Available online at https://journal.rescollacomm.com/index.php/ijqrm/index

International Journal of Quantitative Research and Modeling

e-ISSN 2721-477X
p-ISSN 2722-5046

Vol. 4, No. 4, pp. 223-228, 2023

Determination of Annual Net Single Premium Health Insurance for Epidemic Cases with Model Susceptible-Infected-Recovered

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Abstract

The calculation of a single annual net premium for health insurance from the epidemic disease SIR model has two models, including a single annual net premium with an inpatient benefit model and a single annual net premium with a lump sum benefit model. This study used Bank Indonesia's annual interest rate of 6,5% and the calculation used the equivalence principle. The calculation results from one of the original data obtained an annual net single premium with inpatient benefits is IDR 418,359 for a benefit IDR 1,000,000 and the single annual net premium with lump sum benefits is IDR 15,949 for a benefit of IDR 1,000,000

Keywords: SIR model, single annual net premium, insurance benefit, equivalence principle.

1. Introduction

An epidemic is a condition when a disease afflicts a group of people or an area with a case rate that exceeds the normal incidence of the disease (Banerjee, 2021). Urgent decisions are needed when a disease begins to infect humans and health services are needed to tackle epidemic diseases. Health services can sometimes be too expensive for the average person to buy, so the solution to this problem is to buy health insurance.

Insurance companies collect premiums from vulnerable groups affected by the disease and cover health care benefits for policyholders affected by the disease. Premium is an obligation that the policyholder must pay to the insurance company in a predetermined manner. Premiums that only pay attention to interest rates and mortality rates without regard to other costs are called net premiums. Premium calculation is done on the principle of equivalence, meaning that the insurance company expects not to experience losses.

Through technological developments, humans are facilitated to simulate complex problems. Mathematical modeling is a way to make it easier to simulate complex problems. Concerning epidemics, mathematics has a special form of modeling, namely epidemic modeling. The epidemic model is a mathematical model used to see the rate of disease spread (Siettos, 2013). One epidemic model is the Susceptible-Infectious-Recovered or (SIR) model.

The purpose of this study is to determine the value of a single premium net health insurance for epidemic diseases with the SIR model.

2. Research Method

Netsingle rummy is calculated using the equivalence principle. The steps taken to obtain a net single premium are:

a) Determine the SIR epidemic model for dengue hemorrhagic fever (DHF).
b) Calculating values $\beta, \alpha, s_h\ (t)$, and $i_h\ (t)$.
c) Calculate the net single premium using original data obtained from the Central Bureau of Statistics and simulation data for $N_h\ (t)$ and B_h.

3. Results and Discussion

3.1 SIR Epidemic Model for DHF

The SIR epidemic model for dengue disease identifies two populations individual populations (h) and mosquito populations (v). The assumptions used in the SIR model for DHF are as follows:

a) Birth and death rates are considered the same;
b) Population assumed to be closed;
c) The population is assumed to mix homogeneously, which means each individual has an equal likelihood of making contact with other individuals;
d) diseases can be cured;
e) It is assumed that there is only one disease spreading in the population.

While the parameters used in the SIR model for DHF are b states the average number of mosquito bites per day, μ_h individual birth/death rate ratio, μ_v Mosquito birth/death rate ratio, α_h individual cure ratio, bw_h the ratio of the rate at which individuals are infected, bw_v the ratio of the rate of infected mosquitoes.

Based on the assumptions and parameters used, the SIR model scheme for dengue disease is obtained in Figure 1.

