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Calculation of Net Annual Health Insurance Premium Using Burr Distribution

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Abstract

Health insurance is one form of insurance products specifically ensures healthcare services or medical treatments. Health insurance is considered compulsory for each individual, since it is very useful to aid treatment, especially for those less fortunate people. Hence, to solve this problem, a calculation of net annual health insurance premium is needed. This calculation might be carried out using several methods, including mortality table and Burr distribution. The calculation result of net annual health insurance premium showed that the premium result calculated using the Burr distribution is smaller than the result calculated using mortality table. The premium is personalized based on age, sex, cost and duration of health insurance policy.

Keywords:
Health insurance, insurance premium, mortality table, Burr distribution.

1. Introduction

Sickness is an unpleasant condition which occurred to someone and causes impairment in daily activities either physical, spiritual or social activity The environment is one of the factors affecting human health, especially on the less fortunate families whose daily activities are conducted on unhealthy environment (Workman, 2000). This causes these families to be prone to certain diseases, considering they consume less consumable foods every day. Should any member of these families contracts a certain disease, several costs need to be paid, and even more, should the person needs to be admitted in the hospital or requires intensive care, the hospital bill will increase in amount (Sukono et al., 2017a).

Considering this reason, health insurance is compulsory to each individual due to its benefits to ease access to medical treatment especially for the less fortunate families. The main function of insurance is as a risk-forwarding mechanism, i.e. forwarding the risk from one party (insured) to another (insurer) (Morton, 1999; Sukono et al., 2017b). This risk-forwarding does not necessarily mean total absence of misfortune possibility, but rather that the insurer ensures financial security and calamity to the insured. As a consequence, the insured party provides the least amount of premium compared to the potential loss (Morton, 1999). Insurance has several products, one of which is health insurance (Karnon et al., 2009).

Health insurance is divided into two categories, i.e. individual hospital care health insurance and collective hospital care health insurance (Saputra et al., 2018). This paper discusses individual hospital care health insurance program which is an insurance providing financial support to pay hospital care bills for the insured and his/her family. The amount of premium billed is defined based on the type of insurance and the applied annuity. Annuity is a type of payment in certain amounts paid regularly on an agreed time frame for as long as the person may live (Futami, 1993a; 1993b). Determining the premium of health insurance requires temporary initial annuity, i.e. series of payment due on an equal time range from the agreed time which are paid since the first payment period.

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This paper calculates net health insurance premium using Burr distribution. Burr distribution is one type of distribution in actuary theory which might be applied in insurance claim distribution.

2. Literature Review

2.1 Life Insurance and Mortality Table

In general, insurance is a two-way agreement in which the insurer who receives the agreed premium promises to pay the insured or the appointed person for an uncertain condition mentioned in the contract, either because the insured person or the appointee experienced misfortunes due to other event, or because the listed event impaired the life and health of the insured or appointee (Menge and Fischer, 1985; Sukono et al., 2018).

Life insurance is a two-way contract between the insured and insurer (insurance company) in which the insurer promises to ensure the insured as long as the insured paid the premium to the insurer; and if the insured person passed or if the agreed time is due, the insurer is obliged to pay a certain amount of money to the person appointed by the insured (Menge and Fischer, 1985).

Insurance companies always base their premium calculation, insurance amount and other calculations based on mortality table. Mortality table contains the probability of someone's death based on their age among all insured people. RP-2000 table is a table issued by the Ministry of Finances in 2000 which had been studied by SoA (Society of Actuaries). This table has been adapted following the mortality table and is made based on age, sex and status (employee, retiree, etc.) (Workman, 2000; Dickson et al., 2009).

2.2 Simple and Compound Interest Rate

The amount of payment paid by the fund user to the funder is usually already added with a certain amount of interest. The interest rate depends on the amount of principal, investment time period and the interest rate.

