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ABHANDLUNG

Optimal rate classification for enhanced annuities

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Abstract For a given premium, enhanced annuities pay higher pensions to policyholders with impaired health. Even though risk classification is a common concept in the insurance sector and should allow insurers to increase their profitability, enhanced annuities are rarely offered outside of the United Kingdom. The paper provides a general method of determining an optimal risk classification system for enhanced annuities that will maximize an insurance company's profits. The cost of risk classification, as well as that incurred when insureds are assigned to inappropriate risk classes (a chief component of underwriting risk), are explicitly considered.

Zusammenfassung „Enhanced-Annuity"-Versicherungsverträge zahlen ceteris paribus höhere Renten an Versicherungsnehmer mit reduzierter Lebenserwartung. Obwohl Risikoklassifikation (hier: in Abhängigkeit der Lebenserwartung der Versicherten) im Versicherungssektor eine überaus übliche Vorgehensweise ist und grundsätzlich dazu führt, die Profitabilität des Versicherungsunternehmens zu steigern, finden sich „Enhanced-Annuity"-Kontrakte ausserhalb von Grossbritannien nur sehr

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selten. Die vorliegende Arbeit leitet ein Risikoklassifikationssystem für „Enhanced-Annuity"-Verträge für ein Unternehmen ab, das den erwarteten Gewinn maximieren möchte. Dabei finden sowohl Risikoklassifikationskosten als auch Kosten von Fehlklassifikationen Berücksichtigung.

1 Introduction

For a fixed premium, enhanced annuities pay higher pensions to individuals with impaired health.[1] Except for the U.K. market, where enhanced annuities are well established, in most countries this type of contract is rarely offered. For instance, only around 4% of annuities sold in the U.S. market are based on enhanced rates,[2] and to the best of our knowledge, only one insurer in Germany sells enhanced annuities.

It is not obvious, why the substandard annuity market is so small, given that the concept of risk classification is widely used in different insurance business lines to improve company profitability.[3] Furthermore, enhanced annuities would make private pensions available to a broader range of the population and thus improve retirement income for insureds with impaired health. Hence, there must be important reasons behind the reluctance of many insurers to enter the substandard annuity market.

This paper summarizes the main findings of a working paper written by Gatzert et al. (2008) that was presented by Nadine Gatzert and Gudrun Hoermann at the annual meeting of "Deutscher Verein für Versicherungswissenschaft e. V." in Berlin, March 2009. The idea of the paper is to develop a general model to determine an optimal risk classification system[4] for enhanced annuities that will maximize an insurance company's profits. The costs of risk classification, as well as those of insufficient risk assessment (an important part of an insurer's underwriting risk) that can be incurred when insureds are assigned to inappropriate risk classes, are taken into account. This aspect is crucial, as underwriting risk is considered the most significant risk factor in the issuance of enhanced annuities. In this paper, two strands of literature are interwoven—that on enhanced annuities and that on risk classification. From an insurer's viewpoint, the problem of optimal risk classification for enhanced annuities is solved by taking into consideration classification costs and underwriting risk.

There are several factors that affect the profitability of selling enhanced annuities. First, a reasonable classification system must be established based on insureds' life expectancy. Second, adequate underwriting guidelines are necessary to ensure that applicants are assigned to the proper risk class. These guidelines need to take

[1] See LIMRA and Ernst and Young (2006, p. 10). Enhanced annuities, impaired life, and care annuities are all subsumed within what are known as "substandard annuities" (for a detailed description, see Gatzert et al. 2008). In the U.K. market, all types of substandard annuities are sometimes referred to as enhanced annuities.

[2] See LIMRA and Ernst and Young (2006, p. 18).

[3] For a detailed explanation, see Doherty (1981).

[4] According to *Actuarial Standard of Practice No. 12*, a risk classification system is a "system used to assign risks to groups based upon the expected cost or benefit of the coverage or services provided" (Actuarial Standards Board 2005).

into consideration such factors as medical conditions or lifestyle factors, including smoking, weight, geographical location, education, and occupation. Third, the costs of such classification—e.g., for advanced studies estimating the applicant's life expectancy based on age, medical condition, and lifestyle factors—need to be taken into consideration when pricing the contract. Finally, demand for the product is determined by the annuity amount paid to insureds in each risk class and thus an insurer needs to consider the market competition effects that may result from its use of a specific risk classification system.

