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Estimating Risk Margin and Risk Adjustment Based on Solvency II and IFRS 17 Frameworks Using Cost of Capital Technique Applied to an Egyptian Non-life Insurance Company

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Abstract

Implementing the International Financial Reporting Standard for insurance contracts (IFRS17) has transformed the regulatory landscape for insurance companies through establishing stringent requirements for risk assessment and financial reporting. The key aspect is the non-financial risk adjustment (RA), which must meet specific criteria but allows the insurers' flexibility in the estimation method. Consequently, the main aim of this research is to examine the use of the Cost of Capital (CoC) method employed under Solvency II for risk margin (RM) estimation in assessing RA under IFRS 17. The study utilizes the bootstrap simulation techniques on Mack's (1993) model to assess reserve risks for an Egyptian insurer's motor line. It connects the traditional view of lifetime risks under IFRS 17 with Solvency II's one-year risk perspective. Using Cornish-Fisher and Bohman-Esscher approximations, the research estimates the Probability of Sufficiency (PoS) as a confidence level for CoC risk margin. The findings suggest that CoC can compute risk adjustment with consistent results from distribution-free PoS estimations.

Keywords

IFRS 17, Solvency II, Risk Adjustment, Cost of Capital, Risk Margin, Probability of sufficiency

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1. Introduction

A pair of international directives for insurance companies—Solvency II and IFRS 17—have been developed with various goals for this industry. In contrast to IFRS 17 from an accounting perspective, Solvency II is built from the regulatory standpoint. The IFRS17 corresponds to the Egyptian accounting standard number (50) for insurance contracts which is considered as a mandatory requirement for all companies in the Egyptian insurance market.

Solvency II and IFRS 17 are sets of regulations that aim to enhance the comparability and transparency of the insurance companies. However, they have different perspectives. Solvency II is focused on policyholder protection and reducing insolvency risk by requiring insurers to retain a specific amount of capital in reserve to provide protection against the potential losses to make sure that insurers will be able to fulfill their financial liabilities to policyholders in the event of financial crisis. Moreover, IFRS 17 is focused on harmonizing the accounting standards for insurance and reinsurance contracts that enable the investors and other stakeholders to compare the financial performance of different insurers. (Azevedo, 2021)

There is no obligatory requirement to use a coordinated approach when implementing Solvency II and IFRS 17, but it can be beneficial. This is because the two directives overlap significantly, especially if an entity has already implemented Solvency II. Solvency II is more comprehensive than IFRS 17 as, it defines the methodologies for certain aspects. On the other hand, IFRS 17 is more principles-based and does not define methods, but it may provide examples. Consequently, the specific method used is ultimately up to the entity's judgment.

IFRS 17 is more principles-based than the prior accounting standards, which are usually more rule-based Subsequently; IFRS 17 has fewer strict rules about implementing the standard. The insurers must first interpret the standards then disclose how they have interpreted them. Due to these principles, insurers must develop many interpretations that will impact on the information prepared then; share with financial stakeholders about the financial performance of insurance contracts and the company's financial position. Insurers reporting on IFRS must justify some of their choices in disclosures in an auditable fashion. This information is helpful for financial stakeholders, allowing them to better compare insurers based on reliable information. (Koetsier, 2018)

The insurers' liabilities must be evaluated through the ‘fair value’ principle that would be paid by a knowledgeable, willing party in an arm’s length transaction. Business has to be evaluated by its value in the market. Depending on the principle of fair value, financial economics can be used to achieve market-consistent ‘risk-neutral’ value by discounting the best estimate for the liability cash flows using risk-free interest rate. The nature of insurance liabilities is uncertain. Therefore, holding assets to match the best estimate of the liability's present value; besides, the insurers must also evaluate the risk that their best estimate was underestimated. Bearing these additional assets generates a cost. The required compensation to raise the capital to charge this extra amount across the best estimate is referred to the risk margin. (Brown, 2012)

Under IFRS 17, the required risk adjustment should reflect *"…the compensation an entity requires for bearing the uncertainty about the amount and timing of the cash flows that arise from non-financial risks as the entity fulfills insurance contracts."* (Hannibal, 2018)

For insurance companies are already estimating the cost of capital for Solvency II risk margin, it is preferable to recycle the current techniques of risk margin calculation to calculate the IFRS 17 risk adjustment. It is not only for an attempt to decrease reporting costs, efforts, and time but also to guarantee that the internal capital or the existing regulatory and profit metrics are consistent. This is a critical property for the users of the financial statements, including the market, regulators, and auditors to understand and compare the outcomes.

