Optimization of the Formation of the Capital Structure of the Insurance Company, Taking into Account the National Specifics of Insurance

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Abstract: The study proposed an economic model of capital optimization of the insurance company, based on the actuarial method of calculating insurance tariffs. Features of the national insurance system are considered. A mathematical model and actuarial calculation of insurance tariffs for partners in the implementation of joint activities are proposed. As the algorithm implementation calculations were made for the model of joint life insurance of spouses, which has their own practical interest. A lump-sum net rate has been calculated for a contractual partner in the event of the death of one of the partners (spouses) before the retirement age, depending on the interest rate, the age of the spouses, their residual times to pensions, the death rates and the maximum permissible ages. Average time and variance of the Treaty were calculated. It is practically important for the insurance company when planning the investment of assets under the agreement. The results of the research allow us to calculate the insurance tariffs in the form of a lump sum payment to the insured persons and to evaluate the numerical characteristics of the validity period of the contract.

Keywords: Insurance rates, life insurance, interest rate, net premium, distribution density, distribution function, economic mathematical model of risk insurance.

INTRODUCTION

In our country over the past two decades, there has been a tendency to reduce the level of social protection of the population, the main reason for which is the ineffectiveness of the functioning of the national system of compulsory social insurance. The presence of many unsolved problems at the present stage of the development of social insurance in Russia, exacerbated by the negative impact of the global economic crisis, points to the existence of an acute need to find ways to improve the mechanisms for its organization and functioning. Given the lack of positive results of reforming the Russian system of compulsory social insurance and the current economic situation in the country, there is a need to increase the level of insurance protection of the population against social risks, primarily by developing voluntary personal insurance regulated by the domestic insurance market through the provision of voluntary personal insurance services. At the same time, voluntary personal insurance will raise the level of insurance protection of the population against social risks. And thus, voluntary personal insurance supplements state social insurance.

LITERATURE REVIEW

Currently, the social and economic policy of the Government of the Russian Federation is aimed at accelerating the development of the personal voluntary and retirement insurance of citizens. With regard to this, there arises the problem of a correct calculation of the insurance rates. Such calculation enables an insurance company to form the relevant reserves of the insurance liabilities. The insurance companies need a mathematically grounded cost of the equivalent payment in the case of occurring of an insured event.

Voluntary personal life insurance and retirement insurance are ordinary in all developed countries. This is due to a highly-developed culture of insurance in the developed countries and the people's realizing its necessity. In Russia, there was not been much demand for this kind of insurance so far. The market of such insurance products is still in the formation stage. Given the demographic and economic situation (the introduction of sanctions and anti-sanctions mechanism), numerous problems to the majority of the population of the Russian Federation arise. Pension support of citizens is especially problem-haunted. Longer life expectancy, reorientation of values (in particular, having children at a later age due to women's opting for building the career) results in higher load on the employable working population. So for further economic development of Russia, new tools of ensuring the decent life conditions have to be made popular. Voluntary personal life insurance and retirement insurance promotes solving of the said "pension problem", which in its turn helps to reduce the load on the state, enhances the level of conscience of

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the population and helps ensure a decent level of life after retirement. The object of this investigation is the Russian market of long-term life insurance especially the individual personal insurance.

With each passing year the role of mathematical methods of evaluation in various branches of the economy grows. Thus, the authors devote their research to the mathematical foundations of the theory of life insurance and pension schemes (Bowers N.L. *et al*. 1997), (Burak V.E. 2015), the methodological foundations of housing insurance against natural ecological and technogenic risks (Sukhorukova I., Serdyukov Yu. 2015), the economic model of optimization in the centralized procurement management of subsidiaries of the state corporation (Sukhorukova I., Likhachev, G., 2016), level of development and availability for population of information and communication technologie (Minashkin V.G., 2014). At present, actuarial calculations are part of the mathematical theory of insurance and are used not only in order to estimate tariffs, (Olivieri A., Pitacco E. 2011), but also to justify the company's insurance reserves, franchise volumes, liability limits, estimate the financial stability of the insurance portfolio and address a number of other problems (Gantenbein M, Mata M. 2008), (Zolotarev V. 2016),(Kaas R. *et al*. 2001). This article is an extension of the research carried out by the authors in their work (Chistyakova N., Sukhorukova I. 2017). The calculation of the cost of the insurance contract, as well as the average time of the contract and the dispersion of the validity of the contract, which is practically important for the insurance company when constructing an investment policy related to the assets under the contract. So, in the event of the death of one of the spouses before the onset of his retirement age of the living spouse the sum that shall be paid is specified in the agreement insurance coverage (conditionally equal to one). If both spouses retire, the insurance company pays nothing. Thus, it is a life insurance contract, but of a more complex structure. We calculate the cost of the contract, i.e. the expected cost of the insurer at the time of conclusion of the contract. It is supposed that payment of the contract during its term shall bear interest in accordance with complex interest rate per annum.