Section 2 provides an overview of the literature on enhanced annuities and risk classification. In Sect. 3, we describe the process of optimal risk classification under profit maximization in the context of enhanced annuities. A calculation of classification costs is presented, accompanied by an estimate of underwriting risk costs incurred due to insurer error in classifying insureds. Section 4 concludes.

2 Literature review

There is a substantial body of literature on enhanced annuities and substandard annuities in general as well as on risk classification but, to date, these two strands of work have not been combined.

One strand of this literature focuses on the functioning and market characteristics of substandard annuities in the United Kingdom and the United States (Ainslie 2000; Weinert 2006; LIMRA International and Ernst and Young 2006). Other research covers the development, size, and market potential of substandard annuity markets, and describes and compares different products (Ainslie 2001; Brown and Scahill 2007; Cooperstein et al. 2004; Froehling 2007; Hamdan and Rinke 1998; Richards and Jones 2004; Rinke 2002). These authors also discuss underwriting methods and the challenges associated with the underwriting process, including mortality and risk classification issues. In addition, the impact of introducing substandard products on the standard annuity market, tax considerations, distribution channels, and reinsurance are studied in detail. Other authors focus more particularly on the underwriting process of substandard annuities (Junus et al. 2004; Nicholas and Cox 2003; Turner 2001) or on how individual underwriting can influence an insurer's profit (Hoermann and Russ 2008). Ranasinghe (2007) examines underwriting and longevity risk for individuals with impaired life by means of a provision for adverse deviation.

As to the literature on risk classification in the insurance sector, Williams (1957) presents definitions, economic effects, and government regulation of insurance rate discrimination. Doherty (1980) investigates rate discrimination in the fire insurance market and extends this analysis in Doherty (1981) when studying the profitability of rate classification for an innovating insurer and associated market dynamics. Christiansen (1983) examines the fairness of rate discrimination, including in the case of substandard annuities. The existence of an equilibrium point in a portfolio consisting of several risk classes with respective price-demand functions is shown in Zaks et al. (2008) for the case when the premium amount and the number of policyholders in each risk class are iteratively updated.

The literature chiefly consists of controversial discussions of risk classification that relate to social issues. On the one hand, competition by—especially purely selective—risk classification is said to be inefficient if it results in insurance being unaffordable by high-risk (from the insurer's view) insureds. On the other hand, risk classification is regarded as crucial in avoiding adverse selection. These controversial perspectives are discussed in De Jong and Ferris (2006), Abraham (1985), De Wit (1986), Feldman and Dowd (2000), Rothschild and Stiglitz (1997), Thiery and Van Schoubroeck (2006), Thomas (2007), and Van de Ven et al. (2000). In addition, De Jong and Ferris (2006) present a demand model to examine the impact of changes in risk classification systems. In particular, the authors determine the effect of unisex pricing in the U.K. annuity market on the expected purchase of annuities depending on a person's individual mortality level as described by a frailty factor.

Another concept that plays a part in discussion on risk classification in insurance is social utility (see, e.g., Bond and Crocker 1991; Crocker and Snow 1986, 2000; Hoy 1989, 2006; Sheshinski 2007; Strohmenger and Wambach 2000; Van der Noll 2006; Villeneuve 2000). The inequity arising from considering only certain factors and ignoring others when setting insurance rates is examined in Promislow (1987). Several papers address practical issues associated with risk classification. Kwon and Jones (2006), for instance, develop a mortality model that includes various risk factors. Derrig and Ostaszewski (1995), Horgby (1998), and Lohse (2004) focus on risk classification based on fuzzy techniques. A broad overview of preferred life products is given in Werth (1995), Leigh (1990) reviews the underwriting of life and sickness benefits, and Walters (1981) develops standards for risk classification. Another issue is the impact of genetics on risk classification, which is increasingly important (see, e.g., Brockett et al. 1999; Brockett and Tankersley 1997; Hoy and Lambert 2000; Hoy and Ruse 2005; Macdonald 1997, 1999; O'Neill 1997). Apart from risk classification related to life insurance, a considerable body of literature deals with rate classification in non-life insurance, especially in the automobile sector. The third-party motor insurance industry is analyzed in Schwarze and Wein (2005). In their work, the authors empirically test whether risk classification creates information rents for innovative insurers. Cummins et al. (1983, pp. 27–62) and Driver et al. (2008) address the economic benefits of risk classification and argue that risk classification often contributes to economic efficiency, limits adverse selection, reduces moral hazard, and encourages innovation and competition within the insurance market.

