ be the number of claims occurred during the coverage period (*claims count*);
- $\tau_1, \tau_2, \ldots, \tau_N$, with $t_1 < \tau_1 < \tau_2 < \cdots < \tau_N < t_2$, be the timing of each claim;
- $Z_1, Z_2, \ldots, Z_N > 0$ be the amount of each claim (*claims severities* or *claims sizes*).

The total cost of claims for the insurance is:

$$S = \begin{cases} 0 & \text{if } N = 0 \\ \sum_{i=1}^{N} Z_i & \text{if } N > 0 \end{cases}$$

For semplicity, in the following we are going to just use the notation $S = \sum_{i=1}^{N} Z_i$ with the meaning of 0 if $N = 0$.

Figure 1.1 shows the cash flows corresponding to the insurance contract. From this representation we can interpret the entering into an insurance contract by the policyholder as a way to exchange the negative cash flows $-Z_1, -Z_2, \ldots, -Z_N$ with one single negative cash flow $-P$. On the other hand, the insurer undertakes the negative cash flows $-Z_1, -Z_2, \ldots, -Z_N$ in exchange for a positive cash flow $+P$.

The major difference between these cash flows is that P is a certain amount, while $Z_1, Z_2, \ldots, Z_N$, at the time t_1, are uncertain in the amount, in the count (N) and in the timing ($\tau_1, \tau_2, \ldots, \tau_N$). So the policyholder, paying a premium P, is giving his risk to the insurer.

From a statistical point of view, we can translate this uncertainty saying that N and $Z_1, Z_2, \ldots, Z_N$ are random variables. Therefore, we can say that $\{N, Z_1, Z_2, \ldots\}$ is a stochastic process. Usually, in non-file insurance pricing, the variables $\tau_1, \tau_2, \ldots, \tau_N$ are not taken into account because the coverage span short and from a financial point of view the timing of the claims occurences is negligible.

Previously we said that $Z_1, Z_2, \ldots, Z_N$ are all > 0. This assumption corresponds to the fact that we are excluding the null claims, i.e. the claims that have been opened, but result in no payment due by the insurer. For the values of Z_i with $N < i$ we can use the rule that $N < i \Rightarrow Z_i = 0$. Therefore we can say that $N < i \Leftrightarrow Z_i = 0$.

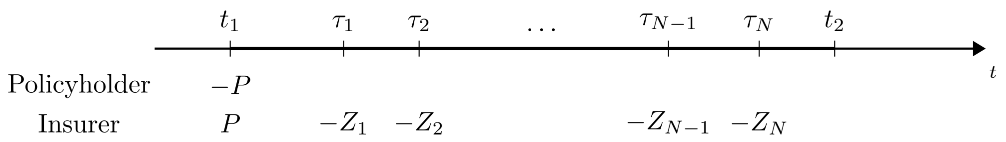

Figure 1.1: Insurance Contract cash flows.

1.2 Non Life insurance pricing

The process of pricing corresponds in defining the set of rules for determining the "proper" premium P, given the known information on the policyholder. In the next sections I am going to better explain what "proper" means.

1.2.1 Compound distribution hypotesis

The first step for evaluating the stochastic process $\{N, Z_1, Z_2, \dots\}$ is to introduce some probabilistic hypotesis. The usual hypotesis assumed are the following:

Definition 1.2 (Compound distribution)**.** Let's assume that:

1. for each $n > 0$, the variables $Z_1|N = n,\ Z_2|N = n,\ \dots,\ Z_n|N = n$ are stochastically independent and identically distributed;
2. the probability distribution of $Z_i|N = n,\ i \leq n$ does not depend on n.

Under these hypothesis we say that:

$$S = \sum_{i=1}^{N} Z_i$$

has a compound distribution.

The variables $Z_i|N = n$ used in this definition can be interpreted as the *claim severity for the* i^{th} *claim under the hypotesis that n claims occurred.* The two hypotesis provided in definition 1.2 imply that the distribution of $Z_i|N = n,\ i < n$ does not depend from i nor from n. In the following, we are going to use the notation Z to represent a random variable with the $Z_i|N = n,\ i < n$ distribution and $F_Z(\cdot)$ for its cumulative distribution function (i.e. $F_Z(z) = P(Z \leq z)$).

