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Estimation model of life insurance claims risk for cancer patients by using Bayesian method

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Abstract. This paper discussed the estimation model of the risk of life insurance claims for cancer patients using Bayesian method. To estimate the risk of the claim, the insurance participant data is grouped into two: the number of policies issued and the number of claims incurred. Model estimation is done using a Bayesian approach method. Further, the estimator model was used to estimate the risk value of life insurance claims each age group for each sex. The estimation results indicate that a large risk premium for insured males aged less than 30 years is 0.85; for ages 30 to 40 years is 3:58; for ages 41 to 50 years is 1.71; for ages 51 to 60 years is 2.96; and for those aged over 60 years is 7.82. Meanwhile, for insured women aged less than 30 years was 0:56; for ages 30 to 40 years is 3:21; for ages 41 to 50 years is 0.65; for ages 51 to 60 years is 3:12; and for those aged over 60 years is 9.99. This study is useful in determining the risk premium in homogeneous groups based on gender and age.

1. Introduction

Lately, people with critical illnesses are expanding. One of them cancer. Ironically, health care costs have also increased rapidly over the past few decades. Things need to be aware, unforeseen events can occur in cancer patients, resulting in cancer patients financially are in need of protection. Therefore, the role of insurance companies is very necessary [2], [8].

Critical illness insurance is devoted to protecting customers' patients with critical illnesses, such as cancer, kidney failure, and heart. Critical illness insurance is different with health insurance [9], [3]. Critical illness insurance provides a number of cash when the customer has been diagnosed with a critical illness [2], [5].

In insurance, the insurer (insurance company), provides financial assistance in the form of insurance money that is called a risk premium to the insured (customer). Determining the risk premiums be reckoned with that the company did not experience a loss [10]. With the increasing number of cancer patients, and the cost of cancer treatment is higher, the number of claims from year to year increasing [12]. This is a problem for the insurer in estimating future claims trends to determine the risk premium. Therefore, in this paper do research on the risk of claims, particularly in cancer patients.

2. Methodology

2.1. Bayesian methods

The person who filed a claim (X) distributed Binomial ($n,\ \theta_B$) where θ_B is a probability of occurrence X. The values θ_B are estimated using Bayesian methods. Maximum likelihood estimation of the random variable X can be formulated with

$$est\theta = \frac{x}{n} \tag{1}$$

Then Bayes' theorem, the posterior distribution of the value obtained as follows.

$$f_{\theta_b}(\theta \mid x) \propto f(x \mid \theta_B) f(\theta_B) \tag{2}$$

The posterior distribution contains all the information about θ_B that can be used for Bayesian estimation of the parameters θ_B the binomial distribution [1]. To estimate the value θ_B of a single observation X (the person filing the claim) with prior distribution θ_B the binomial distribution, turned into the beta distribution with parameters α and β, we can examine the form of the posterior distribution of θ_B [1]:

$$f(\theta_B \mid x) \propto \theta_B^x (1-\theta_B)^{n-x} \theta_B^{\alpha-1} (1-\theta_B)^{\beta-1} = \theta_B^{\alpha+x-1} (1-\theta_B)^{\beta+n-x-1} \tag{3}$$

The value of θ_B given by a data sample $x = (x_1, x_2, \dots, x_n)$ has a loss function $g(x)$, which minimizes the loss estimate by observing its posterior distribution. The loss function commonly used is the quadratic loss function is defined as follows [11]:

$$L(g(x);\theta) = [g(x) - \theta]^2 \tag{4}$$

By minimizing the quadratic loss function, $\theta_B$value can be expressed as the average (mean) of the posterior distribution as follows:

$$\theta_B = \frac{\alpha + x}{(\alpha + x) + (\beta + n - x)} = \frac{\alpha + x}{\alpha + \beta + n} \tag{5}$$

