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AN INTERNAL MODEL FOR MEASURING PREMIUM RISK WHEN DETERMINING SOLVENCY OF NON-LIFE INSURERS

ABSTRACT: *Under contemporary dynamic approaches the solvency of insurance companies is determined by measuring the risks that threaten their business. This paper presents an internal model for measuring premium risk when evaluating the solvency of non-life insurers. The solvency capital requirement is calculated on the basis of a compound distribution of insurance portfolio aggregate claim amount, resulting from combining separately modelled claim frequency and severity distributions, with prior verification of earned technical premium sufficiency. The practical application of the model is illustrated by a case study of a specific non-life insurance company in Serbia. The research findings show that the dynamic model of premium risk measurement results in larger capital requirement and contributes to a more reliable assessment of insurers' solvency than the static model. This proves the inadequacy of the existing fixed ratio model and stresses the need for changes in the current methodology of determining the solvency of insurance companies in Serbia.*

KEY WORDS: *non-life insurance, premium risk, solvency margin, internal model, Solvency II*

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1. INTRODUCTION

The importance of solvency as insurance companies' long-term ability to pay their debts stems from the primary function of insurance, which is providing protection against risk. In modern dynamic approaches the solvency of insurers is evaluated based on the risks to which they are exposed. The most relevant example is Solvency II, the new regulatory framework for insurance companies in the Member States of the European Union (EU). In the context of risk-based approaches, risks should first be identified and then measured in order to determine the amount of capital required to cover them; i.e., the required solvency margin.

Contrary to most business entities, which seek to avoid and transfer the consequences of various risks, the essence of insurance companies' activity is taking over policyholders' risks in exchange for a premium paid as the cost of the insurance service. When the non-life insurance contract is concluded it is not known at what point the insured event will occur and with what harmful consequences, or whether it will occur at all. The absolute uncertainty in this type of insurance means that actuarial (i.e., technical or underwriting) risks are crucial to the evaluation of non-life insurers' solvency and that identifying and measuring them is complex. The most important actuarial risks in non-life insurance are the risks of premiums and claim reserves adequacy, catastrophic risk and reinsurance risk.

The business cycle flow in insurance is the inverse of that of a typical manufacturing, trade, or service company. The insurance premium is determined and charged in advance, while claims and connected expenses are known and paid only if and after the insured event occurs. The amount of insurance premium in the present is based on the projection of losses that will arise in the future, which even when statistically correct may not be adequate if circumstances change in relation to starting actuarial assumptions and previous experience. Premium risk refers to the possible insufficiency of insurance premiums to compensate claims that will arise during and after the period for which the insurer's solvency is determined. Numerous empirical studies show that premium risk is the main cause of non-life insurers' insolvency (Anderson & Formisano 1988; Sharma et al. 2002; A.M. Best 2004; Dibra & Leadbetter 2007).

Premium risk may originate from the insurance premium being too low for the risks absorbed, or from claims and expenses being too high for the funds received (Babbel & Santomero 1996, p.11). Thus it is possible to distinguish two components of premium risk: uncertainty (which encompasses model uncertainty and parameter uncertainty) and volatility (or process risk). Uncertainty is the risk that the expected value of future claims, as the basis on which insurance premiums are determined, is itself based on misspecified claim probability distribution, or is simply misestimated (IAA 2004, p.28). Process risk arises from stochastic fluctuations of claim frequency and/or severity in relation to their expected values. A particular aspect of premium risk is the possibility that insurer's operating expenses exceed the premium loading intended for their coverage. Lack of funds to cover these expenses is compensated by misuse of the technical premium, which jeopardizes the interests of the policyholders to be compensated and undermines the long-term financial capacity of the insurance sector (Jovović 2012, p.239). The required capital for covering premium risk and preserving the solvency of insurers is based on the quantification of process risk.

Since 2005 the fixed ratio model has been used to determine the solvency margin of insurance companies in Serbia. This static model was first introduced in the European Economic Community (EEC) in the 1970s, but due to many shortcomings (see Müller et al. 1997; Trainar 2006; Sandström 2007; Eling & Holzmüller 2008; Jovović 2010) it was replaced in 2016 by the dynamic risk-based Solvency II. A key feature of Solvency II is its explicit appreciation of the risks (and their interactions) faced by insurance companies when determining the solvency capital requirement (SCR). Many countries worldwide have begun the process of developing risk-based approaches to calculating the required solvency margin. In view of such global developments, changes are needed in the methodology for evaluating solvency of insurers in the Serbian insurance market in order to recognize the real risks that jeopardize their business.

According to Solvency II, in addition to a single standard approach, insurers in EU countries can apply alternative internal models to calculate the solvency capital requirement (SCR) to cover risks. The internal model is a risk management system that analyses the overall risk situation of an insurance company, quantifies the risks, and determines the required capital amount on the basis of the company's specific risk profile (CEA & Groupe Consultatif 2007, p.35). Internal models can be full or partial depending on whether they cover all risks or just some risks. The most significant differences between internal models and the standard approach are the greater use of stochastic techniques for risk quantification and the use of the company's own data to evaluate risk parameters. The internal model is expected to meet appropriate criteria in terms of statistical quality and compliance with the basic principles of Solvency II and should be integrated into the insurance company’s risk management system (Jovović & Stanojević 2016, p.282). Therefore, the iterative process of developing risk measurement models has been described as “as much art as engineering and science” (Ronkainen et al. 2007, p.42). The implementation of the internal model results in an economic capital requirement, which, in contrast to a regulatory capital requirement, should not only minimize policyholders’ losses but also ensure that the company continues to function normally in the event of financial difficulties. This paper aims to propose an internal model for measuring premium risk in the function of solvency evaluation of non-life insurers in Serbia, taking into account existing methodological limitations, contemporary trends in the field, and the specifics of the Serbian insurance market.