Let's consider the variabile $Z_i|N > i$. We can interpret it as the *claim severity for the* i^{th} *claim under the hypotesis that the* i^{th} *claim occurred.* From the hypotesis provided in definition 1.2 we can obtain that also $Z_i|N > i$ has the same distribution of $Z_i|N = n,\ i < n$. This can be easily obtained as follows:

$$
\begin{aligned}
P(Z_i|N \geq i) &= P\left(Z_i \middle| \bigvee_{n=i}^{+\infty} (N=n)\right) = && (1.1)\\
&= \sum_{n=i}^{+\infty} \underbrace{P(Z_i \leq z|N=n)}_{=F_Z(z)} P(N=n|N \geq i) = && (1.2)\\
&= \sum_{n=i}^{+\infty} F_Z(z) P(N=n|N \geq i) = && (1.3)\\
&= F_Z(z) \underbrace{\sum_{n=i}^{+\infty} P(N=n|N \geq i)}_{=1} = && (1.4)\\
&= F_Z(z)
\end{aligned}
$$

Where:

- the step (1.1) and the step (1.2) are given by the fact that the event $\{N \geq i\}$ can be decomposed as $\{N \geq i\} = \left\{\bigvee_{n=i}^{+\infty} (N=n)\right\}$ and that the events $\{N=n\}, n \in \{i, i+1, i+2, \dots\}$ are two-by-two disjoint, so they constitute a partition of $\{N \geq i\}$, that allows us to use the disintegrability proprierty of the probability;
- the step (1.3) is due to the fact that the distribution of $Z_i \leq z|N=n$ depends neither on i nor on n;
- the equivalence $\sum_{n=i}^{+\infty} P(N=n|N \geq i) = 1$ at step (1.4) is due to the fact that the events $\{N=n\}, n \in \{i, i+1, i+2, \dots\}$ are a partition of $\{N \geq i\}$.

Therefore, Z can be considered as the *claim severity for a claim under the hypotesis that that claim occurred.*

1.2.2 Distribution of the total cost of claims

Under the hypotesis defined in definition 1.2, it is possible to obtain the full distribution of S given the distribution of N and Z. In this chapter we are going to provide only the formula of the expected value $E(S)$, but, with the same aproach one can obtain all the moments.

The expected values of the total cost of claims $E(S)$ can be obtained from the expected value of the claims count $E(N)$ and the expected value of the claim severity $E(Z)$ as follows:

$$
\begin{aligned}
E(S) &= \sum_{n=0}^{+\infty} P(N=n) E\left(S \mid N=n\right) = && (1.5)\\
&= \sum_{n=0}^{+\infty} P(N=n) E\left(\sum_{i=1}^{n} Z_i \middle| N=n\right) = && (1.6)\\
&= \sum_{n=0}^{+\infty} P(N=n) \sum_{i=1}^{n} \underbrace{E\left(Z_i \mid N=n\right)}_{=E(Z)} = && (1.7)\\
&= \sum_{n=0}^{+\infty} P(N=n) n E(Z) = && (1.8)\\
&= E(Z) \underbrace{\sum_{n=0}^{+\infty} n P(N=n)}_{=E(N)} = && (1.9)\\
&= E(N)E(Z) && (1.10)
\end{aligned}
$$

Where:

- the step (1.5) is given by the fact that the events $\{N=0\},\{N=1\},\{N=2\},\ldots$ constitute a partition of the certain event Ω, that allows us to use the disintegrability proprierty of the expected value;
- the step (1.6) is due to the definition of S;
- the step (1.7) is due to the linearity of the expected value;
- the steps (1.8) and (1.9) are due to the fact that, as assumed by the compound distribution hypothesis, $E\left(Z_i \mid N=n\right)$ does not depends on i and n;
- the step (1.10) is due to the definition of the expected value $E(N) = \sum_{n=0}^{+\infty} nP(N=n)$

This result tells us that, under the hypotesis of the compound distribution, it is possible to easily obtain $E(S)$ from $E(N)$ and $E(Z)$. That means that we can model separately $E(N)$ and $E(Z)$ and, from them, obtain $E(S)$. That result is particularly useful in personalization (paragraph 1.2.3), because, for each individual i, given the information we have on him $x_i = (x_{i1}, x_{i2}, \ldots, x_{ip})$, we can estimate his expected claim size $E(N_i)$ and his expected claim severity $E(Z_i)$ and obtain his expected total cost of claims $E(S_i) = E(N_i)E(Z_i)$.

The expected cost of claims $E(S)$ is important because it gives us a first interpretation of what “proper” premium means.

Definition 1.3 (Risk premium)**.** Said S, the total cost of claims of a policyholder, his risk premium is given by:

$$P^{(r)} = E(S)$$

The risk premium is the premium that on average covers the total cost of claims. As mentioned above, as the coverages spans are usually short, we are not taking into account the timing of the claims and we don't discount the fact that the claim occurs later than the premium payment.

1.2.3 Personalization

1.3 Non-Life Insurance in Italy

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1.4 The actuary role

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Questa è una citazione (Shea et al., 2014; Lottridge et al., 2012)

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2

Statistical models for Non Life Insurance Pricing

2.1 Statistical Models

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2.1.1 GLM

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2.1.2 Elastic Net

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2.1.3 GAM

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2.2 Model comparison

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2.3 The actuary importance

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2.4 Implementation

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3
Practical application

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3.1 Data description

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3.2 Model used

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3.3 Model assessment

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3.4 Results

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