METHODOLOGICAL FRAMEWORK

Objectives

The priority of this economic study is to establish a scientific rationale for a transfer to the actuarial cost method of an insurance contract, as this method assures a balanced solution for long-term socio-economic problems and stability of the insurance portfolio.

Goals

The purpose of the article is the methodological justification for the application of the actuarial control and management system in the field of risk insurance in the implementation of joint activities of partners. Development of an economic-mathematical model for calculating a one-time net rate under a contract for the payment of insurance coverage to a living partner (spouse) in the event of the death of one of the partners (spouses) before the retirement age, depending on the interest rate, the age of the spouses, their residual times to pensions, Mortality and the maximum permissible ages. An analytical expression is obtained for the mathematical expectation and variance of the validity of the contract.

Methodology

The actuarial method of calculating insurance tariffs using mathematical and simulation methods is used.

RESULTS AND DISCUSSION

This paper considers the problem of insurance two companions from early rupture of the joint project because of the actions of the companion. It is assumed that the insured are partners, and the beneficiary is one of them. In case of early exit of the partner from the joint project the current companion is paid specified in the agreement or insurance coverage. As a specific interpretation of the algorithm, calculations were performed for models of joint life insurance spouses, which is of independent practical interest. Namely, in the case of the death of a spouse before the onset of his retirement age provides for the payment of insurance coverage to a living spouse. The calculation of the value of the insurance contract and obtained the average time of the contract, and the dispersion time of the contract, which is practically important for insurance companies when constructing an investment policy related to the assets under the contract. So, in the event of the death of one of the spouses before the onset of his retirement age of the living spouse shall be paid specified in the agreement insurance coverage (conditionally equal to one). If both spouses retire, the insurance company pays nothing. Thus, it is a life insurance contract, but a more complex structure. Calculate the cost of the contract, i.e. the expected cost of the insurer, given at the time of conclusion of the contract. It is expected that during the term of the contract with funds of the policyholder, made as payment of the contract shall bear interest in accordance with complex interest rate $i\%$ per annum. To solve the problem, we use the notation: (x,y) - the age vector, where x -is the age of the wife, y- is the husband's age at contracting; the intervals of time to retirement age will be denoted by (T_1,T_2) respectively, and the vector of maximum ages, for women and men, through (ω_1,ω_2). The moment of conclusion of the insurance contract is considered to be initial and we set it equal to zero. The entered characteristics are given parameters of the task. Along with them, we consider two random variables-the duration of the residual life $\tau_1=\tau_1(x)$, $\tau_2=\tau_2(y)$ - of the wife's *x* age and husband's age *y* respectively. For their probabilistic study, we assume a given mortality model in the form of mortality rates of wife μ_x and husband $\tilde{\mu}_y$ based on their current age $x\in(0,\omega_1)$, $y\in(0,\omega_2)$. Recall that in the theory of personal insurance the mortality rate is a function $\mu_x=\lim\limits_{\Delta t\to 0+}\frac{1}{\Delta t}P\left(\tau(x)<\Delta t\middle|\tau(x)>0\right),0<x<\omega$ where $\tau(x)$ - the residual life time of a person's age x. On the basis of this, it is possible to calculate the probability of reaching the age $x+t$ face of age x ${}_tp_x=P\left(\tau(x)>t\middle|\tau(x)>0\right)=e^{-\int_0^t\mu_{x+u}du}$ and the distribution density of its residual life time $f_{\tau(x)}(t)={}_tp_x\cdot\mu_{x+t}$ [13].