2. LITERATURE REVIEW

The first attempt to measure premium risk in order to determine insurers' solvency was the model created by Campagne (1961), which is the basis for the prescribed fixed-ratio model. The model uses the profitability indicators of the insurance business – loss ratio LR_i^k (the ratio of claims incurred to premiums earned) and expense ratio ER_i^k (the ratio of operating expenses to premiums earned) – for an insurance company i ($i = 1,\dots,n$) in period k ($k = 1,\dots,m$). Campagne considers the expense ratio to be a constant, while the loss ratio is assumed to be distributed according to a beta distribution. The average expense ratio $\overline{ER} = \frac{1}{nm}\sum_{i=1}^{n}\sum_{k=1}^{m} ER_i^k$ and the Value at Risk of the loss ratio distribution $VaR_p(LR) = \inf\{lr | P(LR \le lr) \ge p\}$, at a defined confidence level $p \in (0,1)$, are estimated on the basis of available observations for two variables.

Campagne defines the premium index, or the required solvency margin expressed as a percentage of the insurance premium, as the surplus of the sum of the Value at Risk of the loss ratio and the average value of the claims ratio of all insurers over 1 (100%). He assumes that there is a very low probability that the sum of the average expense ratio and the loss ratio is greater than the required solvency margin. More precisely, the probability of ruin is defined at the level of 3/10,000 for a period of one year: $P\left(\overline{ER} + LR > 1 + sm\right) = 0.0003$ where sm is the percentually expressed solvency margin, i.e., the premium index, resulting in: $sm = \left(VaR_{0.9997}\left(LR\right) + \overline{ER}\right) - 1$.

In order to assess the minimum solvency margin the model was originally applied to data from non-life insurers from eight European countries for the period 1952–1957. The value of the premium index for the observed sample, 25%, was estimated as being too high for most of the EEC member states. After negotiations between the supervisory authorities and representatives of the insurance business, EEC/EU regulations adopted arbitrary compromise values of the premium index of 18% and 16% in the fixed-ratio model (EEC 1973; EC 2002). The same values were incorporated into the fixed-ratio model in Serbia,[1] without any adjustment for the characteristics of the Serbian insurance market.

Despite its ease of application, Campagne's model has often been contested in actuarial literature. The implicit assumption of the model that all loss ratios are independent and identically distributed can be valid for individual companies but not for the entire insurance market. It would be more appropriate to assume that the loss ratios of different companies are interdependent, but that each of them has different probability distributions. Otherwise, as the number of companies included in the sample increases, the variation between them in terms of loss ratios also increases, and hence the value of the calculated solvency margin (Ramlau-Hansen 1982, p.38). Since the premium index is based on the average value of the expense ratio for the entire insurance market, companies that are cost-effective are punished with higher capital requirements than actually needed under other unchanged conditions, and vice versa. The premium index has one value for all insurance companies and all types of non-life insurance, which is illogical, given their different susceptibility to premium risk (Jovović 2014). The results of empirical studies indicate significant discrepancies between the initially estimated (and the prescribed) value of the premium index and the value that would correspond in real terms to individual insurance markets (de Wit & Kastelijn 1980; Pentikäinen & Rantala 1982; Sandström 2006; Dreassi & Miani 2008; Jovović 2015). Finally, the credibility of the profitability indicators of the insurance business is primarily conditioned by

[1] Insurance law. RS Official Gazette, No. 55/2004, 70/2004, 61/2005, 85/2005, 101/2007, 63/2009, 107/2009, 99/2011 and Insurance law. *RS Official Gazette,* No. 139/14.

the adequacy of the values of the insurer's financial statement items on which the calculation of these indicators is based. Therefore, a more precise approach to measuring premium risk is needed that is based on the probability distributions of the actual number and amount of claims in a particular insurance portfolio, instead of on static, retrospective indicators.

Contemporary literature deals with internal models for measuring premium risk to determine insurers' solvency. Doff (2006) proposes a model for measuring underwriting, market, and credit risks. Within underwriting risks the required capital to cover premium risk is determined by the extreme quantile of the distribution of the aggregate claims amount by line of business. Compound claims distribution has not been derived, but its parameters are calculated analytically based on estimated parameters for the separate distributions of claims frequency (modelled by a Poisson distribution) and severity (modelled by a Gamma distribution). A case study of a Dutch insurer is used to demonstrate that a broadly defined internal model results in larger required capital than a fixed-ratio model. However, this result is expected, since the fixed-ratio model only takes into account underwriting risk (or more precisely premium risk) and thus should be compared with a partial internal model which measures that risk only.

Savelli & Clemente (2008) define an internal simulation model in order to quantify required capital regarding premium risk only. Relying on classical risk theory, the distribution of the aggregate claims amount is simulated based on a separately modelled number and amount of claims, assumed to be Negative Binomial and LogNormal distributed, respectively. The model allows variation in claims frequency (due to real growth and short-term fluctuations) and in premium and claims amounts (due to inflation). Using the example of theoretical non-life insurers with a portfolio structure representative of the Italian insurance market, the authors show that compared to the standard Solvency II approach, their internal model results in a lower SCR for larger insurers and a higher SCR for smaller insurers.

The internal model developed by Dos Reis et al. (2009) covers market, credit, and operational risk in addition to underwriting risks. Premium risk is measured based on a linear regression model of the loss ratio of all insurers in one line of business, which is assumed to follow a lognormal distribution. Value at Risk of that distribution at a 99.5% confidence level is used to compute the amount of capital required to cover premium risk. This model completely neglects insurers’ operating expenses, while the credibility of its results depends on the adequacy of the static financial statement items that the loss ratio is based on. Analysing the case of a Portuguese insurer operating in motor insurance, the authors find that capital requirements are similar under the proposed internal model and the standard Solvency II approach.

The focus of the internal model formulated by Bermudez et al. (2013) is a joint measurement of premium and reserve risks in order to determine the solvency capital requirement for their coverage. Using the simple trend regression model, the authors extrapolate a net technical result by line of business for the next year, based on historical data from the whole non-life insurance market. The results are aggregated using Monte Carlo simulations, using copulas to model the dependence between lines of business. The SCR is determined by the expected value and the extreme quantile after simulating the distribution of aggregate net technical result. On the basis of an example from the Spanish non-life insurance market it is concluded that compared to the proposed internal model, the standard Solvency II approach overestimates the capital required to cover the two risks. However, this conclusion should be treated with caution, since this model is also based on the values of items in insurers' official financial statements, which do not provide complete insight into actual claims behaviour.