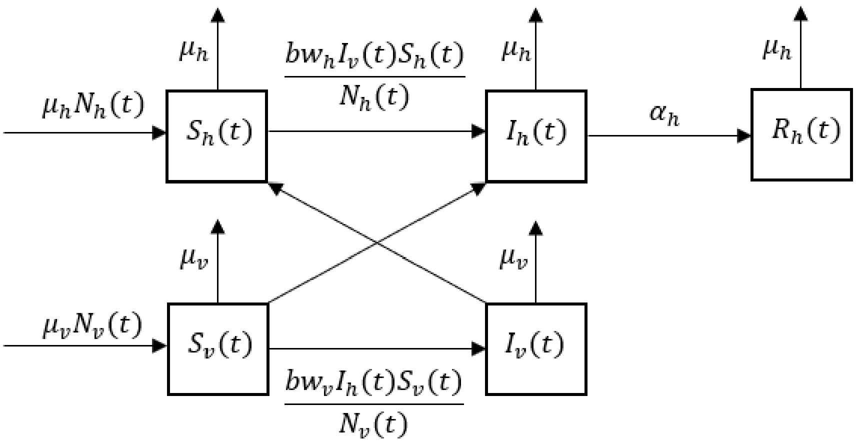

Figure 1: SIR epidemic model scheme for dengue disease

Figure 1 shows the change of each variable over time. Such changes are based on the factors that cause the addition and subtraction of each variable so that it is obtained:

$$\frac{dS_h(t)}{dt} = \mu_h N_h(t) - \frac{bw_h I_v(t) S_h(t)}{N_h(t)} - \mu_h S_h(t), \tag{1}$$

$$\frac{dI_h(t)}{dt} = \frac{bw_h I_v(t) S_h(t)}{N_h(t)} - (\mu_h + \alpha_h) I_h(t), \tag{2}$$

$$\frac{dR_h(t)}{dt} = \alpha_h I_h(t) - \mu_h R_h(t),$$

$$\frac{dS_v(t)}{dt} = \mu_v N_v(t) - \frac{bw_v I_h(t) S_v(t)}{N_h(t)} - \mu_v S_v(t), \tag{3}$$

$$\frac{dI_v(t)}{dt} = \frac{bw_v I_h(t) S_v(t)}{N_h(t)} - \mu_v I_v(t),$$

with $\mu_h N_h(t)$ is the rate of the number of births of individuals into vulnerable individuals per unit of time, $\mu_h S_h(t)$ is the rate of the number of deaths of vulnerable individuals per unit of time, $\mu_h I_h(t)$ is the rate of the number of deaths of individuals per unit of time, and $\mu_h R_h(t)$ is the rate of the sum of all deaths of individuals in the population per unit of time, as well as $\alpha_h I_h(t)$ is the rate of cure of infected individuals per unit time. While $\mu_v N_v(t)$ is the growth rate of mosquitoes into vulnerable mosquitoes, $\mu_v S_v(t)$ the mortality rate of susceptible mosquitoes per unit time, and $\mu_v I_v(t)$ is the death rate of infected mosquitoes per unit of time.

Premium calculation is used in proportion or the form of opportunities, namely $s_h(t) = \frac{S_h(t)}{N_h(t)}$, $i_h(t) = \frac{I_h(t)}{N_h(t)}$, and $i_v(t) = \frac{I_v(t)}{N_v(t)}$. Until, the two segments in equation (1) – (2) are divided by the total population of individuals $N_h(t)$ and equation (3) divided by the total mosquito population $N_v(t)$, then obtained

$$\frac{ds_h(t)}{dt} = \mu_h\big(1 - s_h(t)\big) - \beta i_v(t) s_h(t), \tag{4}$$

$$\frac{di_h(t)}{dt} = \beta i_v(t) s_h(t) - \alpha i_h(t), \tag{5}$$

$$\frac{di_v(t)}{dt} = \delta(1 - i_v(t)) i_h(t) - \mu_v i_v(t), \tag{6}$$

with

$$\beta = \frac{b w_h N_v(t)}{N_h(t)}, \tag{7}$$

$$\alpha = \mu_h + \alpha_h, \tag{8}$$

$$\delta = b w_v. \tag{9}$$

Endemic equilibrium points are required in premium calculations because there is a value $s_h(t)$ that is the proportion of the number of vulnerable individuals, $i_h(t)$ is the proportion of the number of infected individuals, and $i_v(t)$ that is the proportion of the number of infected mosquitoes. The equilibrium point is obtained by solving equations (4) – (6), with $\frac{ds_h(t)}{dt} = \frac{di_h(t)}{dt} = \frac{di_v(t)}{dt}$ and $i_h(t) \neq 0$ and $i_v(t) \neq 0$, so obtained

$$s_h(t) = \frac{\delta\mu_h + \alpha\mu_v}{\delta(\beta + \mu_h)}, \tag{10}$$

$$i_h(t) = \frac{\mu_h(\beta\delta - \alpha\mu_v)}{\alpha\delta(\mu_h + \beta)}, \tag{11}$$

$$i_v(t) = \frac{\mu_h(\beta\delta - \alpha\mu_v)}{\beta(\delta\mu_h + \alpha\mu_v)}. \tag{12}$$