Using the theorem credibility, we can declare the value of Bayesian estimation $\theta_B$in the form:

$$\theta_B = Z\theta + (1-Z)\mu = Z\frac{x}{n} + (1-Z)\mu \tag{6}$$

where credibility factor Z is as follows:

$$Z = \frac{n}{\alpha + \beta + n} \tag{7}$$

and μ is the average of the prior distribution of beta distributions declared by

$$\mu = \frac{\alpha}{\alpha + \beta} \tag{8}$$

In practice, there are some situations where a prior value is unknown. So, we use the value of non-informative priors. For example, if θ_B is the opportunity of a binomial distribution, and θ_B not have any information about the prior distribution, the distribution of which had been distributed prior to the hose Uniform (0,1) would seem appropriate. In this case, the prior distribution is the beta distribution with parameter α = 1 and β = 1. However, the interval that we take not the interval (0,1), but the interval is more realistic. Set the interval $(\theta_{min}, \theta_{max})$ to get a good estimate. We denote the value of s as the average of the prior distribution of beta which is the centre of this interval [1], [11].

$$s = \frac{x_{\min} + x_{\max}}{2} \tag{9}$$

We mark as θ_0 the more distant boundary from the value of 0.5 of the interval $(\theta_{min}, \theta_{max})$. Calculate the *error* h_B as follows:

$$h_B = |\theta_0 - s| \tag{10}$$

and calculate the number of claim q by using formula as follows:

$$q = \frac{2p\theta_0(1-\theta_0)}{ph_B^2 - \theta_0(1-\theta_0)} \tag{11}$$

where p is number of insured in the insurance company. Then, we estimate the value of the parameter α and β of beta prior distributions as follows:

$$\alpha = qs \tag{12}$$
$$\beta = q - qs \tag{13}$$

2.2. *Individual Risk Model*

To determine the risk premium in homogeneous groups according to age and gender, need to be estimated that many insurance policy issued in the following year by extrapolating the trend of the time series using Statistics program *Statgraphics Centurion*. To select the most appropriate trend function, we use the procedure Comparison of Alternative Models [9], [7]. As for estimating the value of n in the following period (in 2009), we use the procedure Forecast. In this research, there are two models of risk, namely the risk model of collective and individual risk models. In the collective risk model, we let $X_{1,}, X_2, X_3 \dots \dots . X_N$is a random variable that the variable determining the amount of the claim. The total of the amount of the claim, denoted by [4]:

$$S = X_{1,} + X_2 + X_3 + \ldots + X_N \tag{14}$$

While the individual risk model, the total of the amount of the claim can be denoted as S_n. So we can write as follows:

$$S_n = Y_1 + Y_2 + Y_3 + \ldots + Y_n \tag{15}$$

where Y_j indicates the number of claims for individual year j, and n indicates the period of observation. However, it is possible some risks will not give rise to a claim. Therefore, the value $Y_j,\ j = 1,2,\dots,n$ may be 0. It will be given two assumptions, namely:

- The number of claims in the year to j, N_j is 0 or 1.
- Possible claims in the year to j is q_j.

Based on the above assumptions, $N_j \sim Bi(1; q_j)$, thus the distribution of Y_j is compound binomial with individual claims are denoted X_j. Then we can write it as follows:

$$E(Y_j) = q_j \mu_j \tag{16}$$
$$D(Y_j) = q_j\left(\sigma_j^2 + \mu_j^2\right) - q_j^2\mu_j^2 = q_j\sigma_j^2 + q_j\left(1 - q_j\right)\mu_j^2 \tag{17}$$

Where $\mu_{j,}$ and σ_j^2 is the average and variance of X_j. Then, the average and variance of S_n are:

$$E(S_n) = E\left(\sum_{j=1}^{n} Y_j\right) = \sum_{j=1}^{n} E(Y_j) = \sum_{j=1}^{n} q_j \mu_j \tag{18}$$

$$D(S_n) = D\left(\sum_{j=1}^{n} Y_j\right) = \sum_{j=1}^{n} D(Y_j) = \sum_{j=1}^{n}\left[q_j\sigma_j^2 + q_j\left(1 - q_j\right)\mu_j^2\right] \tag{19}$$