The Cost of Capital technique to estimate reserve risk margin — the risk adjustment technique is commonly approved according to Solvency II and IFRS 17, there is one additional requirement of IFRS 17 to declare the risk margin's confidence level.

2. Literature Review

This section summarizes a large number of studies investigating the techniques of reserve risk estimation using different approaches and under different regulatory frameworks applied in the non-life insurance sector. This research and many other researches depended on Mack (1993), who derived a distribution-free formula to estimate the standard error result from the chain ladder reserve method. The results have been compared with some moment-based methods using the numerical application. Furthermore, Renshaw (1998) developed a statistical model for the chain ladder method through the generalized linear model and quasi-likelihood technique. Negative incremental claims were allowed in the estimation of the reserve. It has been proposed that the chain-ladder technique offers a limited perspective on the potential scope of models. In England (1999) predicted the reserving error using a simple computational method through a generalized linear model using the bootstrap technique. A comparison was made between the outcome of the bootstrapping technique with other stochastic methods and Mack's distribution-free approach. Additionally, England (2002) presented some stochastic models for reserve calculation used in non-life insurance. The run-off triangle development was smoothed and tail parameters. The paper also considered the B.F method through the Bayesian model. The paper provided a full-predictive distribution for reserve outcomes. In England (2006), an extension is made to England (2002) and has illustrated how to get predictive distributions of outstanding insurance liabilities through bootstrap or Bayesian techniques. The analysis depended on Mack's data set (to allow for negative increments), and the Bayesian technique depended on Markov-chain Monte Carlo. Finally, a comparison between Bootstrap and Bayesian techniques was made. The paper found that predictive distributions have to be required of all stochastic reserve techniques and the Bayesian techniques provide better results than bootstrap. Moreover, Postma (2017) Conducted research to compare the risk margin under Solvency II and the risk adjustment under IFRS 4 Insurance Contracts, and to highlight their commonalities. The research initially examined the official documents of both frameworks, Solvency II and IFRS 4, to delineate their distinct objectives. Subsequently, it detailed the methodologies used to calculate the risk margin and risk adjustment. The findings of the research revealed several key points. Firstly, Solvency II aimed to safeguard policy holders and beneficiaries by quantifying the insurer's exposure to risk. In contrast, IFRS 4 focused on providing insightful financial information about insurers' financial positions. Secondly, regarding calculation methodologies, Solvency II specified the Cost of Capital method, explicitly defining the annual rate, interest rate, and capital to incorporate into calculations. The definitions were precise and unambiguous. In contrast, IFRS 4 has offered more flexibility by permitting three methods: the Confidence Level technique is favored, with the Conditional Tail Expectation and Cost of Capital methods also permissible if they are translated into the Confidence Level technique. Thus, while Solvency II provides clarity and specificity in its calculation approach, IFRS 4 allows for greater choice and flexibility. This flexibility can be perceived both as advantageous and disadvantageous, depending on the context. In order to Comply the requirements of IFRS17, Kravavych (2017) developed techniques for estimating a confidence level for the risk margin through Probability of Sufficiency (PoS). Practical techniques using a distribution-free approach are used to permit the risk margin to be recycled to get the risk adjustment requested under IFRS17. The research has developed a PoS approximation formula for the standalone line of business and the portfolio level. Abdel-Naby (2018) explored a pair of stochastic reserving techniques, bootstrap, and Mack’s distribution-free approach. The empirical study covered a motor comprehensive line of business in an Egyptian insurance company through Visual Basic for Applications (VBA) and R programming language. A comparison between the obtained reserve from the deterministic chain ladder and the bootstrap technique. Finally, the prediction error has been compared according to Mack's distribution-free model and the bootstrap technique. The research found that the bootstrap technique can produce an estimation for the reserve amount, the reserve prediction error and the predictive distribution of overall reserve. Furthermore, Nagy (2019), explored the problem of reserve underestimation in the Egyptian insurance market. Many sources of prediction error were analyzed. The research concluded that predictive techniques are more suitable than deterministic ones. The adequacy of the outstanding claim reserve was analyzed in the Egyptian insurance market. Carlos (2019) Provided a stochastic approach for insurance risk modeling within the IFRS 17 structure. A semi-parametric hierarchical copula has been used to account for the interaction between the business lines in the Canadian insurance market. The research developed double-generalized linear models for unpaid claims liabilities of each line of business. It measured the dependence between the loss triangles of the various lines through the autoregressive features of residuals and its effect on the development year and accident year. A comparison between the estimation of capital requirement based on univariate and multivariate risk measures is made. Moreover, a cost of capital method is used to compute a risk adjustment under the IFRS 17 framework. The research found that, the diversification benefit is achieved using a semi-parametric Hazard Covariance Model (HCM) and through multivariate risk measures when aggregation is considered inappropriate. While multiple methods exist for incorporating dependence within an insurance portfolio, the bivariate approach facilitates understanding by providing visual representations of the joint distribution and its associated risk measures. In Verrall (2019), the research aimed to apply both simulation and analytic techniques to estimate and connect the reserve risk in non-life insurance upon the duration of liabilities and the one-year perspective required under Solvency II requirements. The research depended on the model of (Mack, 1993), though the results have wider applicability. The distribution can be obtained through a recursive re-reserving technique. The research found that the risk margin under Solvency II requires at least, VaR at 99.5% applied to CDRs distribution across one- year time horizon by using suitable risk measures.

