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DETERMINATION OF MOTOR VEHICLE INSURANCE RISK PREMIUM

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ABSTRACT

Insurance is a service that transfers specific financial loss risks to an insurer in exchange for a fixed payment, known as a premium. The determination of this premium is tailored to the policyholder's level of risk. In this study, the calculation of premium risks is conducted by analyzing the frequency and size of claims related to motor vehicle insurance. The analysis focuses on different types of vehicles and their associated risks, as well as variations in vehicle usage based on geographical regions. This approach enables insurers to better understand risk patterns and predict potential future losses, ensuring accurate premium determination.

Keywords : Risk Premium, Claim Frequency, Size Claim, Claim Frequency Rate, Vehicle Insurance

I. INTRODUCTION

Insurance is a service that transfers financial loss risks to an insurer in exchange for a fixed payment. The fundamental role of insurance is to provide financial protection through risk transfer in exchange for premiums [1] & [2]. Each insured individual pays a premium based on the severity of their risk, emphasizing the importance of understanding the nature of risks for accurate premium determination [3]. Risk, defined as the uncertainty of loss, becomes significant when the occurrence of a loss is uncertain, as it complicates financial planning and mitigation strategies [4].

One critical area of non-life insurance is motor vehicle insurance, which serves as a significant source of income in many developed countries [5]. Motor vehicle insurance contracts typically include two primary types of coverage: comprehensive insurance, which protects against physical damage to the vehicle, and third-party insurance, which covers liabilities arising from the vehicle's use [6]. The premium for motor vehicle insurance is determined by various factors, including the physical condition of the vehicle, its type, age, location of use, function, prior loss history, and the chosen type of coverage [7].

Accurate premium calculation requires integrating the likelihood of claims (claim frequency) with the expected cost of those claims (claim size), while considering key risk factors [8]. This approach enables insurers to tailor premiums according to the specific risk profile of each policyholder [1].

This study focuses on motor vehicle insurance premium calculation, utilizing data on claim frequency and claim size across different vehicle types and geographical areas. By examining these variables, the research aims to provide a structured methodology for determining motor vehicle insurance risk premiums that reflect the underlying risk patterns more effectively.

II. METHODS

This study calculates the risk premium for motor vehicle insurance using methods based on previous research by [9], [6], [7], and [10] who focused on claim frequency and claim size data. Secondary data was obtained from motor vehicle portofolio period 2015 to 2018, compiled by Lledo & Pavia (2023) [11]. It comprise 105,555 records and 30 variables. The variables studied include the number of active policies (policies in force), total premiums collected, number of claims, and total claim costs, categorized by vehicle risk type across four categories and two categories geographical area.
As mentioned of the methods, the first step to do analysis is calculate the average claim size using the following formula.

$$MCS_i = \frac{TCS_i}{c_i} \qquad (1)$$

with,

MCS_i = The average claim size for year i
TCS_i = Total claims for year i
c_i = The numbers of claims for year i

Furthermore, to obtained ratio premium for each year, we need to determine the average office premium per year can be done using the following formula:

$$AOP_i = \frac{TOP_i}{N_i} \quad (2)$$

with,

AOP_i = The average office premium for year i

TOP_i = Total amount of premiums for year i

N_i = The number of active policies in year i.

While, the risk premium for each year can be calculated by formula below:

$$RP_i = \frac{TCS_{\mathrm{i}}}{N_i} \quad (3)$$

with,

RP_i = The risk premium in year i

TCS_i = Total claims in year i

N_i = Number of active policies in year i.

The premium ratio can be calculated by dividing the average premium by the risk premium for year i

$$k_i = \frac{AOP_i}{RP_i} \quad (4)$$

III. RESULTS AND DISSCUSSION

The research findings include calculations of the annual mean claim size, average office premium, risk premium per year, company premium-to-risk premium ratio per year, average claim frequency, growth rate in mean claim size, and the sequential relationship between the number of policies, using the data summarized in Table 1.

Table 1 : Revenue and Expenditure of an Insurance Company Based on Vehicle Risk Type 1 and Rural Area Type from 2015 to 2018

Years	Number of Policies	Total Premium Amount	Number of Claims	Total Claims
2015	270	20,547	23	4,984
2016	2,773	228,414	295	52,844
2017	3,346	269,054	270	119,520
2018	4,000	301,451	107	28,857
Total	10,389	819,466	695	206,206

As shown in Table 1, the total claims for 2015 was 4,984 and the number of claims amounted to 23. Based on this data, the average claim size for 2015 was calculated as below.

$$MCS_{2015} = \frac{TCS_{2015}}{c_{2015}} = \frac{4{,}984}{23} = 216.70$$

The average claim size of 216.70 for 2015 indicates that, on average, each claim in the vehicle risk category 1 and rural area was worth this amount. Calculations for subsequent years are shown in

Table 2. Meanwhile, calculations for other vehicle risk types and area types are obtained using the same method.