3.2 Net Single Premium for DHF

The calculation of the annual net single premium for health insurance uses the annual interest rate which refers to Bank Indonesia's interest rate of 6.5%. The annual net single premium calculated in this study has several rules that can be used as a scheme in Figure 2.

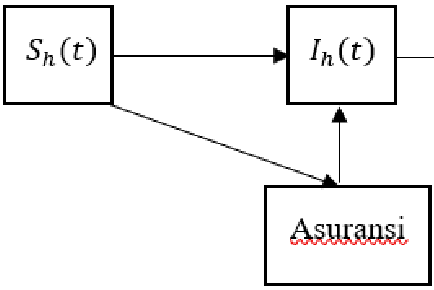

Figure 2: SIR epidemic model insurance scheme

Figure 2 shows susceptible individuals infected at $S_h(t)$ will insure itself to an insurance company by participating in paying premiums at any time, with the *present value* of the annuity the value of the premium to be paid written with $\bar{a}^s_{\overline{T|}}$. Individuals infected with the disease in $I_h(t)$ will get insurance *benefits* in the form of coverage costs during inpatient treatment in the hospital or *lump sum*, with the *present* value of the annuity the value of the inpatient *benefit* written $\bar{a}^i_{\overline{T|}}$ and *the present* value of the *lump sum benefit* value is written $\bar{A}^i_{\overline{T|}}$.

The net single premium is determined by the rate of infection. The rate of infection is the rate at which individuals are at $S_h(t)$ may become infected at times t. The rate of infection is noted by $\mu^s(t)$ and have similarities

$$\mu^s(t) = \beta i_h(t). \tag{13}$$

Insurance participants who are infected and undergo hospitalization will get hospitalization *benefits*. The calculation of insurance premiums with hospitalization benefits requires the present value of hospitalization benefits. In this study, the equivalence principle is used so that *the present value of* hospitalization *benefits* is obtained

$$\bar{a}^i_{\overline{T|}} = \int_0^T e^{-\gamma t} i_h(t)dt \tag{14}$$

and *the present value of* insurance premiums is

$$\bar{a}^s_{\overline{T|}} = \int_0^T e^{-\gamma t} s_h(t)dt. \tag{15}$$

The annual net single premium model with hospitalization benefits is obtained based on equations (14) and (15), so it can be written with (16)

$$\bar{P}\left(\bar{a}_{\overline{T|}}^{i}\right) = \frac{\bar{a}_{\overline{T|}}^{i}}{\bar{a}_{\overline{T|}}^{s}}.$$

Insurance participants who are infected and undergo hospitalization in the hospital in addition to getting hospitalization *benefits*, can choose another benefit, namely *the lump sum benefit*. The calculation of insurance premiums with lump sum benefits requires the present value of lump *sum benefits.* In this thesis, the equivalence principle is used so that *the present value benefit lump sum* is obtained

$$\bar{A}_{\overline{T|}}^{i} = \int_0^T e^{-\gamma t} s_h(t)\mu^s(t)dt. \tag{17}$$

The insurance premium model with *lump sum benefits* is obtained based on equations (15) and (17), so it can be written with

$$\bar{P}\left(\bar{A}_{\overline{T|}}^{i}\right) = \frac{\bar{A}_{\overline{T|}}^{i}}{\bar{a}_{\overline{T|}}^{s}}. \tag{18}$$

Further calculations require variable values and parameters obtained by referring to Zagmutt (2013) so that Table 1 is obtained.