3 The process of optimal risk classification for enhanced annuities

We consider insurers that aim to maximize their profit by offering rate-discriminating annuity products to a general population comprised of all potential insured risks.

3.1 Mortality heterogeneity of the general population

The general population is heterogeneous with respect to the mortality of contained risks, and a frailty model is employed to describe individual mortality rates.[5] The

[5]The model of mortality heterogeneity in the general population is based on Hoermann and Russ (2008).

latter are obtained by multiplying an individual stochastic frailty factor by the average one-year probability of death taken from a population mortality table.

The distribution of individual frailty factors reflects the distribution of different life expectancies in the general population.[6] It is assumed that this distribution is continuous on the positive real numbers, right-skewed, and that its expected value is equal to 1, which corresponds to the fact that the population mortality table specifies average mortality.

A person's individual frailty factor describes his or her life expectancy compared to the average life expectancy in the general population, which is indicated by a frailty factor of 1. A frailty factor greater than 1 means that the individual has a below-average life expectancy; a person with a frailty factor less than 1 is healthier than average and thus has a longer expected remaining lifetime.

3.2 Subpopulations

The general population is comprised of a fixed number of subpopulations that differ from each other and are ordered by the mortality level of their members (from lowest to highest mortality risk) (see Fig. 1). Individuals (i.e., "risks") are sorted into subpopulations based on their individual frailty factors. The insurer is able to correctly assign applicants to these subpopulations depending on health status, but cannot make any finer distinction between individuals than this. This means that the subpopulations represent the maximum number of distinguishable segments that aggregate to the whole general population.

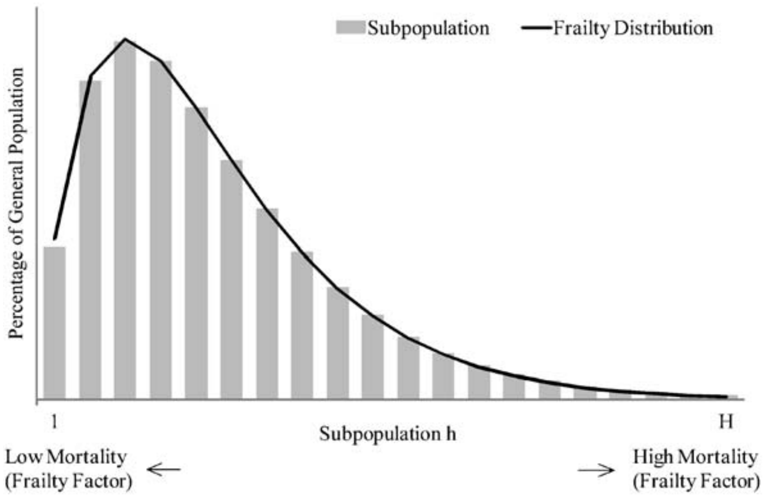

Fig. 1 Segmentation of the general population into H subpopulations depending on mortality levels; mortality level is described by a frailty distribution[7]

[6] See, e.g., Jones (1998, pp. 80–83), Pitacco (2004, p. 15), and Vaupel et al. (1979, p. 440).

[7] See Gatzert et al. (2008).

The number of individuals in a subpopulation can be determined, based on the frailty distribution, as the percentage of risks out of the general population having a frailty factor lying in that subpopulation's frailty factor range. The number of risks in all subpopulations totals the number of risks in the general population.