In special cases, when Y_J, $j = 1,2,\ldots,n$ is a composite of several distribution and is a random variable. Based on the central limit theorem we can approach $S_n$distribution by the normal distribution. Therefore, in this case, we assign the value of the risk premium equal to 95% of the normal distribution with parameters($\mu = E(S_n)$, $\sigma^2 = D(S_n)$). Large risk premium (RP) can be calculated with the calculation below [6], [4]:

$$P(S_n \le RP) = 95\% \tag{20}$$

$$P\left(\frac{S_n - E(S_n)}{\sigma_{S_N}} \le \frac{RP - E(S_n)}{\sigma_{S_N}}\right) = 0.95$$

$$P\left(Z \le \frac{RP - E(S_n)}{\sigma_{S_N}}\right) = 0.95$$

From the standard normal distribution table, it is obtained that

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$$\frac{RP-E(S_n)}{\sigma_{S_n}}=1.96 \;\Rightarrow\; RP=\left(1.96\left(\sigma_{S_n}\right)\right)+E(S_n)$$

$$RP=\left(1.96\left(\sqrt{D(S_n)}\right)\right)+E(S_n) \;\Rightarrow\; RP/\text{person}=\frac{\left(1.96\left(\sqrt{D(S_n)}\right)\right)+E(S_n)}{n_{2009}} \tag{21}$$

3. Results and Discussion

The data used is in the form of simulation data in the form of insured claims data that have been diagnosed with a critical illness at an insurance company for ten years, from 2005 to 2014.

- For insured men aged less than 30 years

Table 1.Bayesian estimation calculation for men aged less than 30 years.

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	67	1	0.015	0.041	8.124	0.005	0.891	89%
2006	108	4	0.037	1.041	74.124	0.014	0.590	59%
2007	123	2	0.016	5.041	178.124	0.028	0.402	40%
2008	384	6	0.016	7.041	299.124	0.023	0.556	56%
2009	688	12	0.017	13.041	677.124	0.019	0.499	50%
2010	985	10	0.010	25.041	1,353.124	0.018	0.417	42%
2011	997	9	0.009	35.041	2,328.124	0.015	0.297	30%
2012	1456	12	0.008	44.041	3,316.124	0.013	0.302	30%
2013	1878	18	0.010	56.041	4,760.124	0.012	0.281	28%
2014	2146	12	0.006	74.041	6,620.124	0.011	0.243	24%
2015				86.041	8,754.124	0.010		

Based on the percentage of the value of Z obtained in Table 1, it can be concluded that the influence of information in previous years to take into account the value of the insured $\theta_B$men aged less than 30 years, namely in 2005, 2006, 2008, and 2009 are very large, in 2007 and in 2010 is large enough, whereas in 2011 until 2014 small.

- For insured women aged less than 30 years

Table 2. Calculation of Bayesian estimation for women aged less than 30 years.

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	55	1	0.018	0.041	8.124	0.005	0.871	87%
2006	89	2	0.022	1.041	62.124	0.016	0.585	58%
2007	94	6	0.064	3.041	149.124	0.020	0.382	38%
2008	222	4	0.018	9.041	237.124	0.037	0.474	47%
2009	587	2	0.003	13.041	455.124	0.028	0.556	56%
2010	878	6	0.007	15.041	1,040.124	0.014	0.454	45%
2011	984	4	0.004	21.041	1,912.124	0.011	0.337	34%
2012	1165	6	0.005	25.041	2,892.124	0.009	0.285	29%
2013	1456	12	0.008	31.041	4,051.124	0.008	0.263	26%
2014	1987	18	0.009	43.041	5,495.124	0.008	0.264	26%
2015				61.041	7,464.124	0.008		

Based on the percentage of the value of Z obtained in Table 2, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B women aged less than 30 years, namely in 2005, 2006 and 2009 was very strong, while in 2007, 2008, 2010 and 2011 is quite large, but in the year 2012 to 2014 is small.

