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Procedia Economics and Finance 20 (2015) 157 – 162

Procedia Economics and Finance

www.elsevier.com/locate/procedia

7th International Conference on Globalization and Higher Education in Economics and Business Administration, GEBA 2013

A review of theoretical concepts and empirical literature of non-life insurance pricing

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Abstract

It seems more and more that we live in a society afraid of everything, where everything can be considered as risk taking. This feeling of uncertainty and fear leads many individuals to manifest a great interest for safety. In the context of a risky society, the requirement for insurances is becoming more and more pronounced, the main concerns of the insureds being the guarantee of financial safety and security against a possible loss on a particular event. The entire process of insurance consists in offering an equitable method of transferring the risk in exchange for a predetermined price or tariff. This article is a review paper that describes the fundamental concepts of insurance pricing and reviews the main statistical tools used in insurance to reasonably discriminate the price.

Peer-review under responsibility of the Faculty of Economics and Business Administration, Alexandru Ioan Cuza University of Iasi.

Keywords: Actuarial science; non-life insurance pricing; risk classification; tariff class; a priori pricing; pure premium; a posteriori pricing; credibility theory; bonus-malus system.

1. Introduction

One of the major concerns for the insurance companies is the design of a tariff structure that will fairly distribute the burden of claims among policyholders. The task of determining the insurance premium belongs mainly to actuaries who, over time, have proposed and applied various statistical models through which they tried to establish a link between the risk occurrence phenomenon and the risk factors. In this context, econometric modeling aims to

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Peer-review under responsibility of the Faculty of Economics and Business Administration, Alexandru Ioan Cuza University of Iasi.
doi:10.1016/S2212-5671(15)00060-X

describe this relationship as realistic as possible in order to determine the probability of risk occurrence, and also to determine the frequency and cost of claims.

The calculation of a differentiated premium within the insurance portfolio is based on the principle represented by a pricing process that involves several stages. In this regard, the risk acceptance of the insurance company is followed by a priori analysis which involves the segmentation of the risks ensemble depending on the influencing factors, so that each group includes the insureds with similar risk profile and pays the same reasonable insurance premium. At this stage of the analysis, the actuary aims to determine the impact of the observable factors or variables of the insured risk and the existence of a data correlation. This step allows determining the basic elements of the pure premium obtained by multiplying the conditional expectation of the claims frequency with the expected cost of claims.

The last stage of insurance pricing process appreciates the predictive power of the individual history of insured, integrating the a posteriori component in the calculation of the insurance premium. In other words, a posteriori analysis allows the correction and adjustment of a priori tariff in order to obtain a reasonable risk classification. Consequently, the pursued result is defined as the product of risk estimation, considering the observable risk characteristics, and the component that summarizes the insured's claim history. Therefore, pricing analysis allows obtaining an equilibrium between the premium paid by policyholders and the risk assumed by the insurance company.

This paper provides an overview of the pricing concept main elements and presents some issues related to the specifics and the methods significance, corresponding to the two-known types of pricing applied in non-life insurance business. Taking into consideration the proposed aim, the paper is organized as follows. Section 2 defines the concept of pricing in non-life insurance, emphasizing the distinction between a priori and a posteriori risk classification. Section 3 proposes a review of the empirical literature, presenting the main statistical techniques that can be practically implemented for pricing risks in non-life insurance. Section 4 presents some concluding remarks.

2. Non-life insurance pricing concept

Etymologically, the term *pricing* comes from the French *tarifaire*, the word designating the tariff action and its outcome. From here, the pricing concept gets the meaning of establishing a price or a tariff. Transposed in insurance business, Denuit (2003) considers that the pricing process designates a procedure for determining a fair premium corresponding to the insured's individual risk profile. Developing this idea, the insurance pricing process can be understood as an ensemble of methods that establishes the price paid by the insureds to the insurance company in exchange for the risk transfer.

