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COMPARISON OF FIRST-TO-DIE AND LAST-SURVIVOR JOINT LIFE INSURANCE UNDER COMMON SHOCK

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ABSTRACT

Joint life insurance is a type of life insurance policy that covers two individuals, typically a married couple, under a single contract. The benefit is paid either upon the first death (First-to-Die) or after both individuals have passed away (Last-Survivor), depending on the policy type. This study explores the comparative analysis of First-to-Die and Last-Survivor joint life insurance policies under the impact of Common Shock. Common Shock refers to external catastrophic events, such as accidents or natural disasters, that simultaneously increase the mortality risk of both insured individuals. In this study, the Common Shock effect is parameterized by assigning additional joint mortality probabilities ranging from 2.5% to 10%, with increments of 2.5%. A total of 8 scenarios were tested. The first four scenarios vary the Common Shock probabilities at 2.5%, 5.0%, 7.5%, and 10.0%, while keeping the Interest Rate constant at 6.25%. The remaining four scenarios vary the Interest Rates at 5.50%, 5.75%, 6.00%, and 6.25%, with the Common Shock probability fixed at 10.0%. The analysis is conducted through actuarial modeling using present value formulas to assess total insurance premiums under these varying conditions. Using a benefit value of IDR 500,000,000.00 and a premium payment period of 10 years, this study demonstrates how these factors influence premium amounts. The incorporation of Common Shock into premium calculations offers a more realistic perspective in assessing insurance risk and cost. Mortality assumptions are based on the 2023 Indonesian Mortality Table published by BPJS Kesehatan, and the present value of future benefits is calculated using the specified interest rates. The findings reveal that the First-to-Die policy consistently results in significantly higher total premiums compared to the Last-Survivor policy under the same assumptions. On average across all scenarios, the total premium for First-to-Die is 5.67 times greater, primarily due to the higher probability of earlier benefit claims and shorter investment durations from the insurer's perspective. The First-to-Die policy is more suitable for those with chronic illnesses or financial dependents, while the Last-Survivor policy is preferable for individuals focused on legacy planning.

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1. INTRODUCTION

Every individual has faced unexpected events that can lead to considerable losses. These unforeseen circumstances, encompassing a diverse array of uncertainties, are what we call risks. To navigate these challenges effectively, there are several powerful strategies for managing risk: Avoidance, Prevention, Assumption or Retention, and Transfer. Out of these, the option to transfer risk to a trustworthy entity is often viewed as the wisest and most strategic approach to safeguarding one's interests in an unpredictable world. The entity being referred to is insurance itself. Insurance is an agreement between the insurer and the insured, where the insured pays a predetermined premium for protection against unforeseen events. If a claim is needed, the insured receives compensation according to their policy. Insurance primarily serves two purposes: it transfers risk, protecting the insured's life and assets, and provides financial support through compensation during crises [1]. It comes in various types, including life, health, and education insurance. This article will focus on life insurance, specifically joint life First-to-Die and Last-Survivor policies.

Insurance is a non-bank industry that can provide protection to the insured if a risk occurs in the future [2]. Life insurance is a transfer of risk related to financial loss caused by the loss of a person's life from the insured party to the insurer. A life insurance company is a company that provides services in managing risks associated with the life or death of an insured person [3]. Anyone who insures their life with an insurance company consciously agrees with the company to a written contract, which is called an insurance policy [4]. The life insurance benefits that may be received by the insured party upon filing a claim consist of a certain amount of compensation funds that can be used according to their needs. The amount of these benefits is determined based on the agreement outlined in the life insurance policy, which was mutually agreed upon by both parties before the occurrence of the insured risk [5].

In life insurance, the benefits will only be paid if a certain event occurs, such as the death of one or both individuals, where the joint life probability will consider the possibility of either individual dying. Life insurance policies are classified into whole life, term, and endowment insurance, each offering different benefits. Life insurance is a basic type of life insurance that provides coverage for a lifetime [6]. Term insurance is a type of insurance that offers life insurance protection for a specified period [7]. Meanwhile, endowment insurance is a policy that provides both benefits and investment to the policyholder, as the sum assured according to the policy will be paid out if the insured passes away during the coverage period or survives until the end of the policy [8].

Based on the number of insured individuals, life insurance is divided into two distinct categories: single life and multiple life. Single life insurance is designed for individuals who seek to secure a policy exclusively for themselves, emphasizing personal protection that cannot be transferred to another party. In contrast, multiple life insurance caters to two or more individuals who wish to collaborate in purchasing a singular policy. An advantage of multiple life insurance lies in its ability to achieve significant cost efficiencies by consolidating coverage for all insured individuals into a single comprehensive policy, thereby reducing administrative and marketing expenses [9].

In multiple life insurance, two key concepts are defined based on the insured's death status: Joint Life First-to-Die (FTD) and Joint Life Last-to-Die, also known as the Last-Survivor (LS). The FTD arrangement takes effect when the first insured individual in the group passes away, leading to the cessation of premium payments and allowing beneficiaries to claim the insurance benefits. In contrast, the LS arrangement remains active until all insured individuals have passed away, at which point premium payments end and the insurance benefits can be claimed [3]. While FTD terminates upon the first insured's death, enabling an immediate claim, LS continues until every insured individual has deceased before disbursing the benefits. The FTD insurance is generally chosen by couples who prioritize immediate financial protection for the surviving partner, especially when they have ongoing financial responsibilities, rather than focusing on leaving a large inheritance. While LS insurance is generally bought by a married couple who have worked hard and want to pass a significant inheritance to their children after their death [10].