For a given insurance demand, the cost of insurance and the price for insurance are given, i.e., a cost function and a price-demand function are defined for each subpopulation. The cost function describes the costs of one unit of annuity insurance depending on sales volume. Since classification of risks is limited to the subpopulation level, risks belonging to a subpopulation are regarded as homogeneous with respect to mortality. Therefore, the cost function of a subpopulation is constant in the number of insureds: it is the actuarial premium price of insuring survival risk for the average potential insured in that subpopulation, which can be calculated depending on the average frailty factor. Since subpopulations are ordered from lowest to highest mortality, average frailty factors increase. Thus, the actuarial premium for annuity insurance is lower for higher subpopulation indices, i.e., for higher mortality levels.

The price-demand function assigns a certain price for one unit of annuity insurance to a given number of insured risks. When the price is lower, more people are willing to purchase coverage, so the price-demand function is monotonously decreasing in the number of insureds. The graph of the price-demand function connects the so-called reservation price for a demand of zero with the point at which the price is zero and where everyone in each subpopulation is assumed to buy insurance. We suppose that reservation prices are higher for lower subpopulation indices because the actuarial premium for annuity insurance is higher for persons with high life expectancy. These individuals may thus value insurance coverage more highly and, consequently, be willing to pay more for it.

Since all risks (i.e., individuals) in one subpopulation are treated as being mortality homogeneous, the same price is charged to each, meaning that there is no price discrimination within subpopulations.[8] That is, we do not consider the possibility of individual underwriting, where each insured would pay a different—individual—price (so-called first-degree price discrimination).[9]

3.3 Classification systems and risk classes

An aggregation of one or more adjacent subpopulations is called a risk class; assignation of all subpopulations to risk classes is a classification system. If an insurer sells a standard annuity product, its classification system consists of only one risk class comprising all existing risks. The price of a standard annuity is thus based on the average mortality in the general population. If there is more than one risk class, annuity prices are lower for risk classes with high mortality and vice versa. In practice, for a given premium, a higher annuity amount is paid to insureds with reduced life expectancy.

Analogously to subpopulations, risk classes, too, characterized by cost and price-demand functions. For risk classes that consist of only one subpopulation, the price-demand and cost functions of the risk class correspond to the respective functions of

[8] See Cummins et al. (1983, pp. 83–92).

[9] See, e.g., Pindyck and Rubinfeld (2008, pp. 393–403) and Baumol (1977, pp. 405–406).

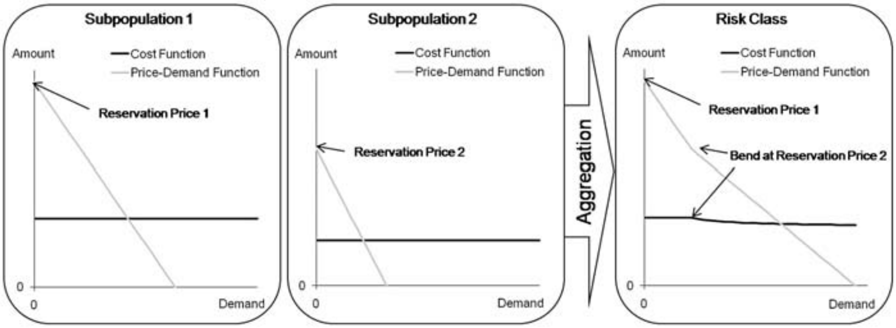

Fig. 2 The aggregation process

the subpopulation. If the risk class contains more than one subpopulation, the price-demand and cost functions of the risk class will need to be determined by aggregating the respective functions of the underlying subpopulations, which is accomplished by use of inverse price-demand functions. As, for each subpopulation, these are only defined at certain intervals (from a price of zero to the reservation price), the aggregated cost and price-demand functions are defined piecewise. They change at each interval, and at each reservation price there is a bend in the curve as risks of other subpopulations are considered.