Alm (2015) constructed a simulation model that generates a solvency capital requirement for non-life underwriting risks (including premium risk and reserve risk). Starting with the definition of solvency as the surplus of assets over liabilities, the model uses the difference between the present value of insurance liabilities (determined on the basis of simulated loss amounts and payment patterns given the predetermined distributions) and the present value of the assets used for their coverage. The risk measure is the Value at Risk at a confidence level of 99.5%. The application of the model to the case of a Swedish motor insurer shows that the resulting solvency capital requirement is significantly affected by different distributional assumptions.

3. CONCEPTUAL FRAMEWORK AND RESEARCH METHODOLOGY

One of the most important tasks in the risk management process in financial institutions is to determine the amount of funds needed to cover the consequences of risk realization (Navarrete 2006, p.1). Losses immanent to the natural course of business can, as “expected”, be funded from the institution’s respective reserves. The excess of actual against expected losses represents "unexpected" losses, which directly threaten the security of the institution and require an additional amount of capital to cover them.

In the case of insurance companies, premiums and the technical reserves derived from them are intended to compensate for expected losses, while unfavourable deviations of actual against expected losses are neutralized by means of insurers' available capital. Therefore, the solvency capital requirement to cover premium risk corresponds to the „greater-than-expected" total claim amount in a given line of business in one business year. In other words, required capital equals the difference between the Value at Risk (or Conditional Value at Risk) of aggregate claim amount probability distribution at a sufficiently high confidence level, and the expected value of that distribution.

For the purposes of the formal expression of such capital requirement, two risk measures are introduced. Given a confidence level $p \in (0,1)$, the Excess Value at Risk (XVaR) of the random variable X, approximating risk exposure, is defined as (Sandström 2011, p.210):

$$XVaR_p(X) = VaR_p(X) - E(X), \tag{1}$$

while the Excess Tail Value at Risk (XTVaR) is defined as:

$$XTVaR_p(X) = TVaR_p(X) - E(X), \tag{2}$$

where $VaR_p(X), TVaR_p(X)$ are the Value at Risk and Conditional Value at Risk of the random variable X with the expected value $E(X)$.

The resulting capital amount is conditioned by the chosen measure of risk and the level of confidence. To maintain consistency with the standard Solvency II approach, the capital requirement within the partial internal model can be determined at a level that ensures protection from premium risk with a probability of 99.5%, using Value at Risk as a the risk measure.

This conceptual framework is not in itself a novelty in actuarial science, although it has only recently been implemented to evaluate insurers' solvency. However, a common implicit assumption of internal models previously defined in the same conceptual framework (see, for example, Doff 2006, p.162; Bermudez et al. 2011, p.10) is that insurance premiums are sufficient to cover expected losses. If such an a priori assumption is not fulfilled in practice, the obtained amount of required capital will not be reliable. This potentially calls into question an insurer's solvency estimate, and consequently the appropriateness of such models. In other words, at the same level of confidence, the amount of capital that is really needed can be higher (or lower) than that calculated, if the amount of technical premium is smaller (or larger) than the expected value of the corresponding claims distribution. Therefore, one important contribution of the partial internal model proposed in this paper is the completion of a given conceptual framework by an inevitable critical element, which implies verification of the real sufficiency of premiums before calculation of the solvency capital requirement. Practical implementation of the proposed internal model requires prior explanation of the methodology for carrying out aggregate claim amount probability distribution.

3.1. Modelling premium risk

Available data on non-life insurance claims is used as the basis for deriving claim probability distributions as the instrument of premium risk measurement. Process risk, as a component of premium risk that should be covered by the solvency capital requirement, stems from two sources. At the beginning of the insurance coverage the insurer does not know how many claims will occur or what the amount of the claims will be if they occur. Thus, the total claim amount at the portfolio level is determined by the frequency and severity of individual claims. Therefore, a probabilistic model of aggregate claims combines two components: the distribution of number of claims and the distribution of individual claim amounts.

Frequency distribution is assumed rather than fitted, since the exposure of the insured changes over the years and the observations are clouded by the fact that the number of claims incurred but not reported must be estimated (Heckman & Meyers 1983, p.23). The most frequently used theoretical distributions to describe the number of insured claims N as a discrete, non-negative random variable are the Poisson, binomial, and negative binomial distributions. On the other hand, in the collective risk model,[2] claim severity X is modelled in terms of absolutely continuous probability distributions with domain $\left(0,+\infty\right]$. It is always assumed that the expected value of the amount of claims is finite, while the dispersion can be infinite (Mladenović 2014, p.39). The most common examples of distributions fitted to past data on claim amounts in non-life

[2] See more on collective and individual risk models in Klugman et al. 2004, pp.135–205.

insurance relate to the exponential, log-normal, Weibull, Pareto, Burr, and log-gamma distributions.

The probability distribution of the aggregate claim amount S in an insurance portfolio for a given period is derived from separately modelled number of claims (frequency) N and amount of individual claim (severity) $X_i, i = 1,2,...$, so that:

$$S = \sum_{i=1}^{N} X_i \ . \tag{3}$$

Obviously, the total claims $S = 0$ if $N = 0$. According to the fundamental assumptions of the collective risk model, the individual claim amounts $X_1, X_2,...$ are independent and identically distributed random variables, and also N and all X_i are independent. We can derive the aggregate claim amount distribution function $F_S(x) = P(S \leq x)$ by noting that the event $\{S \leq x\}$ occurs if n claims occur, $n = 0,1,2,...$, and if the sum of these n claims is not greater than x. Since the event $\{S \leq x\}$ is the union of the mutually exclusive events $\{S \leq x \; and \; N = n\}$ we have:

$$F_S(x) = P(S \leq x) = \sum_{n=0}^{\infty} P(S \leq x | N = n) P(N = n) . \tag{4}$$

Noting that:

$$P(S \leq x | N = n) = P\left(\sum_{i=1}^{n} X_i \leq x\right) = F_X^{*n}(x) , \tag{5}$$

where $F_X^{*n}(x)$ is the n-fold convolution of the individual claim amount distribution $F_X = P(X \leq x)$, and, by convention, we define $F^{*0}(x) = 1$ for $x \geq 0$, with $F^{*0}(x) = 0$ for $x < 0$, leading to a compound distribution function:

$$F_S(x) = \sum_{n=0}^{\infty} F_X^{*n}(x) P(N = n), \quad x \geq 0 . \tag{6}$$

Due to difficult evaluation of the n-fold convolutions of the severity distribution for $n = 2,3,4,...$, alternative solutions to compute the compound distribution function $F_S(x)$ have been suggested. They include closed-form analytic methods, such as the recursive method and the inversion methods (Panjer 1981; Heckman & Meyers 1983; Bühlmann 1984), or open-form stochastic simulation methods such as Monte Carlo simulation.