To claim the insurance benefits, the policyholder must first pay a premium. The premium is a specific amount of money that the policyholder is required to pay to the insurance company [11]. The payment of premiums can be made in a lump sum (all at once) or periodically. Lump sum premium payments are rarely used because of the large amount of money that the insured has to pay, which is usually converted into periodic premiums to ease the payment burden. For periodic premium payments, they are generally paid monthly, quarterly, semi-annually, and annually [12]. Premium determination consists of two stages, namely gross premium calculation and net premium calculation. When calculating gross premium, the company

considers the level of costs incurred, but these costs are not taken into account in the net premium calculation [13]. In this study, only the net premium is calculated, as company expenses are not included in the analysis. In premium payments, the amount of premium that must be paid by the insured is influenced by present value, as this relates to the idea that the value of money today is greater than the value of money in the future. Present value concerns the relationship between Interest Rates, exchange rates, and the present value model based on the trade balance. The higher the Interest Rate, the smaller the present value of future money receipts [14]. Interest Rates can be influenced by several factors such as inflation and monetary policy [15]. Monetary policy can be defined as actions taken by the monetary authority (usually the Central Bank) to influence the money supply which will affect economic activities [16]. In Indonesia, the Central Bank is Bank Indonesia. Bank Indonesia sets the BI-Rate as the benchmark Interest Rate in the banking sector. The BI-Rate reflects the monetary policy stance set by Bank Indonesia (BI) and is announced to the public [17]. Given the influence of Interest Rates on present value, the premiums paid by policyholders are also indirectly affected by changes in Interest Rates.

The assumption of independent mortality risks among individuals often fails in the presence of unforeseen events that simultaneously endanger multiple lives. In the world of life insurance, it is commonly understood that the mortality risk of each individual is independent. However, unforeseen events can disrupt this independence, linking the fates of individuals. This is supported by the findings in [18], titled "*Joint-Life Insurance Premium Model Using Archimedean Copula: The Study of Mortality in Indonesia.*" This study shows that the assumption of independence between husband and wife is considered unrealistic, as there is a possibility that both may be exposed to the same risks simultaneously, such as lifestyle similarities, contagious diseases, and the impact of common shocks. To analyze these risks, actuaries rely on mortality tables, or life tables, which are crucial for constructing premiums and reserves for life insurance, annuities, and pension plans [19]. These tables provide insights into death rates, life expectancy, and mortality patterns of a birth cohort [20].

Unexpected events that cause simultaneous deaths within a group of policyholders are known as Common Shock events. Such occurrences, including natural disasters like earthquakes or plane crashes, can significantly lower life expectancy and create disparities in premium payments, as amounts vary for those affected by these shocks [21]. The analysis of the impact of common shocks in first-to-die and last-survivor insurance is important because it can serve as a reference for preparing premium reserves to address those risks [22].

This study looks into how Interest Rates and Common Shock events affect joint life insurance net premiums, especially for First-to-Die and Last-Survivor policies. By using a practical case involving a married couple, the analysis shows how net premiums shift when either the Interest Rate changes or the chance of both individuals dying at the same time increases. A higher Interest Rate tends to lower premiums because it reduces the present value of future payments. Meanwhile, a higher probability of a Common Shock raises the premium, as the risk of earlier payouts becomes more likely. Through this comparison, the study highlights how sensitive insurance costs are to both financial conditions and mortality risks. The goal is to provide a clearer understanding of how different scenarios can influence insurance planning and help individuals choose the right type of joint life policy based on their personal risk level and financial situation.

This study explores how Interest Rates and Common Shock events affect joint life insurance net premiums, particularly for First-to-Die and Last-Survivor policies. The analysis is based on a practical case involving a married couple, constructed using a deterministic simulation scenario. In this scenario, the couple resides in a disaster-prone region of Indonesia, and assumptions regarding mortality probabilities, Interest Rates, and Common Shock probabilities are defined by the researcher. The study demonstrates how net premiums shift when either the Interest Rate changes or the probability of both individuals dying simultaneously increases. A higher Interest Rate tends to lower premiums because it reduces the present value of future payments, while a higher probability of a Common Shock increases the premium due to the greater likelihood of earlier payouts. This comparison highlights the sensitivity of insurance costs to both financial conditions and mortality risks. While previous studies [9], [12] have typically examined these factors separately, there is a lack of research that analyzes the combined impact of Interest Rates and Common Shock probabilities on net premiums in joint life insurance. The novelty of this study lies in its integrated approach, which simultaneously considers both financial and mortality risk factors within a single, practical case analysis. The aim is to provide a clearer understanding of how different scenarios can influence insurance planning and help individuals choose the most appropriate type of joint life policy based on their personal risk level and financial situation.

2. RESEARCH METHODS

In this study, the researcher employs a descriptive quantitative research method. Descriptive quantitative research is a type of study that analyzes data by presenting the collected information. Descriptive quantitative research is consistent with the research variables, focuses on current issues and ongoing phenomena, and presents research findings in the form of meaningful numerical data [23].

2.1 Case Simulation and Assumptions

In the scenario of a joint life insurance policy for a married couple, the husband is assumed to be 55 years old and the wife 50 years old. This loving couple has chosen to secure their future with a joint life insurance policy, committing to net premium payments over a period of 10 years, ultimately reaping the benefits of an insurance payout amounting to 500 million IDR (Rp 500,000,000.00).

Residing in a region of Indonesia that is susceptible to natural disasters, the couple faces unique challenges. The probability of a Common Shock such as a natural calamity occurring is forecasted at 2.5%, 5.0%, 7.5%, and 10.0% respectively for ten consecutive years. Furthermore, the impact of such disasters on the mortality of either partner is estimated at 0.2, or 20.0%, per year. It is crucial to note that these calamities are treated as independent events, unaffected by one another, and their likelihood remains consistent each year.