Table 2. : The Average Claim Amount from 2015 to 2018

Years	Number of Claims	Total Claim Amount	Average Claim Amount
2015	23	4,984	216.69
2016	295	52,844	179.13
2017	270	119,520	442.67
2018	107	28,857	269.69

Based on Table 2, average claim amount from 2015-2018 reveals increasing significantly in the average claim amount in 2017, reaching 442.67. Although the number of claim cases decreased from 295 in 2016 to 270 in 2017, the total claim value increased dramatically to 119,520. It indicates that despite fewer claims being filed, the per claim value was substantially higher during that year.

As illustrated in Table 1, the total premium amount for 2015 was 20,547, with a number of 270 policies. Using this information, we can calculate the average premium as follows.

$$AOP_{2015} = \frac{TOP_{2015}}{N_{2015}} = \frac{20{,}547}{270} = 76.10$$

The value indicates the average active premium for vehicle risk category 1 and rural area for 2015 was 76.10. The averages premium for the following years are summarized in Table 3. The premiums for other vehicle risk types and area types can be calculated in a similar way.

Table 3 : The average premium for 2015-2018

Years	Total Premium	Number of Policies	Average Premium
2015	20,547	270	76.10
2016	228,414	2,773	82.37
2017	269,054	3,346	80.41
2018	301,451	4,000	75.36

Table 3 demonstrates fluctuations growth in average premium. The highest value was recorded in 2016, followed by a decline, reaching its lowest point in 2018. Despite a continuous increase in total premiums and the number of policies, the average premium demonstrated a downward trend after 2016, possibly reflecting changes in the structure or distribution of premiums.

As referenced in Table 1, the total claims for 2015 amounted to 4,984, with 270 policies. Using this data, the risk premium can be determined as follows.

$$RP_{2015} = \frac{TCS_{2015}}{N_{2015}} = \frac{4{,}984}{270} = 18.46$$

The value indicates the risk premium for vehicle risk category 1 and rural area for 2015 was 18.46. Table 4 shows the risk premiums for the following years. The risk premiums for other vehicle risk types and area types can be calculated in a similar way.

Table 4. Risk Premium for 2015-2018

Years	Total Claims	Policies	Risk Premium
2015	4,984	270	18.46
2016	52,844	2,773	19.06
2017	119,520	3,346	35.72
2018	28,857	4,000	7.21

Resume of risk premium as displayed in Table 4 shows exhibited fluctuations between 2015 and 2018. The highest value was recorded in 2017 at 35.72, while the lowest occurred in 2018 at 7.21. The considerable decline in 2018 reflects the impact of lower total claims despite an increase in the number of policies, which may be attributed to changes in risk management practices or adjustments in the risk profile of insurance portofolio.

Moreover, using information from Table 3 and Table 4, average premium for 2015 was 76.10 with risk premium 18.46, premium ratio can be determined as follows.

$$k_{2015} = \frac{AOP_{2015}}{RP_{2015}} = \frac{76.10}{18.46} = 4.12$$

The value presented above corresponds to the premium ratio for vehicle risk category 1 and rural area for 2015. Table 5 provides the premium ratios for the following years. The premium ratios for other vehicle risk categories and area types can be calculated in a similar way.

Table 5. The Ratio of Premium Over Risk Premium From 2015-2018.

Tahun	Average Premium	Risk Premium	Ratio
2015	76.10	18.46	4.12
2016	82.37	19.06	4.32
2017	80.41	35.72	2.25
2018	75.36	7.21	10.45

Table 5 indicates that rasio between average premium and risk premium fluctuated significantly from 2015 to 2018. It increases slightly from 4.12 in 2015 to 4.32 in 2016, the dropped sharply to 2.25 in 2017 due to a significant in the risk premium. In contrast, the rasio climbed rapidly to 10.45 in 2018, driven by a substantial decrease in the risk premium while the average premium remained stable.

Consequently, the average claim frequency for vehicle risk category 1 and rural area can be obtained by dividing the total number of claims by the total number of policies, as outlined in Table 1.

$$m = \frac{695}{10{,}389} = 0.067$$

Based on the mean claim sizes and the total number of claims recorded by the company, the growth rate can be determined. This growth rate may be modeled using geometric progression assumptions, or a combination of geometric and arithmetic progressions could also be applied.

$$MCS_{i+1} = (1 + r)MCS_i$$

Thus, the value of r can be calculated using the average claim size for 2018 and the average claim size for 2015, as provided in Table 2.

$$MCS_{2018} = (1 + r)MCS_{2015}$$
$$269.69 = (1 + r)^3\ 216.68$$

By solving the equation above, we obtain the value of $r = 7.568\%$, meaning that the average growth rate of claim size for vehicle risk type 1 and rural area from 2015-2018 experienced a positive increase.