The interest calculation method which are based on the ratio of principal and the investment period is known as simple interest. Knowing that principal *P*, interest rate *i* and investment time period *n*, then the amount of interest is written as (Futami, 1993a; 1993b):

$$I = Pni \tag{1}$$

As for compound interest is defined in a *v* function written as follows:

$$v = \frac{1}{1+i} \tag{2}$$

2.3 Lifetime Annuity and Temporary Life Annuity

Lifetime annuity is an annuity which payment is able to be paid as long as the insured still survived; payment can be made in the start (annuity-due) or in the end (annuity-immediate).

The annuity-immediate of a lifetime annuity is written as (Futami, 1993a; 1993b):

$$a_x = \frac{N_{x+1}}{D_x} \tag{3}$$

Meanwhile, annuity-due of a lifetime annuity is noted as $\ddot{a}_x$, and is calculated using the equation below:

$$\ddot{a}_x = \frac{N_x}{D_x} \tag{4}$$

Temporary life annuity is a life annuity which payment is paid on a certain time period. Annuities-immediate of temporary life annuity for a time period of *n* is noted as $a_{x:\overline{n}|}$, while the annuities-due of temporary life annuity is noted as $\ddot{a}_{x:\overline{n}|}$ both are written as (Bain and Engelhardt, 1991):

$$a_{x:\overline{n}|} = \frac{N_{x+1} + N_{x+n+1}}{D_x} \tag{5}$$

$$\ddot{a}_{x:\overline{n}|} = \frac{N_x - N_{x+n}}{D_x} \tag{6}$$

Life annuity paid in the beginning of the period is known as annuity-due temporary life annuity. The cash amount of life annuity depends on the life expectancy and discount factor. The survival and death probability of an insurance client is obtained from the survival function. Survival function is someone's life function aged *x* years who survived

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to the next *t* years. For each probability density function (*x*), there is a distribution function *F(x)* from a random continuous variable *X* which are written down as (Bain and Engelhardt, 1991):

$$F(x) = \int_{-\infty}^{x} f(t)dt \, , -\infty < x < \infty \tag{7}$$

Next, to find the survival probability function, distribution function from a probability density function is needed. Survival function *S*(*x*) is a probability someone might survive to the age of (*x*), and is written down as follows:

$$S(x) = 1 - F(x) \tag{8}$$

In actuary, distribution function depends on the remaining age of someone and the remaining age related with time. For example, *T*(*x*) is a continuous random variable which states the remaining age of someone aged *x* years in the following time period of *t* years. The cumulative distribution function for a continuous random variable of *T*(*x*) is:

$$F_{T(x)}(t) = \frac{F(x+t) - F(x)}{S(x)} \tag{9}$$

The function $F_{T(x)}(t)$ elaborates the probability someone aged (x) years might die within the following *t* years, which could be written down as ${}_tq_x$, and based on the equation (8), the association between survival function and death probability of someone is known as:

$$S_{T(x)}(t) = 1 - {}_tq_x \tag{10}$$

The survival function $S_{T(x)}(t)$ determines the probability of someone aged (*x*) years might survive up to the following *x*+*t* years, which could be written down as ${}_tp_x$, and in (Futami, 1993a; 1993b), the association between the survival probability and death probability on an insurance client aged *x* years is written as follows:

$${}_tp_x = 1 - {}_tq_x \tag{11}$$

2.3 Premium

Insurance premium is the amount of money paid by the insured to the insurance company which could be determined in several ways (Subagyo et al, 1998).