Residing in a region of Indonesia that is susceptible to natural disasters, the couple faces unique challenges. In this study, the probability of a Common Shock—such as a natural calamity affecting both individuals simultaneously—is determined through simulation scenarios developed by the researcher. These scenarios assume fixed probabilities of such events occurring at 2.5%, 5.0%, 7.5%, and 10.0%, with each scenario applied consistently across a ten-year coverage period. Furthermore, conditional on the occurrence of a Common Shock event, the probability that either partner dies as a direct result of the event is estimated at 20.0% per year. It is crucial to note that Common Shock events are modeled as independent occurrences across years, meaning the occurrence of a shock in one year does not affect the probability of shocks in subsequent years. For each scenario, the annual probability of a Common Shock remains constant, and if such an event occurs, the conditional probability of either individual dying due to the shock is applied accordingly.

To assess the likelihood of survival and mortality over the coming years for each individual, this study refers to the Indonesian Mortality Table for the year 2023, published by BPJS Kesehatan. An overview of the tables used in this study is presented in Tables 1 and 2.

Table 1. 2023 Mortality Table for Indonesian Males

Male	
Age	**Alive (Number of lives)**
55	6,302,990
56	6,089,598
57	5,839,190
58	5,659,067
59	5,445,726
60	5,178,112
61	4,937,742
62	4,611,495
63	4,228,161
64	3,944,298
65	3,688,748

Data source: *(https://drive.google.com/file/d/1bpr4XyjRK_lyUiwU2_PSIQFW40ShTCJK/view)*

Based on Table 1, the male mortality table is presented to determine the probability of individuals within the male population surviving certain age.

Table 2. 2023 Mortality Table for Indonesian Females

Female	
Age	**Alive (Number of lives)**
50	7,799,933
51	7,477,189
52	7,313,839

Female	
Age	**Alive (Number of lives)**
53	7,047,492
54	6,726,190
55	6,505,723
56	6,270,734
57	6,009,711
58	5,802,024
59	5,557,433
60	5,262,887

Data source: *(https://drive.google.com/file/d/1bpr4XyjRK_lyUiwU2_PSIQFW40ShTCJK/view)*

The above Table 2 present the probability of survival for individuals the female at a given age. Moreover, the time value of money must be taken into consideration, as the present value of future insurance benefits differs from their nominal worth today. Therefore, the present value is calculated using fixed Interest Rate scenarios based on Bank Indonesia (BI-Rate) values of 5.50%, 5.75%, 6.00%, and 6.25%. Each scenario assumes a constant Interest Rate applied uniformly across the entire 10-year coverage period, without year-to-year variation. This analysis assumes that the Interest Rate will remain stable throughout the 10-years net premium payment period for this couple's joint life insurance policy, providing them with both peace of mind and financial security for the future.

2.2 Single Life Probability of Death

In determining the combined probability of death, the probability of death for each individual, in this case, the husband and wife, is first calculated using the data from Tables 1 and 2, using the formula in Eqs. (1) and (2) [24]:

$$ {}_t\boldsymbol{q_x} = \mathbf{1} - \frac{\boldsymbol{l_{x+t}}}{\boldsymbol{l_x}}, \tag{1} $$

with ${}_t\boldsymbol{q_x}$ representing the probability that a male or husband aged $\boldsymbol{x}$ will die within $\boldsymbol{t}$ years, $\boldsymbol{l_{x+t}}$ representing the number of male alive at age $\boldsymbol{x+t}$, $\boldsymbol{l_x}$ representing the number of male alive at age $\boldsymbol{x}$.

$$ {}_t\boldsymbol{q_y} = \mathbf{1} - \frac{\boldsymbol{l_{y+t}}}{\boldsymbol{l_y}}, \tag{2} $$

with ${}_t\boldsymbol{q_y}$ representing the probability that a female or wife aged $\boldsymbol{y}$ will die within $\boldsymbol{t}$ years, $\boldsymbol{l_{y+t}}$ representing the number of female alive at age $\boldsymbol{y+t}$, $\boldsymbol{l_y}$ representing the number of female alive at age $\boldsymbol{y}$.

2.3 Joint Life First-to-Die Probability with Common Shock

In determining the joint life probability in First-to-Die cases, the probability of death for the couple is calculated by incorporating the single life probability of death for each individual, while also accounting for the impact of Common Shock events, as outlined in Eq. (3).

$$ {}_t\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{FTD}} = {}_t\boldsymbol{q_x} + {}_t\boldsymbol{q_y} - \left({}_t\boldsymbol{q_x} \times {}_t\boldsymbol{q_y}\right) + (\boldsymbol{p_c} \times \boldsymbol{p_i}), \tag{3} $$

with ${}_t\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{FTD}}$ representing the joint life probability that individuals aged $\boldsymbol{x}$ and $\boldsymbol{y}$ will die within $\boldsymbol{t}$ years in the First-to-Die case, $\boldsymbol{p_c}$ representing the probability of a Common Shock (natural disaster) occurring within one year, $\boldsymbol{p_i}$ representing the probability of one or both individuals being affected by a Common Shock (natural disaster) within one year.

2.4 Joint Life Last-Survivor Probability with Common Shock

In determining the joint life probability in Last-Survivor cases, the probability of death for the couple is calculated by incorporating the single life probability of death for each individual, while also accounting for the impact of Common Shock events, as outlined in Eq. (4).

$$ {}_t\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{LS}} = \left({}_t\boldsymbol{q_x} \times {}_t\boldsymbol{q_y}\right) + (\boldsymbol{p_c} \times \boldsymbol{p_i}), \tag{4} $$

with ${}_t\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{LS}}$ representing the joint life probability that individuals aged $\boldsymbol{x}$ and $\boldsymbol{y}$ will die within $\boldsymbol{t}$ years in the Last-Survivor case, $\boldsymbol{p_c}$ representing the probability of a Common Shock (natural disaster) occurring within

one year, $\boldsymbol{p_i}$ representing the probability of one or both individuals being affected by a Common Shock (natural disaster) within one year.