- For insured men aged 30 years to 40 years

Table 3. Calculation of Bayesian estimation for men aged 30 years to 40 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	180	6	0.033	0.041	8.124	0.005	0.957	96%
2006	354	4	0.011	6.041	182.124	0.032	0.653	65%
2007	487	9	0.018	10.041	532.124	0.019	0.473	47%
2008	555	15	0.027	19.041	1,010.124	0.019	0.350	35%
2009	687	18	0.026	34.041	1,550.124	0.021	0.302	30%
2010	987	26	0.026	52.041	2,219.124	0.023	0.303	30%
2011	1165	34	0.029	78.041	3,180.124	0.024	0.263	26%
2012	1548	50	0.032	112.041	4,311.124	0.025	0.259	26%
2013	1856	49	0.026	162.041	5,809.124	0.027	0.237	24%
2014	1951	55	0.028	211.041	7,616.124	0.027	0.200	20%
2015				266.041	9,512.124	0.027		

Based on the percentage of the value of Z obtained in Table 3, it can be concluded that the influence of information in previous years to take into account the value of the insured $\theta_B$men aged 30 years to 50 years ie in 2005 and 2006 are very large, in 2007 and in 2008 is large enough, whereas in the year 2009 to 2014, small.

- For insured women aged 30 years to 40 years

Table 4. Calculation of Bayesian estimation for women aged 30 years to 40 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	165	2	0.012	0.041	8.124	0.005	0.953	95%
2006	289	3	0.010	2.041	171.124	0.012	0.625	63%
2007	348	6	0.017	5.041	457.124	0.011	0.430	43%
2008	498	14	0.028	11.041	799.124	0.014	0.381	38%
2009	512	16	0.031	25.041	1,283.124	0.019	0.281	28%
2010	594	22	0.037	41.041	1,779.124	0.023	0.246	25%
2011	789	31	0.039	63.041	2,351.124	0.026	0.246	25%
2012	987	46	0.047	94.041	3,109.124	0.029	0.236	24%
2013	1254	43	0.034	140.041	4,050.124	0.033	0.230	23%
2014	1789	49	0.027	183.041	5,261.124	0.034	0.247	25%
2015				232.041	7,001.124	0.032		

Based on the percentage of the value of Z obtained in Table 4, it can be concluded that the influence of information in previous years to take into account the value of the insuredθ_B on women aged 30 years to 50 years ie in 2005 and 2006 are very large, in the year 2007 and the year 2008 is large enough, whereas in the year 2009 to 2014, small.

- For insured men aged 40 years to 50 years

Table 5. Calculation of Bayesian estimation for men aged 40 years to 50 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	185	4	0.022	0.041	8.124	0.005	0.958	96%
2006	354	6	0.017	4.041	189.124	0.021	0.647	65%
2007	439	9	0.021	10.041	537.124	0.018	0.445	45%
2008	654	9	0.014	19.041	967.074	0.019	0.399	40%
2009	945	12	0.013	28.041	1,612.074	0.017	0.366	37%
2010	1145	18	0.016	40.041	2,545.074	0.015	0.307	31%
2011	1265	21	0.017	58.041	3,672.074	0.016	0.253	25%
2012	1548	24	0.016	79.041	4,916.074	0.016	0.237	24%
2013	1856	27	0.015	103.041	6,440.074	0.016	0.221	22%
2014	2156	36	0.017	130.041	8,269.074	0.015	0.204	20%
2015				166.041	10,389.074	0.016		

Based on the percentage of the value of Z obtained in Table 5, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B men aged 40 years to 50 years ie in 2005 and 2006 are very large, in 2007 until the year 2010 is quite large, whereas in 2011 until 2014, small.