Until the 1980s, aggregate claim distributions were commonly derived by simulation, despite the excessive computing time that simulation used to require. After the development of analytical methods that were found to be significantly faster at the time, simulation was marginalized. However, thanks to the advancement of computer technology, simulation has regained its primacy in the actuarial field. The popularity of simulation in computing compound distributional values is explained by its significant advantages over other methods. Using fairly straightforward programming, simulation produces the entire aggregate distribution for different combinations of the frequency and severity distributions. It is not limited to certain frequency distributions, nor does it require discretization of the severity distribution, as in the case of the recursive method. Simulation allows analysis of the effects of deductibles and policy limits on the aggregate claim amount distribution. Also, different simulations can be run to examine the sensitivity of the results to different assumptions in terms of the type and parameters of the frequency and severity distributions. This method can lead to a solution even if the restrictive assumptions that $N, X_1, X_2,...$ are independent and the X_is are identically distributed fail to hold (see more in Klugman et al. 2004, pp.619–620), thus providing a more realistic reflection of the insurance portfolio.

The following steps summarize the algorithm for the simulation of the aggregate claim amount distribution:

1) The distributions for claim frequency N and severity X are chosen and their parameters estimated based on the analysis of historical data.
2) A random number of claim occurrences n_1 from the chosen claim frequency distribution is generated and the corresponding claim amounts $x_1, x_2,..., x_{n_1}$ from the chosen severity distribution are simulated for each of these occurrences.
3) The sum $s_1 = x_1 + x_2 + ... + x_{n_1}$ represents the first random realization of the total claim amount S.

4) Steps 2) and 3) are repeated n times in order to create pseudo-data sample $s_1, s_2, \ldots, s_n$, based on which the empirical distribution function which approximates the unknown distribution function of the variable S is carried out.

In accordance with the conceptual framework explained above, for the obtained aggregate claim amount probability distribution we can estimate the Value at Risk with a chosen confidence level and than calculate the economic capital required to cover premium risk (C_P):

$$C_P = XVaR_{0.995}(S) = VaR_{0.995}(S) - E(S), \tag{7}$$

where $VaR_{0.995}(S)$ and $XVaR_{0.995}(S)$ are the Value at Risk and the Excess Value at Risk with confidence level $p = 0.995$ of the aggregate claim amount in the insurance portfolio for one year S with the expected value $E(S)$.

An implicit assumption behind equation (7) is that the net earned technical premium $\widetilde{TP}$ is equal to the expected value of the total claim amount $E(S)$ in a given year. However, if $\widetilde{TP} > E(S)$, i.e., if the technical premium includes a security loading, the required amount of capital C_P may be reduced by a given amount. Conversely, if the technical premium is underestimated so that $\widetilde{TP} < E(S)$, the calculated capital requirement has to be increased in the amount of the difference between the two values.

4. CASE STUDY

In this section we illustrate the previously presented theoretical and methodological framework for premium risk measurement with the example of a specific company operating in non-life insurance in Serbia. In this case study we derive the amount of capital needed to cover the premium risk that the insurer is exposed to. The research starts with an appropriate ratio analysis, i.e., calculation of the relevant indicators of insurance business profitability (loss ratio, expense ratio, and combined ratio). Premium risk is measured via simulation of the aggregate claim amount probability distribution, based on separately modelled claim frequency and severity distributions. All calculations were performed using *R* (see more in Kaas et al. 2008; Dutang et al. 2008) and *EasyFit* softwares.

The data for the research was drawn from the insurer's financial statements and internal databases on insurance policies and claims arising from a five-year period (from calendar year (*t*-4) to year *t*). The National Bank of Serbia databases and publicly available reports on insurance sector supervision were used as additional data sources.[3] For reasons of confidentiality, the research covers only part of the total insurer's portfolio. The data relates to one line of business – motor third-party liability insurance (MTPL), which has an 81.0% average share in the company's total premium income over the period covered. The insurer uses excess of loss non-proportional reinsurance in this line of business. All data refers to one-year insurance policies. The real data were scaled by an arbitrarily selected constant. External validity of the research in terms of the possibility of reapplying the same methodological procedure in other relevant cases is provided.

In accordance with Denuit et al. (2007), claim probability distributions were derived using data on all claims reported to the insurer during one business year, per policies effective in that year and taking into account the reinsurance effects, irrespective of whether claims are settled or reserved at the end of the year. It is important here to exclude from the analysis data on catastrophic claims, since they are the subject of a special model for determining the solvency capital requirement. Burnecki & Weron (2008) advocate “robust” parameter estimation, which trims 1%–5% off the most unfavourable, extreme observations, making the results of risk modelling in insurance as reliable as possible. Therefore, 2.5% of the largest individual claims and the policies related to them were removed from the available data sample.

4.1. Research results

The insurance company's MTPL business was profitable in the last observed year (*t*), since the combined ratio (sum of loss ratio and expense ratio) was lower than 100%, both gross and net, i.e., taking into account the reinsurance effects (Table 1). The gross loss ratio in the same year (38.5%) was near the market average for the given business line (about 41.3%),[4] and declines over time.