2.5 Present Value

The Bank Indonesia Interest Rate (BI-Rate) will be used as the annual Interest Rate reference for calculating the present value of future insurance benefits to be received over the next $\boldsymbol{n}$-years, using the present value formula as outlined in Eq. (5).

$$\boldsymbol{PV_t} = \frac{\boldsymbol{M}}{(\boldsymbol{1+i})^{\boldsymbol{t}}}, \tag{5}$$

with $\boldsymbol{PV_t}$ representing Present Value of insurance benefits in the $\boldsymbol{t}$-th year, $\boldsymbol{M}$ representing the value of insurance benefits to be received in the next $\boldsymbol{n}$-years, $\boldsymbol{i}$ representing the annual Interest Rate, $\boldsymbol{t}$ represents the number of years.

2.6 Annual Net Premium

The determination of the premium value is obtained by multiplying the present value by the joint life probability. The present value is useful for ensuring that the future insurance benefits are calculated in terms of today's monetary value, while the joint life probability helps adjust the premium amount based on the level of risk associated with the insured event. The joint life mortality probability ensures that the premium paid is balanced with the likelihood of claim payments. To determine the annual net premium in the First-to-Die and Last-Survivor cases, the formulas in Eqs. (6) and (7) will be used, respectively.

$$\boldsymbol{P_{FTD}(t)} = {}_{\boldsymbol{t}}\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{FTD}} \times \boldsymbol{PV_t}, \tag{6}$$

with $\boldsymbol{P_{FTD}(t)}$ representing the annual net premium in the First-to-Die case, ${}_{\boldsymbol{t}}\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{FTD}}$ representing the joint life probability that individuals aged $\boldsymbol{x}$ and $\boldsymbol{y}$ will die within $\boldsymbol{t}$ years in the First-to-Die case.

$$\boldsymbol{P_{LS}(t)} = {}_{\boldsymbol{t}}\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{LS}} \times \boldsymbol{PV_t}, \tag{7}$$

with $\boldsymbol{P_{LS}(t)}$ representing the annual net premium in the Last-Survivor case, ${}_{\boldsymbol{t}}\boldsymbol{q}_{\boldsymbol{x:y}}^{\boldsymbol{LS}}$ representing the joint life probability that individuals aged $\boldsymbol{x}$ and $\boldsymbol{y}$ will die within $\boldsymbol{t}$ years in the Last-Survivor case.

2.7 Total Net Premium

In determining the accumulated net premium value over a $\boldsymbol{n}$-years period for the First-to-Die and Last-Survivor cases, the respective formulas will be applied sequentially in Eqs. (8) and (9). In determining the accumulated net premium value over an n-year period for the First-to-Die and Last-Survivor cases, it is essential to first understand what the total net premium represents. This value refers to the overall number of premium payments made by the policyholder over the entire coverage period. Rather than being a single lump sum, these payments are typically made annually, and their accumulation over time reflects the full cost of maintaining the insurance policy. By summing these yearly payments, one can obtain the total net premium, which serves as a key metric for evaluating and comparing the financial implications of different policy structures.

$$\boldsymbol{P_{FTD}^{Total}} = \sum_{\boldsymbol{t=1}}^{\boldsymbol{n}} \boldsymbol{P_{FTD}(t)}, \tag{8}$$

$$\boldsymbol{P_{LS}^{Total}} = \sum_{\boldsymbol{t=1}}^{\boldsymbol{n}} \boldsymbol{P_{LS}(t)}, \tag{9}$$

with $\boldsymbol{P_{FTD}^{Total}}$ representing the accumulated net premium value over a $\boldsymbol{n}$-year's period in the First-to-Die case, $\boldsymbol{P_{LS}^{Total}}$ representing the accumulated net premium value over a $\boldsymbol{n}$-year's period in the Last-Survivor case. These formulas account for the premium payments made annually throughout the $\boldsymbol{n}$-years duration, ensuring an accurate calculation of the total amount paid under each insurance scenario.

3. RESULTS AND DISCUSSION

This section presents the results obtained from the calculations and simulations of joint life insurance under the First-to-Die and Last-Survivor with Common Shock scenarios. The findings are analyzed to

evaluate the differences in death probabilities, the impact of various Common Shock events, and Interest Rate variations on the insurance net premium.

3.1 Calculation of Single Life Probability of Death

The single life probability of death for each individual is obtained using Eqs. (1) and (2). These calculations allow for the estimation of each person's likelihood of death over a specified period. Detailed tables presenting the single life probabilities of death for a 55-year-old husband and a 50-year-old wife, with timeframes ranging from 1 to 10 years, are presented in Table 3.

Table 3. The Probability of a Husband and Wife Died Within the Next 1-10 Years

t (Year)	${}_tq_{55}$ (Husband)	${}_tq_{50}$ (Wife)
1	0.033856	0.041378
2	0.073584	0.062320
3	0.102162	0.096468
4	0.136009	0.137661
5	0.178467	0.165926
6	0.216603	0.196053
7	0.268364	0.229518
8	0.329182	0.256144
9	0.374218	0.287502
10	0.414762	0.325265

Based on the values presented in Table 3, the likelihood of death increases over time for both individuals. For example, the cumulative probability of the husband dying by the end of the first year is 3.39%, which increases significantly to 41.48% by the end of the 10th year. For the wife, the probability starts at 4.14% in the first year and increases to 32.53% by the 10th year. This trend indicates that the longer the time period considered, the higher the likelihood of mortality for each individual. These results align with general mortality trends, which indicate these results reveal an interesting pattern: while the wife has a higher cumulative probability of death than the husband in the first year, this trend reverses after approximately the third year, where the husband's cumulative probability surpasses that of the wife. This crossover occurs because the wife, being younger, initially faces a slightly higher short-term mortality risk due to age-specific mortality rates at the starting point. However, as time progresses, the husband's mortality curve increases more steeply due to gender-specific mortality dynamics, particularly the accelerated increase in male mortality rates at older ages. This aligns with general mortality trends, as men typically exhibit a sharper rise in mortality risks over time, resulting in a lower overall life expectancy compared to women. Additionally, for long-term insurance coverage, premiums are likely to be higher due to the increasing probability of death over time.