Denote by ${}_tp_x$, ${}_t\tilde{p}_y$ the probability of survival to age $x+t$ and $y+t$ women and men respectively, and we assume that their residual lifetimes are independent. Then the density of the joint distribution of the vector of the residual lifetimes of the $(\tau_1(x),\tau_2(y))$ has the form

$$f_{(\tau_1(x),\tau_2(y))}(t,s)={}_tp_x\cdot\mu_{x+t}\cdot{}_s\tilde{p}_y\cdot\tilde{\mu}_{y+s},\quad 0<t<\omega_1-x,\ 0<s<\omega_2-y$$

. (Katsnelson *et al*. 1995; Zhmurko *et al*. 1997). An insurance event occurs if and only if either the wife did not live to pension, and her husband survived, that is $\{\tau_1(x)<T_1\bigcap\tau_2(y)>\tau_1(x)\}$, therefore, the moment of payment coincides with $\tau_1(x)$, либо the husband did not live to pension, and his wife survived, that is $\{\tau_2(y)<T_2\bigcap\tau_1(x)>\tau_2(y)\}$, here the moment of payment coincides with $\tau_2(y)$. Designating by $v=\frac{1}{1+i}$ - discount factor, get the current value of such contract A conditionally with a single payment is a random variable of the form (Sukhorukova I,. Chistyakova N., 2017): Assume that the insured amount is equal to one

$$A=A(\tau_1(x),\tau_2(y))=\begin{cases}v^{\tau_1(x)}\text{ under }\{\tau_1(x)<T_1\bigcap\tau_2(y)>\tau_1(x)\}\\ v^{\tau_2(y)}\text{ under }\{\tau_2(y)<T_2\bigcap\tau_1(x)>\tau_2(y)\}\\ 0\quad\text{in all other cases}\end{cases}$$

Then one-time net rate for such contract in accordance with the principle of equivalence of obligations of the insurer and the policyholder equal to the expected value A.

$$MA=\iint_{R^2}A(t,s)f_{(\tau_1(x),\tau_2(y))}(t,s)\,dtds=$$
$$\int_0^{T_1}v^t\cdot{}_tp_x\cdot\mu_{x+t}dt\int_t^{\omega_2-y}{}_s\tilde{p}_y\cdot\tilde{\mu}_{y+s}ds+\int_0^{T_2}v^s\cdot{}_s\tilde{p}_y\cdot\tilde{\mu}_{y+s}ds\int_s^{\omega_1-x}{}_tp_x\cdot\mu_{x+t}dt \tag{1}$$

We illustrate the result with examples of calculations.

Example 1. Let the vector of ages of the spouses equal $(x,y)=(52,56)$, and the vector of marginal ages: $(\omega_1,\omega_2)=(90,85)$. On the basis of the retirement age population of Russia [14], we have $(T_1,T_2)=(3,4)$. In addition to a simple illustration of the calculation, consider the model of mortality de Moivre (Falin G.I. 1996) according to which $\mu_x=\frac{1}{90-x},x\in(0,90)$, $\tilde{\mu}_y=\frac{1}{85-y},y\in(0,85)$. Then [1]

$$\begin{aligned}&{}_tp_x=e^{-\int_0^t\mu_{x+u}du}=e^{-\int_0^t\frac{1}{90-x-u}du}=\frac{90-x-t}{90-x},\\ &f_{\tau_1(x)}(t)={}_tp_x\cdot\mu_{x+t}=\frac{1}{90-x},\qquad 0<t<90-x\end{aligned}.$$

That is, the distribution density of the residual life time of the wife has a uniform distribution on $(0,90-x)$. Similarly

$$\begin{aligned}&{}_s\tilde{p}_y=\frac{85-y-s}{85-y},\qquad f_{\tau_2(x)}(s)={}_s\tilde{p}_y\cdot\tilde{\mu}_{y+s}=\frac{1}{85-y},\\ &0<s<85-y\end{aligned}.$$