- For insured women aged 40 to 50 years

Table 6. Calculation of Bayesian estimation for women aged over 50 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	176	1	0.006	0.041	8.124	0.005	0.956	96%
2006	326	1	0.003	1.041	183.124	0.006	0.639	64%
2007	399	2	0.005	2.041	508.124	0.004	0.439	44%
2008	587	9	0.015	4.041	905.124	0.004	0.392	39%
2009	878	12	0.014	13.041	1,483.124	0.009	0.370	37%
2010	1059	6	0.006	25.041	2,349.124	0.011	0.308	31%
2011	1159	16	0.014	31.041	3,402.124	0.009	0.252	25%
2012	1478	21	0.014	47.041	4,545.124	0.010	0.243	24%
2013	1784	30	0.017	68.041	6,002.124	0.011	0.227	23%
2014	2111	27	0.013	98.041	7,756.124	0.012	0.212	21%
2015				125.041	9,840.124	0.013		

Based on the percentage of the value of Z obtained in Table 6, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B on women aged 40 to 50 years, namely in 2005 and 2006 are very large, in the year 2007 to the year 2010 was quite large, whereas in 2011 until 2014, small.

- For insured men aged 50 years to 60 years

Table 7. Calculation of Bayesian estimation for men aged 50 years to 60 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	165	6	0.036	0.041	8.124	0.005	0.953	95%
2006	354	4	0.011	6.041	167.124	0.035	0.672	67%
2007	477	9	0.019	10.041	517.124	0.019	0.475	48%
2008	658	15	0.023	19.041	985.124	0.019	0.396	40%
2009	978	18	0.018	34.041	1,628.124	0.020	0.370	37%
2010	1523	26	0.017	52.041	2,588.124	0.020	0.366	37%
2011	1648	34	0.021	78.041	4,085.124	0.019	0.284	28%
2012	1853	50	0.027	112.041	5,699.124	0.019	0.242	24%
2013	2157	49	0.023	162.041	7,502.124	0.021	0.220	22%
2014	3245	55	0.017	211.041	9,610.124	0.021	0.248	25%
2015				266.041	12,800.124	0.020		

Based on the percentage of the value of Z obtained in Table 7, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B men aged 50 years to 60 years, namely in 2005 and 2006 are very large, in 2007 until the year 2010 is quite large, whereas in 2011 until 2014, small.

- For insured women aged 50 to 60 years

Table 8. Calculation of Bayesian estimation for women aged 50 to 60 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	152	6	0.039	0.041	8.124	0.005	0.949	95%
2006	333	4	0.012	6.041	154.124	0.038	0.675	68%
2007	398	9	0.023	10.041	483.124	0.020	0.447	45%
2008	599	15	0.025	19.041	872.124	0.021	0.402	40%
2009	977	18	0.018	34.041	1,456.124	0.023	0.396	40%
2010	1485	26	0.018	52.041	2,415.124	0.021	0.376	38%
2011	1677	34	0.020	78.041	3,874.124	0.020	0.298	30%
2012	1789	50	0.028	112.041	5,517.124	0.020	0.241	24%
2013	2054	49	0.024	162.041	7,256.124	0.022	0.217	22%
2014	2987	55	0.018	211.041	9,261.124	0.022	0.240	24%
2015				266.041	12,193.124	0.021		

Based on the percentage of the value of Z obtained in Table 8, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B on women aged 50 to 60 years ie in 2005 and 2006 are very large, in the year 2007 to the year 2010 was quite large, whereas in 2011 until 2014, small.