3.2 Calculation of Joint Life First-to-Die Probability with Common Shock

The joint life First-to-Die probability with Common Shock is obtained using Eq. (3). This equation takes into account the individual mortality rates of both insured individuals, along with the likelihood of a catastrophic event impacting them simultaneously. This method allows for an accurate estimation of the probability that at least one of the insured individuals will die within a defined timeframe. These probabilities are calculated over timeframes ranging from 1 to 10 years, with Common Shock probabilities set at 2.5%; 5.0%; 7.5%; and 10.0% for each event of the ten consecutive years. Furthermore, in the case of a First-to-Die policy, conditional on the occurrence of a Common Shock event, the probability that each individual dies as a direct result of the event is assumed to be 20.0% per year, applied independently to both partners. Detailed tables presenting the joint life First-to-Die probabilities of death with Common Shock for a 55-year-old husband and a 50-year-old wife are presented in Table 4.

Table 4. The Joint Life First-to-Die Probability of a Husband and Wife Died Within the Next 1-10 Years

	${}_tq_{55:50}^{FTD}$			
t (Year)	$p_c = 2.5\%$	$p_c = 5.0\%$	$p_c = 7.5\%$	$p_c = 10.0\%$
1	0.078833	0.083833	0.088833	0.093833
2	0.136319	0.141319	0.146319	0.151319
3	0.193774	0.198774	0.203774	0.208774
4	0.259947	0.264947	0.269947	0.274947
5	0.319781	0.324781	0.329781	0.334781

	${}_tq_{55:50}^{FTD}$			
t (Year)	**$p_c = 2.5\%$**	**$p_c = 5.0\%$**	**$p_c = 7.5\%$**	**$p_c = 10.0\%$**
6	0.375190	0.380190	0.385190	0.390190
7	0.441287	0.446287	0.451287	0.456287
8	0.506008	0.511008	0.516008	0.521008
9	0.559132	0.564132	0.569132	0.574132
10	0.610120	0.615120	0.620120	0.625120

Based on the values presented in Table 4, it indicates that the probability of a joint life First-to-Die event increases over time for a 55-year-old husband and a 50-year-old wife. As the time horizon extends from 1 to 10 years, the cumulative probability of at least one of the insured individuals dying increases substantially across all Common Shock scenarios. Under a Common Shock probability of 2.5%, the cumulative likelihood starts at 7.88% in the first year and rises to 61.01% by the end of the 10th year. When the Common Shock probability is increased to 5.0%, the first-year cumulative probability escalates to 8.38%, eventually reaching 61.51% by year 10. At a 7.5% Common Shock level, the cumulative probability further intensifies, beginning at 8.88% in the first year and growing to 62.01% by the 10th year. The most extreme scenario, with a 10.0% Common Shock probability, results in a first-year cumulative probability of 9.38%, which expands sharply to 62.51% by the 10th year. Moreover, the probability values exhibit an upward trend as the Common Shock probability (p_c) escalates from 2.5% to 10.0%. This trend suggests that elevated levels of external risk factors, such as natural disasters or pandemics, enhance the likelihood of death for at least one of the insured partners. This increased risk directly affects premium calculations by raising the expected present value of benefits, as a higher probability of early claim payouts reduces the time available for premium accumulation and investment returns.

3.3 Calculation of Joint Life Last-Survivor Probability with Common Shock

The joint life Last-Survivor probability with Common Shock is obtained using Eq. (4). This equation takes into account the individual mortality rates of both insured individuals, along with the likelihood of a catastrophic event impacting them simultaneously. This method allows for an accurate estimation of the probability that both of the insured individuals will die within a defined timeframe. These probabilities are calculated over timeframes ranging from 1 to 10 years, with Common Shock probabilities set at 2.5%; 5.0%; 7.5%; and 10.0% for each event of the ten consecutive years. Furthermore, in the case of a Last Survivor policy, conditional on the occurrence of a Common Shock event, the probability that both individuals die simultaneously as a direct result of the event is assumed to be 20.0% per year. Detailed tables presenting the joint life Last-Survivor probabilities of death with Common Shock for a 55-year-old husband and a 50-year-old wife are presented in Table 5.

Table 5. The Joint Life Last-Survivor Probability of a Husband and Wife Died Within the Next 1-10 Years

	${}_tq_{55:50}^{LS}$			
t (Year)	**$p_c = 2.5\%$**	**$p_c = 5.0\%$**	**$p_c = 7.5\%$**	**$p_c = 10.0\%$**
1	0.006401	0.011401	0.016401	0.021401
2	0.009586	0.014586	0.019586	0.024586
3	0.014855	0.019855	0.024855	0.029855
4	0.023723	0.028723	0.033723	0.038723
5	0.034612	0.039612	0.044612	0.049612
6	0.047466	0.052466	0.057466	0.062466
7	0.066594	0.071594	0.076594	0.081594
8	0.089318	0.094318	0.099318	0.104318
9	0.112589	0.117589	0.122589	0.127589
10	0.139908	0.144908	0.149908	0.154908

Based on the values presented in Table 5, it indicates that the probability of a joint life Last-Survivor event increases over time for a 55-year-old husband and a 50-year-old wife. As the time horizon extends from 1 to 10 years, there is a significant rise in the likelihood of both insured individuals died. Moreover, the probability values exhibit an upward trend as the Common Shock probability (p_c) escalates from 2.5% to 10.0%. This trend suggests that elevated levels of external risk factors, such as natural disasters or pandemics, enhance the likelihood of death for both insured partners. This increased risk directly impacts premium calculations by raising the expected present value of benefits. A higher probability of early claim payouts, due to increased joint mortality risk, reduces the time horizon for premium payments and investment returns.