Now, from (1) we obtain

$$MA=\int_0^3v^t\frac{1}{38}dt\int_t^{29}\frac{1}{29}ds+\int_0^4v^s\cdot\frac{1}{29}ds\int_s^{38}\frac{1}{38}dt=$$
$$\left[\frac{1}{38\cdot 29}\int_0^3v^t(29-t)\,dt+\frac{1}{38\cdot 29}\int_0^4v^s\cdot(38-s)\,ds\right].$$

In view of the uniformity of the two integrals obtained, we take the first of them.

$$\int_0^3 v^t \frac{1}{38} dt \int_t^{29} \frac{1}{29} ds = \frac{1}{38 \cdot 29} \int_0^3 v^t (29 - t) dt =$$

$$\frac{1}{38 \cdot 29} \left(29 \frac{v^t}{\ln v} \Big|_0^3 - t \frac{v^t}{\ln v} \Big|_0^3 + \int_0^3 \frac{v^t}{\ln v} dt \right) =$$

$$= \frac{1}{38 \cdot 29} \left(29 \frac{v^3 - 1}{\ln v} - \frac{3v^3}{\ln v} + \frac{v^3 - 1}{\ln^2 v} \right)$$

Then

$$MA = \frac{1}{38 \cdot 29} \left(29 \frac{v^3 - 1}{\ln v} - \frac{3v^3}{\ln v} + \frac{v^3 - 1}{\ln^2 v} \right) + \frac{1}{38 \cdot 29} \left(38 \frac{v^4 - 1}{\ln v} - \frac{4v^4}{\ln v} + \frac{v^4 - 1}{\ln^2 v} \right)$$

Below are the values of a one-time net rate for the corresponding values of the annual interest rate.

Table 1: Table of Net-Rates under the Contract

Interest rate i	Discount factor v	Net rate of the contract MA
0,03	0,970874	0,195075
0,04	0,961538	0,191816
0,05	0,952381	0,188661

Recall that with insurance coverage that is S unit, a one-time net premium is calculated by multiplying by S a net rate. In the more complicated models of survival, it is expedient to use the numerical methods of integration in the basic formula (1). If you have difficulty with the analytical description of mortality laws, you can apply numerical algorithms that, according to the mortality table, approximate the instantaneous death rate at some points in time, and then pick up a smoothing curve. It may be useful to use simulation for practical calculations of the characteristics obtained.

Let us now turn to the study of the validity of the contract and obtain for it a mathematical expectation and variance. We denote a random variable equal to the time of the contract through τ. As before, $\tau_1 = \tau_1(x)$ and $\tau_2 = \tau_2(y)$ - the residual life time of the wife *x* of age and husband *y* age, respectively. There are three fundamentally different situations. Obviously, with the surviving of both spouses before retirement, no payments are made, and the validity period of the contract is terminated at the time $\tau = \max\{T_1, T_2\}$. Further, it is possible that the wife did not live to retirement, and her husband survived, that is $\{\tau_1(x) < T_1 \bigcap \tau_2(y) > \tau_1(x)\}$; either the husband did not live to retirement, and his wife survived, that is $\{\tau_2(y) < T_2 \bigcap \tau_1(x) > \tau_2(y)\}$. In the first case, payment occurs at the time $\tau = \tau_1(x)$, in the second $\tau = \tau_2(y)$, - at the time, and the contract is terminated. Finally, it is possible that the husband died as a pensioner, and his wife after him, not reaching retirement age, that is $\{\tau_1(x) < T_1 \cap \tau_2(y) > T_2 \cap \tau_1(x) > \tau_2(y)\}$. In this case, the payment will not be made, as there are no beneficiaries left. The moment of termination of the contract coincides with the moment of death of the husband, that is $\tau = \tau_2(y)$. In a symmetrical situation $\tau = \tau_1(x)$, when $\{\tau_2(y) < T_2 \cap \tau_1(x) > T_1 \cap \tau_2(y) > \tau_1(x)\}$.