The research develops a unified model to estimate the risk margin and risk adjustment for the non-life Egyptian insurance market by connecting the reserve risk across the lifetime of liability required under IFRS17 and the one-year perspective of reserve risk required based on Solvency II. The research also will estimate the confidence level required for IFRS 17 with more than one method and compare the results of these methods.

3. Research Methodology

3.1. Measure of Reserve risk

There are many approaches to quantify the reserve risk. According to the outputs, a standard deviation can be provided using analytical-based approaches, while a full predictive distribution can be provided using a full predictive distribution technique. In terms of liability time scales, there exists that the conventional perspective spanning the entire lifetime of liabilities, alongside the one-year perspective mandated by Solvency II requirements.

In essence, the "ultimate perspective" evaluates all potential reserve trajectories until complete run-off, whereas the "one-year perspective" considers only the various paths within the initial year and the resulting reserves estimated by an actuary after observing each of these one-year paths (often termed as the "actuary-in-the-box" approach, referring to a re-reserving algorithm). (Carrato, McGuire, & Scarth, 2016)

Claims Reserving Notation:

The triangle of cumulative claims for each line of business can be assumed to be in the following form:

$$\begin{array}{llll} C_{1,0}, & C_{1,1}, & \dots, & C_{1,J} \\ C_{2,0}, & \dots, & C_{2,J-1} & \\ \vdots & & & \\ C_{n,0} & & & \end{array}$$

The run-off triangle has indices $i \in \{`1,2,\dots,n\}$ and $j \in \{0,1,2,\dots,n-i\}$, where i & j are the accident years and the development years, respectively. The cumulative paid claim amounts of accident year i up to development year j are$c_{i,j}$.

(Mack, 1993) Introduced a stochastic methodology for the chain-ladder technique. Beyond the primary objective of the reserving process, which involves estimating the missing lower part of the claim triangle, this approach also facilitates the calculation of the mean and variance of the cumulative claims as follows:

$$E\left[c_{i,j+1} \setminus c_{i,0},\dots,c_{i,j}\right] = \lambda_j c_{i,j} \quad and \quad Var\left[c_{i,j+1} \setminus c_{i,0},\dots,c_{i,j}\right] = \sigma_j^2 c_{i,j}$$

only the first two moments of the cumulative claims rather than the entire distribution, are specified, the model is considered "distribution-free." The variance and the expected value correspond to the previous claims. The unknown parameters λ_j and σ_j^2 are derived (Mack, 1993), as:

$$\hat{\lambda}_j = \frac{\sum_{i=1}^{n-j-1} w_{i,j} f_{i,j}}{\sum_{i=1}^{n-j-1} w_{i,j}} \qquad (1)$$

Where, $w_{i,j} = c_{i,j}$ and $f_{i,j} = \frac{c_{i,j+1}}{c_{i,j}}$

And, $$\hat{\sigma}_j^2 = \frac{1}{n-j-2} \sum_{i=1}^{n-j-1} w_{i,j}(f_{i,j} - \hat{\lambda}_j)^2 \qquad (2)$$

The final unknown parameter

$$\hat{\sigma}_{j-1}^2 = \min\left(\hat{\sigma}_{J-3}^2, \hat{\sigma}_{J-2}^2, \hat{\sigma}_{J-2}^4 / \hat{\sigma}_{J-3}^2\right) \qquad (3)$$

The development factors λ_j are estimated using the standard volume-weighted chain-ladder estimator. Subsequently, the variance estimator $\hat{\sigma}_j^2$ is computed by dividing the residual sum of squares by the degrees of freedom for each development period.