Premiums must be adjusted upwards to match the higher expected present value of benefits, ensuring the insurer maintains balance between expected liabilities and collected premiums.

3.4 Calculation of Present Value

The present value of insurance benefits amounting to Rp 500,000,000.00 for each year over a period of ten consecutive years is obtained using Eq. (5), which accounts for the time value of money by discounting future benefits using The Bank Indonesia Interest Rate. These rates, applied consecutively at 5.50%; 5.75%; 6.00%; and 6.25%, were previously used as benchmark Interest Rates in Indonesia. The results of this calculation are presented in Table 6.

Table 6. Annual Present Value of Joint Life Insurance Benefits

t (Year)	PV_t			
	$i = 5.50\%$	$i = 5.75\%$	$i = 6.00\%$	$i = 6.25\%$
1	Rp 473,933,649.29	Rp 472,813,238.77	Rp 471,698,113.21	Rp 470,588,235.29
2	Rp 449,226,207.86	Rp 447,104,717.51	Rp 444,998,220.01	Rp 442,906,574.39
3	Rp 425,806,832.09	Rp 422,794,059.11	Rp 419,809,641.52	Rp 416,853,246.49
4	Rp 403,608,371.65	Rp 399,805,256.85	Rp 396,046,831.62	Rp 392,332,467.28
5	Rp 382,567,176.92	Rp 378,066,436.73	Rp 373,629,086.43	Rp 369,254,086.86
6	Rp 362,622,916.51	Rp 357,509,632.85	Rp 352,480,270.22	Rp 347,533,258.22
7	Rp 343,718,404.28	Rp 338,070,574.79	Rp 332,528,556.81	Rp 327,090,125.38
8	Rp 325,799,435.33	Rp 319,688,486.80	Rp 313,706,185.67	Rp 307,849,529.77
9	Rp 308,814,630.65	Rp 302,305,897.69	Rp 295,949,231.77	Rp 289,740,733.90
10	Rp 292,715,289.71	Rp 285,868,461.17	Rp 279,197,388.46	Rp 272,697,161.32

Based on the values presented in Table 6, it indicates that the annual present value of the joint life insurance benefits decreases each year over the ten-year period. Based on the values presented in Table 6, it can be observed that the annual present value of joint life insurance benefits exhibits a decreasing trend over the ten years. This indicates that, over time, the value of the benefits-when calculated in present value terms-becomes progressively smaller each year. This trend reflects the time value of money principle, in which amounts received further in the future are more heavily discounted, resulting in lower present values. When the interest rate increases, the present value of future insurance benefits decreases. This occurs because a higher interest rate more significantly reduces the value of future payouts. Conversely, a lower interest rate leads to a higher present value, as the discounting effect is less substantial.

This trend reflects the time value of money principle, whereby amounts received further in the future are discounted more heavily, resulting in lower present values. When the Interest Rate rises, the present value of future insurance benefits declines. This happens because a higher Interest Rate reduces the worth of future payouts more significantly. On the other hand, a lower Interest Rate results in a higher present value since the discounting effect is less pronounced. Therefore, selecting an appropriate Interest Rate is crucial when assessing long-term insurance benefits, as it significantly affects the current value of future payouts.

3.5 Calculation of Annual Net Premium

The annual net premium for the First-to-Die and Last-Survivor cases is obtained using Eqs. (6) and (7). The results compare the impact of different Common Shock probabilities and Interest Rates, as presented in Tables 4, 5, and 6, on the joint life insurance net premium for a benefit amount of Rp 500,000,000.00. Both cases consider two scenarios, one with a constant Interest Rate of 6.25% but varying Common Shock probabilities of 2.5%; 5.0%; 7.5%; and 10.0%; and another with a constant Common Shock probability of 10.0% but varying Interest Rates of 5.50%; 5.75%; 6.00%; and 6.25%. All these combinations are applied to the annual net premium calculations over a 10-year period, with the results presented in Tables 7, 8, 9, and 10.

Table 7. Annual Net Premium for the First-to-Die Case with Varying Common Shock Probabilities and a Constant Interest Rate

Year	Annual Net Premium $(p_c; i)$			
	2.50%;6.25%	5.00%;6.25%	7.50%;6.25%	10.00%;6.25%
1	Rp 37,097,692.31	Rp 39,450,633.49	Rp 41,803,574.66	Rp 44,156,515.84
2	Rp 60,376,413.06	Rp 62,590,945.93	Rp 64,805,478.80	Rp 67,020,011.68
3	Rp 80,775,262.16	Rp 82,859,528.39	Rp 84,943,794.62	Rp 87,028,060.85
4	Rp 101,985,473.47	Rp 103,947,135.81	Rp 105,908,798.15	Rp 107,870,460.48

Year	Annual Net Premium $(p_c; i)$			
	2.50%;6.25%	5.00%;6.25%	7.50%;6.25%	10.00%;6.25%
5	Rp 118,080,370.80	Rp 119,926,641.24	Rp 121,772,911.67	Rp 123,619,182.11
6	Rp 130,391,139.00	Rp 132,128,805.29	Rp 133,866,471.58	Rp 135,604,137.87
7	Rp 144,340,709.65	Rp 145,976,160.27	Rp 147,611,610.90	Rp 149,247,061.53
8	Rp 155,774,337.69	Rp 157,313,585.34	Rp 158,852,832.99	Rp 160,392,080.64
9	Rp 162,003,268.27	Rp 163,451,971.94	Rp 164,900,675.61	Rp 166,349,379.28
10	Rp 166,377,891.88	Rp 167,741,377.68	Rp 169,104,863.49	Rp 170,468,349.30

Based on the values presented in Table 7, the results clearly indicate that the annual net premium for joint life insurance increases as the probability of a common shock rises. This trend reflects the heightened risk that insurers face when there is an increased likelihood of both insured individuals dying simultaneously due to shared exposure to certain events, such as natural disasters, accidents, or common lifestyle-related illnesses. Consequently, accurately incorporating Common Shock factors into premium calculations is essential to ensure fair pricing, prevent underestimation of risk, and guide policyholders in selecting coverage that aligns with their specific risk profiles and protection needs.