3 National Bank of Serbia. Insurance Companies Operations and Insurance Sector Reports. Retrieved from: https://www.nbs.rs/internet/english/60/index.html

4 Author's calculations based on data from the National Bank of Serbia.

Table 1: Indicators of the insurer's MTPL business profitability

Indicator	Value in year t		Average value (from (t-4) to t)		Average annual growth rate (from (t-4) to t)	
	gross	net	gross	net	gross	net
Loss ratio	38.5%	38.6%	51.7%	49.3%	–10.6%	–6.9%
Expense ratio	49.4%	50.7%	49.0%	48.2%	–1.1%	0.2%
Combined ratio	**87.9%**	**89.3%**	**100.7%**	**97.5%**	**–6.8%**	**–4.0%**

Source: Author's calculations based on the financial statements and internal databases of the insurance company.

On the other hand, the expense ratio reached a higher value in the same year (49.4%), meaning that most of the earned premium is spent on covering operating expenses, rather than settling liabilities upon the realization of insured risks. The fact that these expenses in the same year were 2.4 times higher than the premium loading intended for their coverage is indicative. Moreover, their share in MTPL earned premium does not decline. The conducted ratio analysis warns of the possible insufficiency of the MTPL premium due to high operating expenses and also suggests the need for a more precise approach to measuring premium risk in order to determine an adequate solvency capital requirement to cover it.

In order to derive the distribution of the compound claim amount as a basis for premium risk measurement within the partial internal model, it is necessary, first, to specify both the claim number distribution and the claim severity distribution and to evaluate their parameters. By using the insurance policy as a unit of risk exposure and Poisson distribution for modelling claim number data from the past, it is possible to estimate the value of the parameter λ as the average frequency of claims under the insurance policy during its validity. The average claim frequency per policy in motor third-party liability insurance is estimated at 0.01639. The estimated variance of the number of claims per policy (0.01699) is very close to the mean, which justifies the application of the Poisson model to describe claim frequency. For 100,000 effective MTPL insurance policies the company can expect 1,639 reported claims annually on average. Thus, there were 1,262 reported claims during year t with 76,993 effective policies in the given line of business in the same year. The average claim amount is RSD 131,874 while the standard deviation of claim amount is RSD 298,102. The data on individual claim amounts can be approximated by the Burr distribution, which has a probability density function of the form:

$$f(x)=\frac{\tau\alpha\left(\frac{x}{\theta}\right)^{\tau-1}}{\theta\left(1+\left(\frac{x}{\theta}\right)^{\tau}\right)^{\alpha+1}},\quad 0\le x<+\infty \tag{8}$$

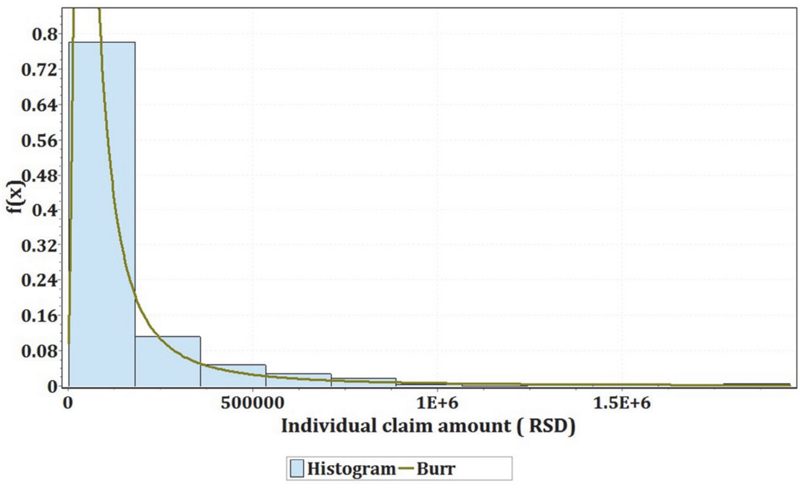
with parameters $\hat{\theta}=41{,}781$, $\hat{\alpha}=0.4191$, and $\hat{\tau}=2.6175$. According to the Kolmogorov-Smirnov test, since p-value 0.14364 > 0.05, at the 5% significance level the null hypothesis is not rejected and the Burr distribution is a plausible model for claim severity (Table 2). Figure 1 shows a histogram of claim amount data, together with the estimated probability density function.

Table 2: Kolmogorov-Smirnov goodness-of-fit test for claim severity

Test			Kolmogorov-Smirnov
Sample size			1,262
Test statistic			0.03217
P-value			0.14364
Significance level	0.05	0.02	0.01
Critical value	0.03823	0.04273	0.04586

Source: Author's calculations based on internal database of the insurance company

Figure 1: Histogram and density function for claim severity in MTPL



Source: Author's calculations based on internal database of the insurance company

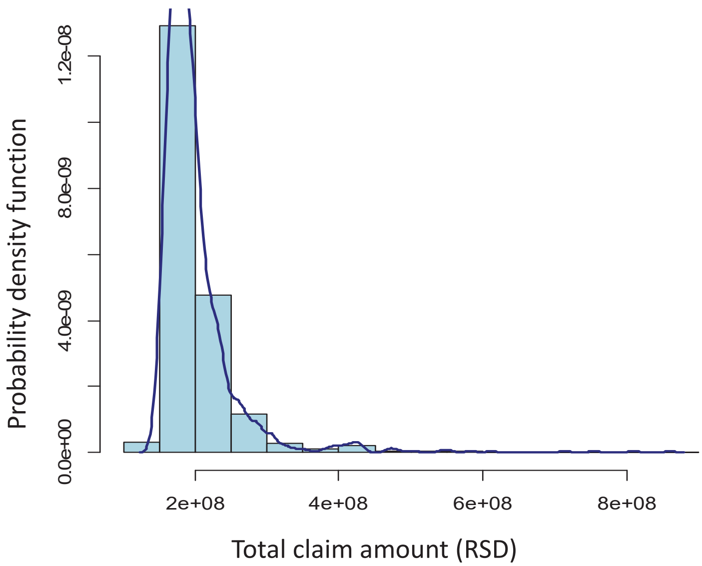
Based on the selected distributions of claim frequency and severity and the estimated values of their parameters, the compound Poisson-Burr distribution of the total claim amount during one business year under the insurer's effective MTPL policies was derived by the simulation method. The empirical distribution function which approximates the unknown distribution function of the actual claim amount was obtained as a result of 10,000 simulations. The selected descriptive statistics of the simulated distribution are shown in Table 3 and the corresponding frequency histogram and density function in Figure 2.