Within the insurance business, the necessity of different charging tariffs is emphasized by the insurance portfolio heterogeneity that leads directly to the so-called concept of asymmetrical information. The information problems between the insurance company and the policyholders arise when the insurer has difficulties in evaluating the risk level of the insured. The economics literature presents two aspects of asymmetrical information, namely moral hazard and adverse selection. Denuit (2007) considers that adverse selection occurs when the policyholders have a better knowledge of their claim behaviour than the insurer does and they take advantage of information unknown to the insurer. Chiappori, Jullien, Salanié and Salanié (2006) stressed the fact that moral hazard arises when the probability of risk occurrence depends on the insured behaviour and his decisions. The difference between the two phenomena is remarked also by Dionne, Michaud and Pinquet (2013), who argued that adverse selection is the effect of unobserved differences among individuals that affect the optimality of insurance contracting while moral hazard is the effect of contracts on individuals' unobserved behaviour. In other words, in the context of insurance markets, the information problems can be defined as the effect of applying the same premium for the entire portfolio. This basically presumes that the unfavourable risks are also assured (at a lower price comparing with the real cost of the risk occurrences) and it discourages insuring medium risks.

In recent empirical studies, Chiappori and Salanié (2000) and Dionne, Gouriéroux and Vanasse (2001, 2006) argued that insurance pricing is efficient to combat the asymmetrical information by dividing the insurance portfolio into sub-portfolios, where the risks can be considered independent. This leads to defining risk classes that will have

assigned different premium depending on the gravity of risks that define them. In this respect, an important notion is emphasized by risk classification criteria. Hence, if the risks are grouped based on a priori information regarding the insured or the insured assets, the obtained groups are called a priori. Conversely, if are taken into account information on the claim history of every insured, there are obtained a posteriori risk classes.

Considering this distinction, the actuarial literature presents two concepts of pricing, namely a priori and a posteriori pricing. By applying various actuarial techniques, corresponding to each type of pricing, the reference papers aimed to find an integrated solution that will allow establishing a fair premium depending on the risks nature and classification.

3. Empirical perspective of non-life insurance pricing

According to McClenahan's (2001) observations, in the 18th century, the determination of fire insurance premiums was based upon the roof type and the structure of buildings, and the premium for marine insurance, considered to be the oldest form of insurance, was based on the design characteristics of the ship. The author argues that, considering the presence of uncertain events that may occur depending on certain risk factors, actuaries have always aimed to find a mathematical formulation in order to determine the probability of risk occurrence and to establish the insurance premium.

Based on risks mathematical theory, the involvement of actuarial science in insurance business has a long and rich history. Under the notable influence of Lundberg's (1903) and Cramer's (1930) studies, considered the founders of mathematical theory of risks, actuaries were interested in approaching the risks from the insurance companies perspective.

The famous monograph published by Hans Bühlmann (1970) requires the recognition of actuarial mathematics as a fundamental subject in probabilities theory and applied statistics of non-life insurance. As mentioned by Hans Gerber (1979) in his paper's introduction, the determination of the probability law of risk occurrence cost has always been the central topic in risk theory literature. Obviously, the recurrent nature of risk theory prevails, being corroborated by the impressive evolution of the methods introduced over time in non-life insurance business.

Analyzing retrospectively, the actuarial science was limited to the use of Gaussian linear models, assuming the usage of regression analysis which aims to quantify the impact of explanatory variables on the phenomenon of interest. The linear model, proposed by Legendre and Gauss in 19th century, has taken the lead in econometrics, but the applicability of this model in insurance has been found to be difficult. In this context, the linear modeling implies a series of hypothesis (Gaussian probability density, the linearity of the predictor and homoscedasticity) that are not compatible with the reality imposed by the frequency and cost of the damages generated by the risks occurrence.

While the complexity of the statistical criteria has become more pronounced, the actuaries had to solve the problem of finding some models that explain as realistic as possible the risk occurrence. Although no mathematical model will describe completely the reality, the models analysis and the confrontation of theoretical properties of the studied phenomenon with those observed is a pragmatic way to acquire a better understanding of reality and to predict the future responses of analyzed events.