The graph of the aggregate price-demand function of a risk class is achieved by the horizontal addition of the price-demand functions of the corresponding subpopulations. It starts at the highest reservation price, where only one subpopulation buys insurance. The aggregate demand is then the sum of the number of insureds in each subpopulation who purchase annuity insurance for a given price. Figure 2 illustrates the aggregation process for two subpopulations.

The aggregate cost function describes the average cost of one unit of annuity insurance for individuals in a risk class. It can be determined by averaging the sum of the number of policyholders in each subpopulation weighted with the corresponding costs. The former must be determined by means of inverse price-demand functions, as there is no inverse cost function at the subpopulation level (because the cost function is constant in the number of insured risks in a subpopulation). In general, the aggregate cost function decreases because costs are lower for higher subpopulation indices and only adjacent subpopulations can be combined into a risk class.

Establishing risk classes incurs classification costs. These costs can be assumed to be proportional to the number of classifications because, for example, costly underwriting guidelines will are needed for each risk class. Thus, offering a standard annuity product to the total general population carries no classification costs.

3.4 Profit maximization

In a specific risk class, the insurer's profit is the difference between earnings (i.e., the product of the number of insureds times the corresponding market price) and costs (i.e., the product of the number of insureds times the cost of insurance). In other words, selling insurance to any particular risk class will be profitable if the price that can be obtained for it is more than it costs to provide the insurance. For a classification system, total profit is the sum of the profit in each contained risk class less classification costs.[10]

To maximize an insurer's profit, the optimal number and size of risk classes, as well as the optimal price-demand combination in each risk class, must be identified, keeping in mind classification costs. If there are no classification costs, the maximum number of risk classes is optimal, i.e., each subpopulation comprises its own risk class.[11] In the case where there are classification costs, however, the optimal number of risk classes will be highly dependent on those costs.

The optimal profit-maximizing classification system can be discovered by comparing all possible classification systems given the optimal price-demand combination in each risk class. It is determined by, first, differentiating the profit function of a risk class with respect to the number of risks, setting it equal to zero, and solving for the optimal number of insureds.[12] Second, resulting profits for each risk class are totaled and then reduced by classification costs to obtain the overall profit of a particular classification system—the classification system with maximum profit is optimal. For an optimal classification system, the maximum amount of classification costs can be derived provided that the system remains optimal. This amount can be compared with actual costs of establishing underwriting guidelines, for instance.

In searching for the optimal classification system, it is crucially important that insurers not neglect to take into consideration underwriting risk costs, i.e., the risk that insureds are assigned to inappropriate risk classes. For example, if policyholders are assumed to belong to a risk class with higher average mortality than they actually have, the true cost of one unit of annuity will be underestimated. If, based on this erroneous assignment to risk class, the insurer charges a relatively low price for the annuity, demand will increase, and thus the original error compounds itself, as an increasing number of people who will live longer than expected are paying less than is necessary for the insurer to make a profit; in the worst case, the insurer will certainly lose money. This is what is known as underwriting risk and fully taking it into consideration will have a large impact on the insurer's optimal classification system.

Insufficient risk assessment (e.g., underwriting risk) is one of the greatest hazards for insurers in the issuance of enhanced annuities. Thus, it is vital to consider underwriting risk costs in the optimization problem. Underwriting risk can be integrated by means of underwriting error probabilities, which reflect the frequency with which an insured is classified into a risk class with higher average mortality than is appropriate for that individual. A comprehensive formal description of how to include underwriting risk in the optimization problem can be found in the underlying working paper by Gatzert et al. (2008).

An overview of the risk classification process, along with relevant terms and definitions, is provided in Fig. 3.

[10] For a formal description of this setting, see Gatzert et al. (2008).

[11] See Doherty (1981).

[12] See, e.g., Baumol (1977, pp. 416–417), assuming that the functions are differentiable.

A risk classification process for enhanced annuities

Identify general population

General population consists of N potential policyholders ("risks") with different gender and/or age willing to buy annuity insurance with a given gender and at a specific age.