Table 1: Parameter and variable values

Symbol	**Kind**	**Value**
bw_h	Parameter	0.75/day
α_h	Parameter	0.32883/day
μ_v	Parameter	0.0323
bw_v	Parameter	0.375/day
$N_v(t)$	Variable	3.016.625,95

Calculation of net single premium with original data i.e. using value $N_h(t)$ amounting to 3,761,870 individuals and B_h or the number of births of 36,045 individuals for the D. I Yogyakarta region. The net single premium is calculated using equations (16) and (18) so that the results are obtained in Table 2.

Table 2: Calculation results $\bar{P}\left(\bar{a}_{\overline{T|}}^{i}\right)$ and $\bar{P}\left(\bar{A}_{\overline{T|}}^{i}\right)$

Region	$\boldsymbol{\bar{P}\left(\bar{a}_{\overline{T\vert}}^{i}\right)}$	$\boldsymbol{\bar{P}\left(\bar{A}_{\overline{T\vert}}^{i}\right)}$
Yogyakarta D.I Province	0.41835932	0.015949043

In this study, the author examined the value of hospitalization benefits and *lump sum benefits* of IDR 1,000,000. Furthermore, it can be explained by insurance participants to get *benefits* of IDR 1,000,000, then insurance participants must pay premiums with annuities of IDR 418,359 per year or insurance participants can choose to pay lump sum premiums of IDR 15,949 per year. Based on the results obtained, the premium value for *lump sum* benefits is too small and does not match the premium for hospitalization benefits, so further calculations are carried out with simulation data.

In this calculation, the author simulates the value $N_h(t)$ of 3,000,000 individuals and 5,000,000 individuals with B_h different birth ranges resulting in a net single premium value result in Table 3 and Table 4.

Table 3: Calculation results $\bar{P}\left(\bar{a}_{\overline{T|}}^{i}\right)$ and $\bar{P}\left(\bar{A}_{\overline{T|}}^{i}\right)$ for simulation data 1

$\boldsymbol{N_h(t)}$	$\boldsymbol{B_h}$	$\boldsymbol{\bar{P}\left(\bar{a}_{\overline{T\vert}}^{i}\right)}$	$\boldsymbol{\bar{P}\left(\bar{A}_{\overline{T\vert}}^{i}\right)}$
3,000,000	50,000	0.752706851	0.034189179
3,000,000	150,000	1.152499662	0.089309753
3,000,000	300,000	1.221371506	0.14766964
3,000,000	350,000	1.209049838	0.162336451

Table 4: Calculation results $\bar{P}\left(\bar{a}^{i}_{\overline{T}|}\right)$ and $\bar{P}\left(\bar{A}^{i}_{\overline{T}|}\right)$ for simulation data 2

$N_h(t)$	B_h	$\bar{P}\left(\bar{a}^{i}_{\overline{T}|}\right)$	$\bar{P}\left(\bar{A}^{i}_{\overline{T}|}\right)$
5,000,000	50,000	0.31883137	0.012223138
5,000,000	300,000	0.691572043	0.057086353
5,000,000	500,000	0.707662834	0.079365368
5,000,000	550,000	0.70332813	0.083622112

Based on Tables 3 and 4, each value is known $N_h(t)$ i.e. 3,000,000 individuals and 5,000,000 individuals for value B_h which is getting bigger. The net single premium obtained for simulated data 1 yields a fairly small value for the net single premium for *the lump sum* benefit and a very large for the net single premium for the hospitalization *benefit*.

4. Conclussion

Based on the results and discussion presented, it can be concluded that the annual net premium model of health insurance obtained from the SIR epidemic model for dengue disease has two models, namely the net premium model for hospitalization benefits and the net premium model for lump sum benefits.
The following are the results of the annual net single premium for DHF disease in the D.I Yogyakarta region:

a) The amount of annual net single premium with hospitalization benefit is IDR 418,359 per year for benefit of IDR 1,000,000,
b) The amount of the annual net single premium with lump sum benefit is IDR 15,949 per year for the benefit of IDR 1,000,000.

The author considers the results of simulation 1 and simulation 2 so that it is concluded that the annual net single premium value cannot be applied in reality.

Based on the results of the discussion and simulations carried out, the author suggests that the next researcher use more precise parameter and variable data so that they will get a more appropriate net single premium result.

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