Table 8. Annual Net Premium for the First-to-Die Case with a Constant Common Shock Probabilities and Varying Interest Rate

Year	Annual Net Premium $(p_c; i)$			
	10.00%;5.50%	10.00%;5.75%	10.00%;6.00%	10.00%;6.25%
1	Rp 44,470,424.72	Rp 44,365,293.69	Rp 44,260,658.57	Rp 44,156,515.84
2	Rp 67,976,289.89	Rp 67,655,268.90	Rp 67,336,516.60	Rp 67,020,011.68
3	Rp 88,897,335.47	Rp 88,268,347.23	Rp 87,645,278.85	Rp 87,028,060.85
4	Rp 110,970,731.55	Rp 109,925,078.23	Rp 108,891,712.16	Rp 107,870,460.48
5	Rp 128,076,149.18	Rp 126,569,387.73	Rp 125,083,848.01	Rp 123,619,182.11
6	Rp 141,491,977.54	Rp 139,496,823.39	Rp 137,534,414.42	Rp 135,604,137.87
7	Rp 156,834,333.57	Rp 154,257,300.85	Rp 151,728,548.58	Rp 149,247,061.53
8	Rp 169,744,125.78	Rp 166,560,272.46	Rp 163,443,445.46	Rp 160,392,080.64
9	Rp 177,300,310.62	Rp 173,563,439.82	Rp 169,913,875.55	Rp 166,349,379.28
10	Rp 182,982,074.36	Rp 178,701,987.42	Rp 174,531,768.90	Rp 170,468,349.30

Based on the values presented in Table 8, the result clearly indicates that the annual net premium for joint life insurance decreases as the interest rate increases. This trend illustrates the fundamental principle of the time value of money, where future cash flows such as insurance payout benefits are discounted more significantly at higher interest rates. As the interest rate rises, the present value of future payouts declines, meaning that the insurer needs a lower premium today to cover those future obligations. Essentially, a higher interest rate reduces the financial burden on the insurer in meeting future claims, as the invested premiums can grow more over time. As a result, policyholders benefit from lower premium costs in high interest rate environments. This highlights the critical role of interest rate assumptions in actuarial calculations, as even small variations can greatly impact premium pricing and the long-term sustainability of life insurance products. For insurers, inaccurate interest rate projections can lead to insufficient reserves and strained solvency margins, emphasizing the importance of robust asset-liability management and proactive risk monitoring strategies.

Table 9. Annual Net Premium for the Last-Survivor Case with Varying Common Shock Probabilities and a Constant Interest Rate

Year	Annual Net Premium $(p_c; i)$			
	2.50%;6.25%	5.00%;6.25%	7.50%;6.25%	10.00%;6.25%
1	Rp 3,012,175.61	Rp 5,365,116.79	Rp 7,718,057.97	Rp 10,070,999.14
2	Rp 4,245,606.38	Rp 6,460,139.25	Rp 8,674,672.12	Rp 10,889,205.00
3	Rp 6,192,471.05	Rp 8,276,737.28	Rp 10,361,003.52	Rp 12,445,269.75
4	Rp 9,307,337.02	Rp 11,268,999.36	Rp 13,230,661.69	Rp 15,192,324.03
5	Rp 12,780,746.91	Rp 14,627,017.35	Rp 16,473,287.78	Rp 18,319,558.22
6	Rp 16,495,901.79	Rp 18,233,568.08	Rp 19,971,234.37	Rp 21,708,900.66
7	Rp 21,782,319.10	Rp 23,417,769.73	Rp 25,053,220.35	Rp 26,688,670.98
8	Rp 27,496,517.80	Rp 29,035,765.45	Rp 30,575,013.10	Rp 32,114,260.75
9	Rp 32,621,499.23	Rp 34,070,202.90	Rp 35,518,906.57	Rp 36,967,610.24
10	Rp 38,152,424.23	Rp 39,515,910.04	Rp 40,879,395.85	Rp 42,242,881.65

Based on the values presented in Table 9, the result clearly indicates that the annual net premium for joint life insurance increases as the probability of a common shock rises. Additionally, it can be observed that the annual premium for a Last Survivor policy is generally lower than that of a First-to-Die policy. This difference arises because Last Survivor insurance pays out only after both insured individuals have passed away, which delays the payout and reduces the present value of the future liability. In contrast, First-to-Die insurance triggers payment upon the first death, resulting in an earlier claim payout and consequently a greater financial obligation in present value terms. Insurers reflect this difference in their premium structures. From a policyholder's perspective, these product characteristics influence coverage suitability depending on financial objectives. First-to-Die policies are often preferred by families seeking immediate financial protection for surviving dependents after the first loss, whereas Last Survivor policies are typically used for estate planning or legacy purposes, where the primary concern is wealth transfer after both individuals have passed. Understanding these distinctions helps policyholders align their insurance choices with their long-term financial goals.