Finally, we obtain in the case $T_1 > T_2$

$$\tau = \begin{cases} T_1, & \text{if } \{\tau_1(x) > T_1 \cap \tau_2(y) > T_2\}, \\ \tau_1(x), & \text{if } \{\tau_1(x) < T_1 \cap \tau_2(y) > \tau_1(x)\}, \\ \tau_2(y), & \text{if } \{\tau_2(y) < T_2 \cap \tau_1(x) > \tau_2(y)\}, \text{ or} \\ \{\tau_1(x) < T_1 \cap \tau_2(y) > T_2 \cap \tau_1(x) > \tau_2(y)\}. \end{cases}$$

When $T_2 > T_1$

$$\tau = \begin{cases} T_2, & \text{if } \{\tau_1(x) > T_1 \cap \tau_2(y) > T_2\}, \\ \tau_2(y), & \text{if } \{\tau_2(y) < T_2 \cap \tau_1(x) > \tau_2(y)\}, \\ \tau_1(x), & \text{if } \{\tau_1(x) < T_1 \cap \tau_2(y) > \tau_1(x)\}, \text{or} \\ \{\tau_2(y) < T_2 \cap \tau_1(x) > T_1 \cap \tau_2(y) > \tau_1(x)\}. \end{cases}$$

Now the required average time of the contract is calculated by the formula of the mathematical expectation of the function from the random vector $M\tau = \iint_{R^2} \tau(t,s) f_{(\tau_1,\tau_2)}(t,s)\, dtds$. It depends on the ratio between (T_1, T_2) and is equal to:

when $T_1 > T_2$

$$M\tau = T_1 \int_{T_1}^{\omega_1 - x} dt \int_{T_2}^{\omega_2 - y} f_{(\tau_1,\tau_2)}(t,s) ds + \int_0^{T_1} tdt \int_t^{\omega_2 - y} f_{(\tau_1,\tau_2)}(t,s) ds + \int_0^{T_2} sds \int_s^{\omega_1 - x} f_{(\tau_1,\tau_2)}(t,s) dt + \int_{T_2}^{T_1} sds \int_s^{T_1} f_{(\tau_1,\tau_2)}(t,s) dt, \tag{2}$$

when $T_2 > T_1$

$$M\tau = T_2 \int_{T_1}^{\omega_1 - x} dt \int_{T_2}^{\omega_2 - y} f_{(\tau_1,\tau_2)}(t,s) ds + \int_0^{T_2} sds \int_s^{\omega_1 - x} f_{(\tau_1,\tau_2)}(t,s) dt + \int_0^{T_1} tdt \int_t^{\omega_2 - y} f_{(\tau_1,\tau_2)}(t,s) ds + \int_{T_1}^{T_2} tdt \int_t^{T_2} f_{(\tau_1,\tau_2)}(t,s) ds.$$

We illustrate the computations according to formulas (2) under the conditions of Example 1 for the de Moivre mortality model. In addition, in Example 1 it was obtained that $f_{(\tau_1,\tau_2)}(t,s)=\frac{1}{90-x}\cdot\frac{1}{85-y}$, $0<t<90-x,\ 0<s<85-y.$, or taking $(x,y)=(52,56)$ into account, we get $f_{(\tau_1,\tau_2)}(t,s)=\frac{1}{38}\cdot\frac{1}{29}$, $0<t<38,\ 0<s<29$. In our case $T_2>T_1$, therefore, we use the second version of formula (2)

$$M\tau=4\int_3^{38}dt\int_4^{29}\frac{1}{38}\cdot\frac{1}{29}ds+\int_0^4 sds\int_s^{38}\frac{1}{38}\cdot\frac{1}{29}dt+\int_0^3 tdt\int_t^{29}\frac{1}{38}\cdot\frac{1}{29}ds+\int_3^4 tdt\int_t^4\frac{1}{38}\cdot\frac{1}{29}ds=$$

$$=\frac{1}{38}\cdot\frac{1}{29}\left[4\cdot35\cdot25+\int_0^4 s(38-s)ds+\int_0^3 t(29-t)dt+\int_3^4 t(4-t)dt\right]=\cdot$$