Table 3: Descriptive statistics of the total claim amount probability distribution (in 000 RSD)

Statistics	Min	First quartile	Median	Expected value	Third quartile	Max
Value	179,940.3	273,186.8	316,376.1	477,768.6	387,754.9	17,418,408.4

Source: Author's calculations based on internal database of the insurance company.

Figure 2: Histogram and density function for the total claim amount in MTPL



Source: Author's calculations based on internal database of the insurance company.

Value at Risk at a 99.5% confidence level for the simulated aggregate claims distribution equals RSD 1,799,587,974. If the net earned technical premium is equal to the expected value of the given distribution (i.e., RSD 477,768,652), the required capital for covering premium risk in the considered line of business would be RSD 1,321,819,322. However, the net earned technical premium in the year *t* (the calculation of which is shown in Table 4), reduced by the amount of the same premium per policies that resulted in 2.5% of extreme claims, amounted to RSD 833,060,794; that is, it was higher than the expected value of the total claim amount. However, the conducted ratio analysis indicates that the insurer's technical premium, as an accrual category, does not reflect the actual amount intended to cover claims in MTPL business.

Since the operating expenses (to the amount of RSD 552,331,315) exceeded the premium loading in this line of business, part of the technical premium had to be used to cover them. The premium loading participated with 21.27% in MTPL gross premium in year *t*, while the share of the operating expenses was as high as 49.39%. Therefore, the real technical premium corresponds to the gross written premium less the actual expenses (Table 5). The real net earned technical premium per considered policies amounted to RSD 535,410,635 in year *t*. By comparing this amount with the expected value of the total claims, it follows that the security loading of RSD 57,641,983 serves to cover unexpected losses and decreases the capital requirement to RSD 1,264,177,339 (Table 6).

Table 4. Calculation of the insurer's technical premium earned in MTPL (in 000 RSD)

Year	Gross written premium	Net written premium	Technical premium share (%)	Technical premium	Net technical premium	Unearned technical premium at the beginning of the year	Unearned technical premium at the end of the year	Earned technical premium	Unearned net technical premium at the beginning of the year	Unearned net technical premium at the end of the year	Net earned technical premium
	1	**2**	**3**	**4=1*3**	**5**	**6**	**7**	**8=4+6-7**	**9**	**10**	**11=5+9-10**
***t* - 4**	1,336,481.5	1,303,335.7	76.34	1,020,269.9	994,966.5	515,979.8	484,635.2	1,051,614.6	515,979.8	484,635.2	1,026,311.1
***t* - 3**	1,075,882.2	1,051,571.5	76.34	821,328.5	802,769.7	484,635.2	406,402.3	899,561.4	484,635.2	406,402.3	881,002.6
***t* - 2**	1,044,967.1	1,028,016.5	77.34	808,177.6	795,067.9	411,725.9	402,301.9	817,601.6	411,725.9	402,301.9	804,492.0
***t* - 1**	1,090,862.4	1,071,522.4	78.74	858,945.0	843,716.8	409,584.3	409,366.8	859,162.5	409,584.3	409,366.8	843,934.2
t	1,118,079.7	1,093,559.6	78.73	880,264.1	860,959.4	409,314.8	436,745.2	852,833. 7	409,314.8	436,745.2	833,529.0

Source: Author's calculations based on internal database of the insurance company.

Table 5. Calculation of the real amount of the insurer's technical premium earned in MTPL (in 000 RSD)

Year	Gross written premium	Net written premium	Real technical premium share (%)	Real technical premium	Real net technical premium	Unearned technical premium at the beginning of the year	Unearned technical premium at the end of the year	Real earned technical premium	Unearned net technical premium at the beginning of the year	Unearned net technical premium at the end of the year	Real net earned technical premium
	1	**2**	**3**	**4=1*3**	**5**	**6**	**7**	**8=4+6-7**	**9**	**10**	**11=5+9-10**
***t* - 4**	1,336,481.5	1,303,335.7	48.11	643,000.6	627,053.7	325,183.9	305,429.7	662,754.8	325,183.9	305,429.7	646,807.9
***t* - 3**	1,075,882.2	1,051,571.5	50.31	541,264.2	529,033.7	319,379.7	267,823.4	592,820.4	319,379.7	267,823.4	580,590.0
***t* - 2**	1,044,967.1	1,028,016.5	52.62	549,903.5	540,983.5	280,148.3	273,735.9	556,315.9	280,148.3	273,735.9	547,395.8
***t* - 1**	1,090,862.4	1,071,522.4	53.23	580,700.2	570,404.9	276,904.4	276,757.4	580,847.3	276,904.4	276,757.4	570,552.0
t	1,118,079.7	1,093,559.6	50.60	565,748.4	553,341.2	263,067.8	280,697.4	548,118.7	263,067.8	280,697.4	535,711.6

Source: Author's calculations based on internal database of the insurance company.