⇩

Calibrate the frailty model

Use a frailty distribution to model mortality heterogeneity in the general population (see Fig. 2). The frailty factor describes an individual's state of health. A person with a frailty factor less than 1 has an above-average life expectancy; a frailty factor greater than 1 indicates that the individual is impaired and has a reduced expected remaining lifetime; a person with a frailty factor equal to 1 has average mortality.

⇩

Divide general population into subpopulation

Subpopulations are distinguished by the health status of their members and are ordered by mortality level (higher subpopulations have higher average mortality). Assume that an insurer is able to distinguish only a limited number of different subpopulations (which aggregate to total general population). Risks (i.e., individuals) are assigned to particular subpopulations based on their individual frailty factor.

⇩

Determine price-demand function

Price-demand functions are defined for the number of insureds in each subpopulation. First, specify how many risks would purchase one unit of annuity insurance for a given price. The price-demand function is monotonously decreasing in the number of risks, i.e., the lower the price, the greater the number of persons who are willing to buy insurance. This can be estimated using, e.g., conjoint analysis.

⇩

Determine the cost function

The cost function describes the actuarial premium for covering the cost of one unit of annuity insurance for the average potential insured in a subpopulation, independent of the quantity of sales (insurer cannot distinguish beyond subpopulations).

⇩

Fig. 3 The process of risk classification for enhanced annuities with terms and definitions

Establish risk classes

A risk class can encompass one or more subpopulations. If a risk class consists of more than one subpopulation, the aggregated price-demand function for the risk class must be determined based on the price-demand functions of the included subpopulations. Only adjacent subpopulations can be merged to risk classes since subpopulations are specified by decreasing average life expectancies (in our setting).

⇩

Define a classification system

Sorting subpopulations into risk classes (with different annuity prices for each class) results in a classification system. If only a standard annuity product is offered, and is available to anyone in the general population willing to purchase it, the insurer basically has a classification system comprised of only one risk class, i.e., the general population.

⇩

Calculate classification costs

A classification system consists of several risk classes. Classification costs are those incurred in distinguishing between risk classes (e.g., costs of drawing up underwriting guidelines for each risk).

⇩

Account for underwriting risk costs

Model underwriting risk by assuming that a policyholder is wrongly assigned to a higher risk class with a given error probability (can be estimated or based on sound assumptions).

⇩

Solve the optimization problem

First, find the optimal price-demand combination in each possible risk class that maximizes the expected profit (earnings less costs) for this class. Second, find the optimal classification system (i.e., the best combination of subpopulations into risk classes) that maximizes the insurer's expected total profit (the sum of the profit from each risk class less classification costs). In this context, the underwriting risk in the process has been accounted for.

Fig. 3 (*Continued*)

4 Summary and conclusion

This paper provides an approach to determining an optimal risk classification system for enhanced annuities. We discuss the general problem of risk classification and the relevant literature on that topic, and then go on to demonstrate how existing findings can be applied to the very timely subject of enhanced annuities in the insurance sector. Following the common practice of classifying risk based on rating factors, we suggest employing frailty factors to describe individual probabilities of death and thus to model mortality heterogeneity of the general population. Subpopulations contain individuals with frailty factors in a certain range and, since subpopulations represent the highest possible degree of classification, the cost of insurance for that subpopulation depends on the average frailty factor of its members. The optimal combination of subpopulations into risk classes depends on costs and price-demand dependencies for their mortality levels and can be derived by solving an optimization problem. This approach thus simultaneously accounts for cost-oriented pricing, which is standard procedure in the insurance sector, and customer insurance demand.

Several issues must be addressed when using our proposed model. First, the mortality structure of the general population, and the distinguishable mortality levels within it, must be identified. For each subpopulation, the nature of price-demand dependencies needs to be estimated, including, e.g., the maximum number of potential insured risks, the reservation price, etc. Finally, it is essential to account for classification costs, for example, those incurred by the necessity of having several risk-class-specific underwriting guidelines. Calibration of the model will be a challenging task and involve a certain degree of uncertainty. However, if an insurer is interested in offering rate-discriminating annuity products (and the market for same is at this point wide open), making these types of calculations will be essential to success.

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