Table 10. Annual Net Premium for the Last-Survivor Case with a Constant Common Shock Probabilities and Varying Interest Rate

Year	Annual Net Premium $(p_c; i)$			
	10.00%;5.50%	**10.00%;5.75%**	**10.00%;6.00%**	**10.00%;6.25%**
1	Rp 10,142,593.92	Rp 10,118,616.16	Rp 10,094,751.50	Rp 10,070,999.14
2	Rp 11,044,578.13	Rp 10,992,419.63	Rp 10,940,629.74	Rp 10,889,205.00
3	Rp 12,712,581.54	Rp 12,622,634.36	Rp 12,533,533.74	Rp 12,445,269.75
4	Rp 15,628,961.85	Rp 15,481,693.51	Rp 15,336,155.68	Rp 15,192,324.03
5	Rp 18,980,051.73	Rp 18,756,759.49	Rp 18,536,612.17	Rp 18,319,558.22
6	Rp 22,651,486.40	Rp 22,332,081.67	Rp 22,017,919.12	Rp 21,708,900.66
7	Rp 28,045,442.80	Rp 27,584,612.43	Rp 27,132,415.67	Rp 26,688,670.98
8	Rp 33,986,759.78	Rp 33,349,277.58	Rp 32,725,215.63	Rp 32,114,260.75
9	Rp 39,401,221.73	Rp 38,570,781.70	Rp 37,759,743.69	Rp 36,967,610.24
10	Rp 45,343,843.27	Rp 44,283,217.01	Rp 43,249,816.69	Rp 42,242,881.65

Based on the values presented in Table 10, the result clearly indicates that the annual net premium for joint life insurance decreases as the interest rate increases. This trend illustrates the fundamental principle of the time value of money, where future cash flows such as insurance payout benefits are discounted more significantly at higher interest rates. Both the Common Shock probability and the Interest Rate significantly influence the annual net premium for joint life insurance in the First-to-Die case. In Tables 7 and 9, where the Interest Rate remains constant while the Common Shock probability increases, the premiums become higher, reflecting the impact of the Common Shock on insurance premiums. Conversely, in Table 8 and Table 10, where the Common Shock probability remains constant while the Interest Rate rises, the annual net premium decreases due to a higher discounting effect, highlighting the influence of Interest Rates on insurance net premiums.

3.6 Calculation of Total Net Premium

The total net premium for the First-to-Die and Last Survivor cases is calculated using Eqs. (8) and (9), representing the cumulative sum of all annual net premiums paid over a 10-year premium payment period, rather than a single lump-sum payment. The results, presented in Table 11, highlight the substantial differences in total net premium between the First-to-Die and Last Survivor policies, as well as the sensitivity of these premiums to variations in Common Shock probabilities and Interest Rates. From a practical standpoint, these findings have direct implications for policy affordability and selection, as higher total premiums may pose affordability challenges for policyholders, while insurers must ensure adequate reserving strategies to match the earlier claim liabilities associated with First-to-Die coverage.

Table 11. Total Net Premium for All Scenarios of First-to-Die and Last-Survivor

Common Shock & Interest Rate $(p_c; i)$	Total Net Premium	
	First-to-Die	**Last-Survivor**
2.5%;6.25%	Rp 1,157,202,558.28	Rp 172,086,999.13
5.0%;6.25%	Rp 1,175,386,785.38	Rp 190,271,226.22
7.5%;6.25%	Rp 1,193,571,012.47	Rp 208,455,453.32
10.0%;6.25%	Rp 1,211,755,239.57	Rp 226,639,680.41
10.0%;5.50%	Rp 1,268,743,752.68	Rp 237,937,521.15
10.0%;5.75%	Rp 1,249,363,199.73	Rp 234,092,093.55

10.0%;6.00%	Rp 1,230,370,067.09	Rp 230,326,793.65
10.0%;6.25%	Rp 1,211,755,239.57	Rp 226,639,680.41

Based on the values presented in Table 11, both Common Shock probabilities and Interest Rates significantly affect total premiums in joint life insurance. With a fixed Interest Rate of 6.25%, increasing the Common Shock probability from 2.5% to 10.0% raises the total premium in both First-to-Die and Last-Survivor cases. Conversely, when the Common Shock probability is held at 10.0%, higher Interest Rates lead to lower premiums due to the discounting effect. The First-to-Die case consistently yields higher total premiums than the Last-Survivor case, highlighting the impact of differing benefit structures between the two types of joint life insurance.

4. CONCLUSION

This study confirms that the structure of joint life insurance policies has a significant impact on net premium costs. On average, the total net premium for the First-to-Die policy across all scenarios is 5.67 times higher than that of the Last-Survivor policy for the same coverage amount and payment period. This is due to the higher likelihood of early claims and shorter investment time for insurers. The First-to-Die policy is more suitable for individuals with higher health or occupational risks, or those with financial dependents. In contrast, the Last-Survivor policy is better for low-risk individuals focused on leaving a financial legacy. FTD insurance suits couples seeking immediate financial protection for the surviving partner, while LS insurance is preferred by those aiming to leave a significant inheritance for their heirs.

The findings also show that both Common Shock events and Interest Rates strongly influence net premium values. Higher probabilities of Common Shocks increase premiums, while higher Interest Rates reduce them by lowering the present value of future payouts. These insights are important for designing fair and accurate net premium models in life insurance planning. However, it should be noted that this study is based on deterministic scenarios and simplified assumptions regarding mortality rates and Common Shock parameterization, which may not fully capture real-world stochastic variability and policyholder behavior.

Author Contributions

Neva Satyahadewi: Conceptualization, Format Analysis, Methodology, Writing – Original Draft. Louis Putra Jaya: Data Curation, Project Administration, Software, Writing – Review & Editing. Hendri Kurniawan: Format Analysis, Supervision, Validation, Visualization – Original Draft. Yuyun Eka Pratiwi: Format Analysis, Methodology, Writing – Original Draft. All authors discussed the findings, contributed critical feedback, and approved the final manuscript.

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Declarations

The authors declare that they have no conflicts of interest to report study.

Declaration of Generative AI and AI-assisted Technologies

AI-assisted technology (ChatGPT) was used to support sentence restructuring and clarity improvements. The authors affirm that the basic ideas, arguments, data analysis, and conclusions are original and not generated by AI. All AI-assisted revisions have been critically reviewed and verified by the authors

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