- *Net Single Premium of Temporary Life Insurance*

$$A^1_{x:\overline{n}|} = \frac{M_x - M_{x+n}}{D_x} \tag{12}$$

- *Net Annual Premium*

Annual premium is the premium paid on the beginning of the year which amount might be constant or vary on each year (Sembiring, 1986).

$$P\ddot{a} = A \tag{13}$$

- *Net Annual Premium of Lifetime Life Insurance*

For lifetime life insurance, the formula to calculate the premium is similar with that of temporary insurance; with $n \to \infty$, it is known that:

$$P_x = \frac{A_x}{\ddot{a}_x} \tag{14}$$

- *Net Annual Premium of Temporary Life Insurance*

Net annual premium of life insurance for a period of *n* year, with due money noted as 1, and was paid in the end of police year was written down as:

$$P^1_{x:\overline{n}|} = \frac{A^1_{x:\overline{n}|}}{\ddot{a}_{x:\overline{n}|}} \tag{15}$$

- *Health Insurance*

Health insurance is one insurance product which specifically ensure the healthcare bill of insurance clients should they got sick or been in an accident (Tadikamalla, 1980).

$$P\ \ddot{a}_{x:\overline{n}|} = \frac{T^{sh} \sum_{t=0}^{n-1} \overline{D}_{x+t}\ q^{sh}_{x+t}}{N_x - N_{x+n}} \tag{16}$$

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3. Object and Method

3.1 Study Object

The object of this study was data analysis, i.e. calculating net annual premium of Allianz health insurance clients using Burr distribution. The data being used in this study was a secondary data obtained from www.allianz.co.id/produk/asuransi-kesehatan/smarthealth-maxi-violet. This was a data comprising the costs paid by health insurance clients obtained from Allianz health insurance.

3.2 Calculation Method

Net annual premium of Allianz health insurance was calculated based on insurance cost paid to cover hospital service bills. The calculation for hospital care insurance was basically similar with other life insurance, only that in health insurance, hospital care costs were used to calculate health insurance premium.

3.2.1 Calculation of Annual Health Insurance Premium

Burr distribution was first introduced by Irving W. Burr in 1941. Burr distribution was one type of distribution in actuary theory which could be applied in insurance claim distribution. This paper aims to determine the amount of health insurance premium using initial temporary annuity, i.e. series of payment due on an equal time range from the agreed time which are paid since the first payment period (Tadikamalla, 1980).

Before determining the health insurance premium, survival probability should be first determined using Burr distribution. Probability density function from Burr distribution was determined from the equation below:

$$f(x,c,k) = \begin{cases} ck\dfrac{x^{c-1}}{(1+x^c)^{k+1}} & x > 0 \\ 0 & other\ x \end{cases} \quad (17)$$

where c resembles form parameter and k resembles scale parameter with $c > 0$ and $k > 0$. The parameter value of c and k, which were obtained using Easyfit software, were used to determine the survival probability of health insurance client who underwent treatment in the hospital.

Before determining the survival and death probability using Burr distribution, cumulative distribution function and survival function were determined first. Based on equation (17), the cumulative distribution function based on Burr distribution for x year is as follows:

$$F(x,c,k) = 1 - (1+x^c)^{-k} \qquad x > 0, \quad (18)$$

Based on equation (18), the cumulative distribution function using Burr distribution for a client aged x+ t years was written as follows:

$$F(x+t) = 1 - (1+(x+t)^c)^{-k} \quad (19)$$

The survival function of someone aged x years calculated using Burr distribution was determined by substituting equation (18) to equation (8) is written as follows:

$$S(x) = (1+x^c)^{-k} \quad (20)$$

Then, by substituting the equations (18), (19) and (20) to equation (9), distribution function for a person aged x years until the person reach the age of $x + t$ years is written down as:

$$F_{T(x)}(t) = 1 - \frac{(1+(x+t)^c)^{-k}}{(1+x^c)^{-k}} \quad (21)$$

Cumulative distribution function $F_{T(x)}(t) = {}_tq_x$ which showed that the death probability of an insurance client aged x years and will die on the next t years was written down using Burr distribution as:

$${}_tq_x = 1 - \frac{(1+(x+t)^c)^{-k}}{(1+x^c)^{-k}} \quad (22)$$

The survival probability of an insurance client aged x years was probably would survive up to age $x + t$ years based on Burr distribution on equation (22), and was written down as:

$${}_tp_x = \frac{(1+x^c)^k}{(1+(x+t)^{ck}} \quad (23)$$

Cash value of initial life temporary annuity of health insurance client aged x years was written down as follows:

$$\ddot{a}_{x:\overline{n}|} = \sum_{t=0}^{n-1} v^t\ {}_tp_x \quad (24)$$

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Knowing that *v* was discount factor defined as current value of payment as much as 1 unit payment due one year later, was written down as:

$$v = \frac{1}{1+i} \tag{25}$$

By substituting equation (23) to equation (24), the cash initial life temporary annuity value for *n* years for a client aged *x* years using Burr distribution was written down as:

$$\ddot{a}_{x:\overline{n}|} = \sum_{t=0}^{n-1} v^t . \frac{(1+x^c)^k}{(1+(x+t)^{ck}} \tag{26}$$

Net single individual health insurance premium of insurance clients aged *x* years with T^{sh} denoting average hospital care cost and q_x^{sh} denoting the probability of a client aged *x* years being admitted in a hospital was calculated using the equation below:

$$A^1_{x:\overline{n}|} = T^{sh} \sum_{t=0}^{n-1} v^{t+\frac{1}{2}} \; {}_tp_x \; q^{sh}_{x+t} \tag{27}$$

By substituting equation (23) to equation (27), net single health insurance premium for hospital care could be calculated using Burr distribution as follows (Tadikamalla, 1980):

$$A^1_{x:\overline{n}|} = T^{sh} v^{\frac{1}{2}} \left(q_x^{sh} + \sum_{t=1}^{n-1} v^t \frac{(1+x^c)^k}{(1+(x+t)^{ck}} \; q^{sh}_{x+t} \right) \tag{28}$$

The amount of net annual premium on hospital care health insurance by using association between single temporary health insurance premium with initial life annuity and payment due on the beginning of the year was written as follows:

$$P_{x:\overline{n}|} = \frac{A^1_{\overline{x:n}|}}{\ddot{a}_{\overline{x:n}|}} \tag{29}$$

By substituting equations (26) and (28) to equation (29), the annual temporary hospital care health insurance premium was obtained using Burr distribution for individual life status with payment due in the beginning of the period was written down as follows:

$$P_{x:\overline{n}|} = \frac{T^{sh} v^{\frac{1}{2}} \left(q_x^{sh} + \sum_{t=1}^{n-1} v^t \frac{(1+x^c)^k}{(1+(x+t)^{ck}} \; q^{sh}_{x+t} \right)}{\sum_{t=0}^{n-1} v^t . \frac{(1+x^c)^k}{(1+(x+t)^{ck}}} \tag{30}$$

3.2.1 Annual Health Insurance Premium Calculation Using Mortality Table

Calculation of annual health insurance premium using mortality table is written down as follows (Dickson et al., 2009; Tadikamalla, 1980):

$$P \; \ddot{a}_{\overline{x:n}|} = T^{sh} \sum_{t=0}^{n-1} v^{t+\frac{1}{2}} \; {}_tP_x \; q^{sh}_{x+t}$$

$$P = \frac{T^{sh} \sum_{t=0}^{n-1} v^{t+\frac{1}{2}} \frac{l_{x+t}}{l_x} \; q^{sh}_{x+t}}{\frac{N_x - N_{x+n}}{D_x}}$$

$$= \frac{T^{sh} \sum_{t=0}^{n-1} v^{t+\frac{1}{2}} \frac{l_{x+t}}{l_x} \; q^{sh}_{x+t} \; D_x}{N_x - N_{x+n}}$$

$$= \frac{T^{sh} \sum_{t=0}^{n-1} v^{x+t+\frac{1}{2}} \; l_{x+t} \; q^{sh}_{x+t}}{N_x - N_{x+n}}$$

$$= \frac{T^{sh} \sum_{t=0}^{n-1} \overline{D}_{x+t} \; q^{sh}_{x+t}}{N_x - N_{x+n}}$$

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3. Numerical Illustration

4.1 Calculation Result

Within this study, calculating the net annual health insurance premium was done using two methods, the Burr distribution method and mortality table method which will be classified based on the sex of the client.