- For insured men aged over 60 years

Table 9. Calculation Bayesian estimation for men aged over 60 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	88	6	0.068	0.041	8.124	0.005	0.915	92%
2006	120	4	0.033	6.041	90.124	0.063	0.555	56%
2007	155	9	0.058	10.041	206.124	0.046	0.418	42%
2008	258	15	0.058	19.041	352.124	0.051	0.410	41%
2009	394	18	0.046	34.041	595.124	0.054	0.385	39%
2010	478	26	0.054	52.041	971.124	0.051	0.318	32%
2011	658	34	0.052	78.041	1,423.124	0.052	0.305	30%
2012	698	50	0.072	112.041	2,047.124	0.052	0.244	24%
2013	789	49	0.062	162.041	2,695.124	0.057	0.216	22%
2014	841	55	0.065	211.041	3,435.124	0.058	0.187	19%
2015				266.041	4,221.124	0.059		

Based on the percentage of the value of Z obtained in Table 9, it can be concluded that the influence of information in previous years to take into account the value of the insured θ_B men aged over 60 years, namely in 2005 and 2006 are very large, in the year 2007 to in 2010 large enough, whereas in 2011 until 2014, small.

- For insured men aged over 60 years

Table 10.Calculation -Eighteen Bayesian estimation for over 60 years

year	n	x	$\frac{x}{n}$	α	β	θ_B	Z	$\%Z$
2005	74	6	0.081	0.041	8.124	0.005	0.901	90%
2006	95	4	0.042	6.041	76.124	0.074	0.536	54%
2007	111	9	0.081	10.041	167.124	0.057	0.385	39%
2008	198	15	0.076	19.041	269.124	0.066	0.407	41%
2009	242	18	0.074	34.041	452.124	0.070	0.332	33%
2010	298	26	0.087	52.041	676.124	0.071	0.290	29%
2011	397	34	0.086	78.041	948.124	0.076	0.279	28%
2012	874	50	0.057	112.041	1,311.124	0.079	0.380	38%
2013	897	49	0.055	162.041	2,135.124	0.071	0.281	28%
2014	985	55	0.056	211.041	2,983.124	0.066	0.236	24%
2015				266.041	3,913.124	0.064		

Based on the percentage of the value of Z obtained in Table 10, it can be concluded that the influence of information in previous years to take into account the value θ_B insured women over the age of 60 years, namely in 2005 and 2006 are very large, in the year 2007 to the year 2009 big enough, whereas in the year 2010 to 2014, small.

Table 11. Calculation of the risk premium for insured males by age group

Age	θ_B	n_{2009}	$E(Y_j)$	$D(Y_j)$	The risk premium / person
< 30 years	0,01	2.146	179.628	1,707.642	0,85
30 to 40 years	0.027	2.156	51,861.258	49,340,328.857	3.58
40 to 50 years	0.016	2.156	35,770.747	37,168,956.545	1.71
50 to 60 years	0.020	3.245	86,276.357	110,450,316.148	2.96
> 60 year	0.059	841	24,683.851	10,354,477.324	7.82

Table 12. Calculation of the risk premium for insured women by age group

Age	θ_B	n_{2009}	$E(Y_j)$	$D(Y_j)$	The risk premium / person
< 30 years	0.008	1.987	12,115.687	9,045,503.896	0.56
30 to 40 years	0.032	1.789	41,465.275	29,037,717.865	3.21
40 to 50 years	0.013	2.111	26,374.527	25,957,640.904	0.65
50 to 60 years	0.021	2.987	72,548.771	88,639,531.691	3.12
> 60 year	0.064	985	32,052.294	12,355,569.095	9.99

4. Conclusion

Bayesian estimation theory provides a great method for estimating the risk premium for the next period of the claim data information in the previous period. In this study, a large risk premium for insured males aged less than 30 years is 0.85, for those aged 30 to 40 years is 3:58, for those aged 40 to 50 years is 1.71, for those aged 50 to 60 years was 2.96, and for age over 60 years is 7.82. Meanwhile, for insured women aged less than 30 years is 0.56, for those aged 30 to 40 years is 3:21, for those aged 40 to 50 years is 0.65, for those aged 50 to 60 years was 3:12, and for those aged over 60 years is 9.99.

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