$$=\frac{1}{38}\cdot\frac{1}{29}\left[3500+\frac{38\cdot4^2}{2}-\frac{4^3}{3}+\frac{29\cdot3^2}{2}-\frac{3^3}{3}+\frac{4}{2}\left(4^2-3^2\right)-\frac{4^3-3^3}{3}\right]$$

$$\approx 3,5455$$

For the variance of the validity of the contract, we calculate $M\tau^2=\iint_{R^2}\tau^2(t,s)f_{(\tau_1,\tau_2)}(t,s)\,dtds$. It is equal to:

when $T_1>T_2$

$$M\tau^2=T_1^2\int_{T_1}^{\omega_1-x}dt\int_{T_2}^{\omega_2-y}f_{(\tau_1,\tau_2)}(t,s)ds+\int_0^{T_1}t^2dt\int_t^{\omega_2-y}f_{(\tau_1,\tau_2)}(t,s)ds+\int_0^{T_2}s^2ds\int_s^{\omega_1-x}f_{(\tau_1,\tau_2)}(t,s)dt+\int_{T_2}^{T_1}s^2ds\int_s^{T_1}f_{(\tau_1,\tau_2)}(t,s)dt, \quad (3)$$

when $T_2>T_1$

$$M\tau^2=T_2^2\int_{T_1}^{\omega_1-x}dt\int_{T_2}^{\omega_2-y}f_{(\tau_1,\tau_2)}(t,s)ds+\int_0^{T_2}s^2ds\int_s^{\omega_1-x}f_{(\tau_1,\tau_2)}(t,s)dt+\int_0^{T_1}t^2dt\int_t^{\omega_2-y}f_{(\tau_1,\tau_2)}(t,s)ds+\int_{T_1}^{T_2}t^2dt\int_t^{T_2}f_{(\tau_1,\tau_2)}(t,s)ds.$$

Then in our example

$$M\tau^2=16\int_3^{38}dt\int_4^{29}\frac{1}{38}\cdot\frac{1}{29}ds+\int_0^4 s^2ds\int_s^{38}\frac{1}{38}\cdot\frac{1}{29}dt+\int_0^3 t^2dt\int_t^{29}\frac{1}{38}\cdot\frac{1}{29}ds+\int_3^4 t^2dt\int_t^4\frac{1}{38}\cdot\frac{1}{29}ds=$$

$$=\frac{1}{38}\cdot\frac{1}{29}\begin{bmatrix}16\cdot35\cdot25+\int_0^4 s^2(38-s)ds+\\ \int_0^3 t^2(29-t)dt+\int_3^4 t^2(4-t)dt\end{bmatrix}=.$$

$$=\frac{1}{38}\cdot\frac{1}{29}\left[14000+\frac{38\cdot4^3}{3}-\frac{4^4}{4}+\frac{29\cdot3^3}{3}-\frac{3^4}{4}+\frac{4}{3}\left(4^3-3^3\right)-\frac{4^4-3^4}{4}\right]$$

$$\approx 13,504$$

For the dispersion of the validity of the contract, we obtain $D\tau=M\tau^2-(M\tau)^2\approx0,933$

CONCLUSION

In order to optimize the business of insurance companies to maintain the stability of capital, the features of constructing models for actuarial calculation of insurance tariffs are considered taking into account the estimation and forecast of a variety of statistical factors that take into account the regional differentiation of the subjects of the Russian Federation. Analytical expressions are obtained for the likelihood of a joint project break due to companion actions, as well as expressions for calculating insurance tariffs in the form of a lump sum payment of insurance coverage to a living companion in the event of death of another before the retirement age, depending on the interest rate, companion ages, up to pensions, death rates and maximum permissible ages. The probability of obtaining insurance coverage by each of the companions and the value of the contract (mathematical expectation of the insurer's expenses) calculated at the time of the contract conclusion were calculated. The performed calculations allow to determine the amount of redeemed reduced insurance amounts, which enables insurance companies to recalculate insurance premiums when changing the conditions of life insurance contracts.

The proposed methodology for calculating insurance tariffs ensures the sustainable development of the insurance company in the insurance services market increases its competitiveness and ensures the achievement of the leading positions in the segment of individual personal insurance.

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