Table 1. Policy Holder

No	Age	Cost	Sex	Duration of Insurance
1	26	IDR 48,925,000	M	10 years
2	26	IDR 48,925,000	F	10 years

4.2 Net Annual Health Insurance Premium Using Burr Distribution.

Based on the available data, it was known that the total hospital care cost was:

For the calculation in Polis Holder No. 1: given that the sex of the insurance client is male (M). Using *Easyfit* software, the obtained Burr distribution parameter value is as follows:

$$c = 0.54815 \text{ and } k = 0.0817$$

By calculating net annual health insurance premium completed using Combined Healthy RP-2000 table and Microsoft Excel®, the obtained discount factor was:

$$v = \frac{1}{1+i} = \frac{1}{1+0.025} = 0.9756$$

Based on RP-2000 table, Male Combined Healthy for male aged 26 years was 0.00378. Hence, the cash initial temporary life annuity value for insurance client aged 26 years with payment time range of 10 years was:

$$\ddot{a}_{26:\overline{10}|} = \sum_{t=0}^{9} v^t \ {}_tp_{26}$$

$$= \sum_{t=0}^{9} v^t \frac{(1+x^c)^k}{(1+(x+t)^c)^k}$$

$$= 1 + (0.9756 \times 0.9986) + (0.9756^2 \times 0.9972) + \cdots + (0.9756^9 \times 0.9885)$$

$$= 8.9196$$

Net single hospital health insurance premium which needs to be paid by insurance client aged 26 years was:

$$A^1_{26:\overline{10}|} = T^{sh} v^{\frac{1}{2}} \left(q^{sh}_{26} + \sum_{t=1}^{10-1} v^t \frac{(1+26^c)^k}{(1+(26+t)^c)^k} q^{sh}_{26+t} \right)$$

= IDR 48,925,000 x 0.9878 x {(0.0038 + (0.0037 + 0.0037 + ...+ 0.0061)}

= IDR 2,189,580.371

The amount of annual hospital care health insurance premium calculated using Burr distribution for insurance client aged 26 years paid annually for 10 years.

$$P_{40:\overline{10}|} = \frac{T^{sh} v^{\frac{1}{2}} \left(q^{sh}_{40} + \sum_{t=1}^{10-1} v^t \frac{(1+40^c)^k}{(1+(40+t)^c)^k} q^{sh}_{40+t} \right)}{\sum_{t=0}^{9} v^t \frac{(1+x^c)^k}{(1+(x+t)^c)^k}}$$

$$= \frac{Rp\ 2.189.580,371}{8.9196}$$

= IDR 245,479.9144

Hence, annual hospital care health insurance premium calculated using Burr distribution was IDR 245,479.9144

Meanwhile for calculation on Polis Holder No. 2: given that the sex of insurance client is female (F). The calculation of net annual health insurance premium from Combined Health RP-2000 table and Microsoft Excel® leads to calculation of discount factor as much as:

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$$v = \frac{1}{1+i} = \frac{1}{1+0.025} = 0.9756$$

Based on Female Combinated Healthy RP-2000 table for client aged 26 years was 0.0021. Hence, the cash initial temporary health annuity value for insurance client aged 26 years with payment time range of 10 years was

$$\ddot{a}_{26:\overline{10}|} = \sum_{t=0}^{9} v^t \ {}_tp_{26}$$
$$= \sum_{t=0}^{9} v^t \frac{(1+x^c)^k}{(1+(x+t)^c)^k}$$
$$= 1 + (0.9756 \times 0.9986) + (0.9756^2 \times 0.9972) + \cdots + (0.9756^9 \times 0.9885)$$
$$= 8.9196$$