Considering the consecrated distinction between a priori and a posteriori pricing, actuarial researches were focused on finding adequate methods or tools for each of the two types of pricing applied in non-life insurance. By analyzing the contribution of actuarial science in this area, it can be observed that the entire activity of actuaries is based on completing and developing the methods of establishing the tariffs. The complexity and practicability of the analyzed phenomenon explain entirely the imperious need for studies in this research field.

3.1. A priori pricing

Charpentier and Denuit (2004) suggest that the fundamental idea in a priori pricing is to segment the insured risks in several categories so that within each category the risks are considered equivalent and grouped by the same law. According to Delaporte (1972), a priori pricing allows grouping the risks assembly in tariff classes, each group including policyholders with identical risk profile that will pay the same reasonable premium. An important remark

on the independence risk is given by Bühlmann (1967) who states that the independence assumption is so natural, that many authors forget to mention it.

The first milestone of a priori pricing in non-life insurance is considered to be the minimum bias risk classification procedure proposed by Bailey and Simon (1960) and Bailey (1963). This method utilizes an iterative algorithm in calculating the optimal values for each risk level by minimizing the bias function. Although it was created outside a recognized statistical framework, the actuarial literature argues that this "heuristic" iteration approach is a particular case of Generalized Linear Models (GLMs).

Starting with the actuarial illustration of McCullagh and Nedler (1989), the GLMs have become a common statistical industry practice for non-life insurance pricing. They highlighted the two main advantages of GLMs techniques. Firstly, the generalization of the linear modeling allows the deviation from the assumption of normality, the regression being extended to distributions from the exponential family (Normal, Poisson, Binomial and the Gamma distributions). Secondly, the GLMs allow the linear regression to be related to the dependent variable through a link function, modeling the additive effect of independent variables on a transformation of the mean, instead of the mean itself. In other words, this function connects the linear predictor or the score with the mean of the dependent variable. Comparing to the minimum bias procedure techniques, the GLM models have the advantage of a theoretical framework that allows the usage of statistical tests in order to evaluate the fitting of models.

In the actuarial literature, Jean Lemaire (1985) stood out by illustrating and measuring the effectiveness of the methods used to estimate the insured risks. In this area, a remarkable contribution goes also to Arthur Charpentier and Michel Denuit (2004, 2005) who have succeeded to cover in a modern perspective all the actuarial aspects of insurance business. Also, the paper of Ohlsson and Johansson (2010) has treated in an exhaustive manner the methods considered to be the base in insurance risk classification, giving a particular attention to statistical techniques for calculating the auto insurance premium. Some recent studies have pointed out the contribution and the merits of Jong and Zeeler (2008), Kaas and al. (2009) and Frees (2010) who have emphasized the theoretical and practical aspects of the pricing methods in order to assess the insurance premium. In this category is also included the paper of Antonio and Valdez (2012), by means of which the authors present a conceptual and empirical approach of insurance pricing process.

3.2. A posteriori pricing

The actuarial literature has demonstrated that the usage of a priori pricing involves the lack of casualty between some tariff variables and risk occurrence. Certain important risk factors cannot be observed, leading to violation of homogeneity assumption of an effective risk classification system. The limits of this type of pricing require the approach of a posteriori actuarial models that take into consideration additional information about the individual claims history of policyholders.

The a posteriori pricing is based on credibility theory. Savage (1954) author emphasizes that the notion of credibility is closely related to risk perception, individuals giving different degrees of credibility to the occurrence of certain events. Savage also discusses about the degree of belief, this notion being firstly introduced by Thomas Bayes (1763) in his essay about the doctrine of chances. Although the concept of credibility appeared in the middle of the 20th century, since 1910, General Motors employees who were insured against work accidents have benefited from a premium calculated according to this principle, formalized later by Mowbray (1914).

Assuming known the probability of an accident occurrence (q), Mowbray proposes the calculation of the minimum number of employees insured, (n), so that the probability that the number of accidents does not deviate more than 100k% from the average, to be greater than 100p%. Denoting by N the distribution of accidents, the mathematical relationship of the above statement is given by:

$$P[(1-k)E[N] \leq N \leq (1+k)E[N]] \geq p$$

where $N \sim B(n,q)$. Subsequently, the usage of a normal approximation for N distribution allows establishing the foundation of stable credibility theory.