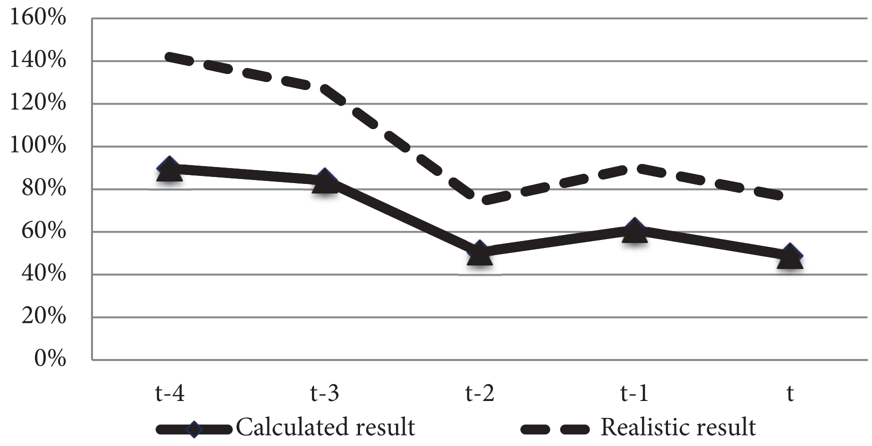
Table 6: Calculation of the insurer's required capital to cover premium risk in MTPL

Calculation	Indicator	Value (RSD)
1	**99.5% VaR of the total claim amount distribution**	1,799,587,974
2	**Expected value of the total claim amount**	477,768,652
3	**Real net earned technical premium**	535,410,635
4=3-2	**Security loading**	57,641,983
5=max (1-2-4, 0)	**Required capital to cover premium risk**	**1,264,177,339**

Source: Author's calculations based on internal database of the insurance company.

The validity of the results of the applied internal model, according to which the earned technical premium is sufficient to cover the expected claims, can be further examined through the calculation of the real technical result. As a percentage share of the claims incurred in the earned technical premium, the technical result is used in actuarial practice to check the adequacy of the premium and correct its eventual underestimation or overestimation. If the value of the given indicator is positive (i.e., less than 100%) the premium is sufficient to cover the respective claims, and vice versa. In order for the technical result to be considered realistic it is necessary to take into account the real operating expenses (instead of the premium loading) when calculating the relevant technical premium. This indicator for the observed insurer is calculated based on the data contained in Tables 4 and 5.

Figure 3: Calculated and real insurer's technical result in MTPL



Source: Author's calculations based on internal database of the insurance company.

The calculated technical result in year *t* was 48.92%. Although higher (76.11%), the real value of this result was still positive, which confirms the sufficiency of the company's earned technical premium in MTPL insurance. Also, there was a significant decrease in the real technical result in comparison with year *t*-4, when it amounted to 142.36% (Figure 3). However, based on the available data it is not possible to project the future trend of this indicator since the observed period is not sufficient to cover the effects of the insurance market cycle. Although reduced, the deviation between the calculated and the real technical result remains relatively high, pointing to the constantly present problem of uncovered operating expenses by the premium loading in the given line of business.

4.2. Discussion

The full relevance of these results is apparent when they are compared with the results obtained when applying a static fixed-ratio model, regularly used by the company for calculating the required solvency margin. In accordance with applicable law and regulations,[5] the required solvency margin is equal to the highest of the amounts obtained on the basis of three alternative criteria. Firstly, a premium index of 18% is applied to premiums written in the last 12 months up to amount of the dinar equivalent of EUR 50 million, while an index of 16% is applied to the remaining premiums. The second criterion for determining the required solvency margin applies a claim index of 26% to the average amount of claims incurred during the last 36 months up to the dinar equivalent of EUR 35 million and an index of 23% to the remaining amount of claims incurred. In both cases, the result obtained is corrected by a retention rate as the ratio of the amount of incurred claims in the insurer's retention to total claims incurred during the last 12 months, the value of which cannot be less than 50%. The third criterion is the prescribed minimum amount of the core capital required to perform the given type of insurance (Insurance law, article 28).

Tables 7 and 8 show the calculation of claims incurred in the total amount and in the insurer's retention as the necessary inputs for calculating the required solvency margin of the company in the given line of business, according to the fixed-ratio model.

5 Insurance law. RS Official Gazette, No. 139/14, articles 120–123 and Decision on capital adequacy of insurance/reinsurance undertakings. *RS Official Gazette,* No. 51/2015.

Table 7. Calculation of gross incurred claims in MTPL insurance (in 000 RSD)

Year	Gross paid claims	Gross RBNS* at the beginning of the year	Gross RBNS at the end of the year	Gross IBNR** at the beginning of the year	Gross IBNR at the end of the year	Coefficient of claim settlement costs	Reimbursements collected	Gross incurred claims
	1	2	3	4	5	6	7	8=(1+3+5-2-4)*6-7
t - 4	827,440.0	486,237.4	521,.299.4	68,899.6	173,632.4	1.017	40,142.7	943,535.1
t - 3	505,892.9	521,299.4	514,594.2	173,632.4	415,332.0	1.055	24,543.1	757,463.5
t - 2	444,210.6	514,594.2	355,235.6	415,332.0	522,465.1	1.096	16,618.5	412,997.1
t - 1	448,149.8	355,235.6	278,.095.8	522,465.1	650,079.8	1.087	18,279.4	523,675.7
t	427,860.7	278,095.8	213,655.5	650,079.8	707,806.7	1.094	43,554.1	417,223.4

Source: Author's calculations based on internal database of the insurance company.

Table 8. Calculation of net claims incurred in MTPL (in 000 RSD)

Year	Net claims paid	Net RBNS at the beginning of the year	Net RBNS at the end of the year	Net IBNR at the beginning of the year	Net IBNR at the end of the year	Coefficient of claim settlement costs	Reimbursements collected	Net claims incurred
	1	2	3	4	5	6	7	8=(1+3+5-2-4)*6-7
t - 4	769,628.3	486,237.4	419,824.4	68,899.6	173,.632.4	1.017	40,142.7	781,540.5
t - 3	476,199.9	419,824.4	415,051.0	173,632.4	415,332.0	1.055	24,543.1	728,161.6
t - 2	411,903.9	415,051.0	286,510.1	415,332.0	522,465.1	1.096	16,618.5	411,365.2
t - 1	401,070.4	286,510.1	237,888.9	522,465.1	650,079.8	1.087	18,279.5	503,502.2
t	410,038.5	237,888.9	183,867.7	650,079.8	707,806.7	1.094	43,554.8	409,123.5

Source: Author's calculations based on internal database of the insurance company.