Net single hospital health insurance premium which must be paid by insurance client aged 26 years was

$$A^1_{26:\overline{10}|} = T^{sh} v^{\frac{1}{2}} \left(q^{sh}_{26} + \sum_{t=1}^{10-1} v^t \frac{(1+26^c)^k}{(1+(26+t)^c)^k} q^{sh}_{26+t} \right)$$

= IDR 48,925,000 x 0.9878 x {(0.0021 + (0.0022 + 0.0022 + ...+ 0.0038)}
= IDR 1,328,008.91

The amount of annual hospital care health insurance premium calculated using Burr distribution for insurance client aged 26 years paid annually for 10 years was:

$$P_{40:\overline{10}|} = \frac{T^{sh} v^{\frac{1}{2}} \left(q^{sh}_{40} + \sum_{t=1}^{10-1} v^t \frac{(1+40^c)^k}{(1+(40+t)^c)^k} q^{sh}_{40+t} \right)}{\sum_{t=0}^{9} v^t \frac{(1+x^c)^k}{(1+(x+t)^c)^k}}$$
$$= \frac{Rp1.328.008{,}91}{8{,}9196}$$

= IDR 148,886.7538

Hence, the annual hospital care health insurance premium using Burr distribution was IDR 148,886.7538

4.3 Net Annual Health Insurance Premium Using Mortality Table

The net health insurance premium using mortality table was calculated by equation (16) and made a commutation table beforehand to determine the values of $D_x, \overline{D}_x, \text{and } N_x$ with interest rate $(i) = 2.5\%$. Within the calculation, the data would be divided into two based on the sex of the client. Microsoft Excel® 2013 was used to aid premium calculation. The data being used in this method was the similar data to those in the Burr distribution.

For the calculation in Polis Holder No. 1: given that the sex of the insurance client is male (M).

$$P = \frac{T^{sh} \sum_{t=0}^{n-1} \overline{D}_{x+t} \ q^{sh}_{x+t}}{N_x - N_{x+n}}$$

$$P = Rp\ 48.925.000 \times \frac{\left[\begin{matrix} (52.261{,}6713 \times 0.0038) + (50.944{,}6772 \times 0.0038) + \\ \ldots + (41.547{,}0632 \times 0.0077) \end{matrix} \right]}{1.429.660{,}776 - 979.404{,}2425}$$

= IDR 257,995.4639

Thus, the annual hospital care health insurance premium calculated using mortality table was IDR 257,995.4639

Meanwhile for calculation on Polis Holder No. 2: given that the sex of insurance client is female (F).

$$P = \frac{T^{sh} \sum_{t=0}^{n-1} \overline{D}_{x+t} \ q^{sh}_{x+t}}{N_x - N_{x+n}}$$

$$P = Rp\ 48.925.000 \times \frac{\left[\begin{matrix} (52.674{,}4480 \times 0.0021) + (51.367{,}0950 \times 0.0022) + \\ \ldots + (41.973{,}3798 \times 0.0048) \end{matrix} \right]}{1.484.988{,}147 - 1.030.618{,}062}$$

= IDR 156,513.8533

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Thus, the annual hospital care health insurance premium calculated using mortality table was IDR 156,513.8533 .

4. Conclusion

The calculation of net health insurance premium is completed by first determining the initial temporary life annuity, net single health insurance premium and then, net annual health insurance premium. In determining the initial temporary life annuity, the survival probability of the client was first obtained using Burr distribution. Net annual health insurance premium calculation model using association between single health insurance temporary premium with initial life annuity and agreement that payment was due in the beginning of the policy year is written down as follows: The amount of net annual health insurance premium calculated using Burr distribution is smaller compared to those calculated using mortality table. This result is affected by single health insurance premium.

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