The annual number of active policies displayed in Table 1 demonstrates both geometric and arithmetic growth. The relationship between the number of policies in consecutive years for vehicle risk type 1 in rural areas from 2015 to 2018 can be calculated as follows.

$$n_2 = \frac{The\ number\ of\ policies\ in\ 2016}{The\ number\ of\ policies\ in\ 2015} n_1 = \frac{2773}{270} n_1 = 10.270 n_1$$
$$n_3 = (10.270 - 9.063) n_2$$
$$n_4 = (10.270 - 2\ \times 9.063) n_3$$
$$n_5 = (10.270 - 3\ \times 9.063) n_4$$

The equation above can be expressed as a general formula

$$n_{i+1} = [10.270 - (i - 1)\ \times 9.063] n_i$$

The value of -9.063 can be obtained by calculating $n_3 = (10.270 + x)n_2$, where n_3 is the number of policies in 2017 and n_2 is the number of policies in 2016

$$\begin{aligned} n_3 &= (10.270 + x)n_2 \\ 3346 &= (10.270 + x)2773 \\ 3346 &= 28478.71 + 2773x \\ 3346 - 28478.71 &= 2773x \\ x &= -\frac{25132.71}{2773} \\ x &= -9.063 \end{aligned}$$

The following assumptions were made in the calculations above:

a) The number of policies and average claim size in 2015 were 270 and 216.68 respectively.

b) The claim frequency over the next 4 years remained constant at 6.7%.

c) The average claim size increased by 7.568%.

d) The number of policyholders increased according to the relationship

$$n_{i+1} = [10.270 - (i - 1)\ \times 9.063] n_i$$

Given the assumptions outlined earlier, the calculations for the average claim size, policy count, claim count, and total claims paid annually are summarized in Table 6.

Table 6. Number of Policies And Claim Amount Under The Assumptions.

i	Years	Average Claim Amount	Number of Policies	Number of Claims	Total Claim Amount
1	2015	216.68	270	18	3,575
2	2016	179.13	2,773	186	57,674
3	2017	442.67	53,613	224	79,727
4	2018	269.69	95,019	268	36,084
Total				695	

The claim frequency rate, calculated as the ratio of the number of claims to the risk exposure, serves as a foundation for estimating the potential number of claims that could arise each year. The number of claims, represented as C_i in Table 6, can be determined using the following formula.

$$C_i = m_i \times n_i$$

The total claim amount for each year is determined by accounting for the number of claims made during that year, with half of the average claim amount paid in the same year, and the remaining half paid in the subsequent year

$$TCS_i = \frac{c_i}{2}(MCS_i + MCS_{i+1})$$

For instance, in 2015, the value of m_i is 0.067, while the value of n_i represents the number of policies in 2015, which totals 270. This gives $C_{2015} = 0.067 \text{ x } 270 = 18.09$. This indicates that in 2015, there were approximately 18 claims filed. Meanwhile, the total claim amount for 2015 in Table 6 is calculated as follows

$$TCS_{2015} = \frac{18.09}{2}(MCS_{2015} + MCS_{2016})$$
$$= \frac{18.09}{2}(216.68 + 179.13) = 3{,}575$$

The calculation results presented in Table 6 can be used to calculate the risk premium for vehicle type 1 and rural area type for the years 2015-2018. The risk premium is the ratio of the total claim amount to the number of policies.

Table 7 : Risk Premium under the Assumptions

i	Years	Number of Claims	Number of Policies	Total Claims	Risk Premium
1	2015	18	270	3,575	13.240
2	2016	186	2,773	57,674	20.799
3	2017	224	53,613	79,727	1.487
4	2018	268	95,019	36,084	0.380
Total		695	151,676	177,060	

Table 7 gives description about risk premium decreased significantly over the years with the most substantial decline observed in 2017 and 2018, despite a continuous increase in the number of policies.

The total net risk premium can be calculated by multiplying the original number of policies by the planned or assumed risk premium. The results are shown in Table 8.

Table 8 : Total Net Premium for Vehicle Type 1 and Rural Area Type

i	Year	Number of Policies	Planned Risk Premium	Total Net Premium
1	2015	270	13.240	3,575
2	2016	2,773	20.799	57,674
3	2017	3,346	1.487	4,976
4	2018	4,000	0.380	1,519
Total		10,389		67,744

Table 8 provides a comprehensive overview of the insurer's Vehicle type 1 portofolio in rural area between 2015-2018. Over this four-year period, the insurrer issued a total of 10,389 policies, indicating a sustained expansion in market coverage. Concurrently, 695 claims was recorded, thus offering insights into the portofolio's claim frequency and underlying risk exposure. Based on the assumptions employed, the projected total net risk premium for this period is 67,744. It represents the anticipated underwriting return derived from the policy base and associated risk profile over multiple years.

IV. CONCLUSION

Based on the discussion in this study, it can be concluded that the results of the planned risk premiums for vehicle risk type 1 and rural area were calculated as 13,240 for 2015, 20,799 for 2016, 1,487 for 2017, and 0.380 for 2018, with a total net premium of 67,744 over four years. This total was derived by multiplying the risk premiums by the number of policies each year. However, the total claims during the same period amounted to 177,060, significantly exceeding the net premium, indicating financial losses for the insurance company. Future research could explore strategies to optimize risk assesment methodologies and premium calculations for diverse vehicle risk types and geographic areas, aim to enhance profitability and risk management effectiveness in the insurance sector.

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