RBNS* - Reported but not Settled, IBNR** - Incurred but not Reported

Table 9: Calculation of the required solvency margin using the fixed-ratio model (in RSD)[6]

		Premium written in the last 12 months	Premium index	Claims incurred in the last 12 months		Retention rate	Result
Premium basis		1	2	3	4	5=4/3	6=1*2*5
	Up to EUR 50 mil.	1,118,079,670	0.18	Gross claims	Net claims		197,329,881
	Above EUR 50 mil.	0	0.16				0
	Total	1,118,079,670		417,223,359	409,123,513	0.9805	**197,329,881**
		Average claims incurred in the last 36 months	**Claims index**	**Claims incurred in the last 12 months**		**Retention rate**	**Result**
Claim basis		1	2	3	4	5=4/3	6=1*2*5
	Up to EUR 35 mil.	451,298,734	0.26	Gross claims	Net claims		115,049,586
	Above EUR 35 mil.	0	0.23				0
	Total	451,298,734		417,223,359	409,123,513	0.9805	**115,049,586**
						Minimum capital amount	**308,680,750**

Source: Author's calculations based on internal database of the insurance company.

According to the fixed-ratio model, the required solvency margin in year *t* corresponds to a minimum core capital amount of RSD 308,680,750, which exceeds the amounts obtained by applying the premium index and the claims index (Table 9). The research results show that compared to the static model, the application of the dynamic model of premium risk measurement results in a higher level of required capital, thus ensuring that the insurer's solvency assessment is more reliable. The required solvency margin calculated on the basis of the official methodology is 75.5% lower than the outcome of the

6 The dinar equivalent value of premium and claim amounts (of EUR 50 million and EUR 35 million, respectively), and the minimum prescribed core capital (of EUR 2.5 million for motor third-party liability insurance and casco insurance of motor vehicles) was determined according to the official middle exchange rate of the National Bank of Serbia at the end of year *t*.

proposed partial internal model (Table 10). In other words, if the internal model was applied instead of the fixed-ratio model, the required capital, as the lower threshold of the insurer's available capital, would be about four times higher.

Table 10: Comparison of results of static and dynamic models for calculating capital required to cover premium risk

Model	**Capital requirement (RSD)**
Fixed-ratio model	308,680,750
Partial internal model for premium risk	1,264,177,339

Source: Author's calculations based on internal database of the insurance company.

The obtained result confirms the inadequacy of the existing fixed-ratio model and its parameters with regard to real risks in the non-life insurance market in Serbia. When taking into account that the premium risk, although important, is not the only risk that determines insurers' long-term financial strength, the significance of this finding is even greater. If other actuarial risks as well as financial and operational risks were covered by the analysis, the required amount of capital according to the dynamic model would be even higher, and the fixed-ratio model's underestimation would be even more pronounced.

A particular disadvantage of the fixed-ratio model is its insensitivity to possible underestimation of the insurance premium as a category that presents exposure to risk. When the required solvency margin is determined by the premium index, the fixed-ratio model generates inadequate results. If an insurance company increases its premium the required amount of capital will also increase, although with unchanged liabilities the insolvency risk will be reduced in real terms, and vice versa. Consequently, when applying this model, non-life insurers may be encouraged to underestimate premiums in order to demonstrate lower capital requirements, thereby directly endangering their own financial health. On the other hand, if the required solvency margin is determined by the minimum prescribed capital, as in the considered case, it will not depend on insurance premiums, i.e., it will be completely insensitive to premium risk. In terms of premium risk measurement the Solvency II standard approach is factor-based and thus also does not create appropriate incentives for non-life insurers (Doff 2008). This shortcoming is eliminated by the proposed internal model through the correction of the capital requirement upwards when the earned technical premium is underestimated, and vice versa.

5. CONCLUSIONS

This paper presents a partial internal model for measuring premium risk in the determination of non-life insurers' solvency, the application of which is illustrated by the example of an actual insurance company in Serbia. The possibility of overcoming shortcomings in the fixed-ratio model by the dynamic methodology for assessing insurers' solvency occupies an important place in contemporary literature. It is an extremely complex research task to place this issue within the framework of the Serbian insurance market in order to take into account its characteristics and to give concrete answers to the numerous challenges of creating a model for determining solvency. Standard approaches to evaluating insurer's solvency, even when dynamic like Solvency II, correspond to the characteristics of an average insurer in a hypothetical insurance market. However, precise measurement of actuarial risks – including premium risk – and thus reliable calculation of solvency capital requirements implies the development of an internal model that will, as much as possible, reflect the features of specific insurance market and of each individual insurance company to which the model is applied.

The research results show that the dynamic model of premium risk measurement results in a higher level of required capital than the static model, thus providing a more reliable assessment of insurers' solvency. This proves the inadequacy of the fixed-ratio model for the Serbian insurance market and the need for changes in the prescribed methodology for determining the solvency of non-life insurers, in order to take into account the real risks that jeopardize their business.

The calculation of the required capital in the proposed internal model is based on the entire probability distribution of total claim amount, instead of the static positions of financial statements. The empirical claims data used for deriving the claims probability distribution provide actual risk characteristics of the specific insurance portfolio, which eliminates the problem of the arbitrariness of the standard approach parameters. The problem of the static fixed-ratio model insensitivity to the possible underestimation of the insurance premium, as a category that presents the exposure to premium risk, is overcome by introducing a reversely proportionate relationship between the premium and the resulting capital requirement. The proposed model allows, first, identifying the shortfall or the surplus in real compared to needed premiums, and then adjusting the resulting capital requirement in the same amount. Accordingly, this model differs from previously defined models that a priori assume that the insurance premium is sufficient to cover expected claims. At the same time, in addition to the capital requirement itself, the model produces information that can be useful in forming insurance premiums. Discrepancies between net technical premium and the expected value of the simulated probability distribution of the total amount of claims may indicate appropriate changes to the insurer's tariff policy.

As well as making a theoretical contribution, the results presented in this paper have practical implications. Both the supervisory authority in the insurance sector and the management of companies dealing with non-life insurance can benefit from the proposed partial internal model for premium risk measurement. As an indicator of insurers' potential insolvency, the model strengthens the risk-based insurance supervision function. At the same time, the model can be used by insurers to determine the optimal level of capital and its allocation in a way that protects the interests of policyholders and preserves the financial health of insurers, as well as improving it through an improved risk management system.

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