In this stage, credibility theory admits only two levels, one and zero. This situation means, for an employer situated just below the eligibility threshold, a significant difference regarding the premium he has to pay. To answer this criticism, Whitney (1918) introduces the concept of partial credibility, arguing that the problem of assessing the experience comes from the need to find a balance between collective experience, on the one hand, and individual risk experience, on the other hand. Therefore, Whitney declares that the basic principle of credibility is to establish a weighting factor, emphasizing the definition of pure premium as a balance between experience of an individual risk and that of a risk class.

Hans Bühlmann (1967) solves the problem of finding an optimal estimation for the premium corresponding to the nth period, by taking into account the observations regarding the risks registered in previous periods. He succeeds to revolutionize the credibility theory by introducing a credibility factor. Leaving from these concepts, Bühlmann (1970) developed together with Erwin, the Bühlmann-Straub Straub famous model, the main improvements to the initial model being the definition of the structural parameters estimators. Most of the principles of credibility theory aligns with the basic model proposed by Bühlmann, around which are formulated all the other models accepted in this area as generalizations of the former.

Denuit (2006) sustains that although the credibility theory can be seen as the art to combine different collections of data to obtain an accurate overall estimate, its specific methods are difficult to be implemented in practice due to their mathematical complexity. Therefore, insurance companies have approached some methods which are simplified versions of those imposed by credibility theory. In this sense, one of the commercial versions of the credibility theory is the bonus-malus system introduced by Pesonen (1962). He tried to establish the rules for obtaining optimal premiums for each risk classes depending on the bonus-malus levels.

The fundamental idea of this system is detailed later by Lemaire (1995). He sustains that within the bonus-malus system, described as a scale that consists of a finite number of levels, policyholders are given a certain place according to transition rules and to the number of claims at fault. To each level it corresponds a certain coefficient that will be applied to the pure premium calculated in the a priori stage of analysis. According to Denuit (2006), bonus-malus systems allow premiums to be adapted for hidden individual risk factors by taking into consideration the past claim record. Therefore, in the context of insurance markets, the main purpose of the bonus-malus system is to assess in an equitable manner the individual degree of risk so that the insurance company will demand a premium corresponding to the insured risk profile and claim history.

4. Conclusions

This study aims to present theoretical aspects of non-life insurance, insisting on the definition of the fundamental concepts imposed by this research area. It also includes several modeling frameworks to illustrate the main techniques used in order to establish a reasonable and equitable insurance premium, highlighting the importance of observable and unobservable risk characteristics.

Considering the first group of risk factors, the ones that can be observed and registered by the insurance company, tariff classes can be defined and a pure premium can be calculated depending on the risk level. According to the actuarial literature, this stage of insurance pricing process is known as a priori ratemaking that involves the approach of the common techniques of Generalized Linear Models. Obviously the class identified with the insured's profile is not totally identical, which shows that there is a degree of heterogeneity more or less pronounced, depending on the relevance of the information available to insurer. This can be explained by the existence of unobserved or unmeasured risk factors that can have a significant influence on risk occurrence. According to the credibility theory, the a priori premium is adjusted a posteriori by taking into account the individual insured's claims history. This stage of the pricing process may be understood as a method of recovering inaccessible a priori information and is approached by using the commercial alternative form of credibility theory known as bonus-malus system.

The assessed risk for the next period based on observable variables is multiplied by a bonus-malus coefficient, thus obtaining a premium that integrates the individual claim history. In this context, the criteria of a posteriori technique change the risk perception and therefore encourage the policyholders to adopt a more cautious behaviour regarding the risk.

The empirical literature presented in the paper indicates clearly the importance and the role of pricing process for the insurance companies' activity. The complexity of the risk assessment and the development of the insurance markets indicate explicitly the need for studies in this research field, meaning that there is still room for improving the existing actuarial methods.

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