Table 1: Motor comprehensive link ratios and Mack's Parameters

	DP 1	DP 2	DP 3	DP 4	DP 5
2018	1.333	1.004	1.008	1.002	1.001
2019	1.336	1.015	1.007	1.002	
2020	1.32	1.029	1.006		
2021	1.32	1.019			
2022	1.273				
CL factors (λ)	1.317	1.017	1.007	1.002	1.001
σ	568.50	258.69	27.51	9.55	9.55

Source: The researcher based on R.

3.1.1. Bootstrapping reserve variability across the lifetime of the liabilities:

The bootstrapping of Mack's model depends on expressing the data as ratios f instead of cumulative claims $c_{i,j}$, resulting in the following modified equations for the expected value and the variance:

$$E[f_{i,j} \setminus c_{i,0}, \dots, c_{i,j}] = \lambda_j \quad and \quad Var[f_{i,j} \setminus c_{i,0}, \dots, c_{i,j}] = \sigma_j^2 / c_{i,j} \tag{4}$$

3.1.2. Bootstrapping the Claims Development Result across One-Year

According to (Verrall, 2019), the simulation technique of the CDR to get a predictive distribution compatible with (Merz & Wuthrich, 2008) and the assumptions of (Mack, 1993). The simulated CDR can be expressed as:

$$CDR_{i,s}^{n+1} = \hat{R}_i^n - I_{i,s}^{n+1} - \hat{R}_{i,s}^{n+1} = \hat{U}_i^n - \hat{U}_{i,s}^{n+1} \tag{5}$$

In each simulation s, the initial reserves at the beginning of the year are predetermined, thus requiring simulation solely of the payments occurring during the upcoming calendar period and the estimated reserves at year-end, contingent upon these payments.

To incorporate projected payments for each origin period across the upcoming calendar period, it is essential to expand the original payments triangle. These projected payments, observed within a one-year timeframe, are utilized in the standard chain-ladder method. This approach involves fitting the chain-ladder model anew for each simulated triangle, based on the claims that arise during the year. This iterative adjustment of the reserving methodology has resulted in the "actuary-in-the-box" procedure, alternatively referred to as "re-reserving." (Diers, 2009)

Based on the payments observed throughout the year (derived from bootstrap results) and the reserves at year-end (obtained through the re-reserving method), the CDR for each simulation can be assessed using the following equation:

$$CDR_{i,s}^{n+1} = \hat{R}_i^n - I_{i,s}^{n+1} - \hat{R}_{i,s}^{n+1} = \hat{U}_i^n - \hat{U}_{i,s}^{n+1} \tag{6}$$

Table 2:The motor Comprehensive bootstrapped expected reserve and the bootstrapped standard deviation of ultimate reserve and one year CDRs

Acc.year	Paid	Avg Reserves	Avg Ultimate	Bstrap SD	Bstrap CoV	CDR SD	CDR SD Ratio
2017	627,050,522	0	627,050,522	-	-	-	-
2018	723,181,389	624,638	723,806,027	373,827	59.80%	373,827	59.90%
2019	748,803,496	2,024,789	750,828,285	498,703	24.60%	384,030	19.00%
2020	666,553,898	6,601,283	673,155,181	942,027	14.30%	850,352	12.90%
2021	618,366,470	16,921,542	635,288,012	7,212,045	42.60%	7,165,965	42.60%
2022	540,414,835	190,624,417	731,039,252	16,953,844	8.90%	15,138,466	7.90%
Overall	3,924,370,610	216,796,670	4,141,167,280	19,011,983	8.80%	17,356,224	8.00%

Source: The researcher based on R

Table (2) has shown the expected reserve, prediction error (Standard deviation) and the coefficient of variation of bootstrapping Mack's model through 10000 simulations of motor comprehensive claims triangle. The standard deviations of one year ahead CDRs also has been shown using re-reserving approach. In the latest column the standard deviations are expressed as a proportion of the expected reserves at the start of each year.

3.1.3. Simulating the CDR beyond one year perspective of liabilities

To connect between the lifetime and one year perspective of reserve risk , it is necessary to obtain a complete predictive distribution of the extended CDRS.

$$\mathrm{CDR}_{i,s}^{n+K+1} = \widehat{\mathrm{R}}_{i,s}^{n+k} - \mathrm{I}_{i,s}^{n+k+1} - \widehat{\mathrm{R}}_{i,s}^{n+k+1} = \widehat{\mathrm{U}}_{i,s}^{n+k} - \widehat{\mathrm{U}}_{i,s}^{n+k+1} \tag{7}$$

For k≥1, the reserve at the beginning of year n+k+1, $\hat{R}_{i,s}^{(n+k)}$, and ultimate cost of claims at the beginning of the year, $\hat{U}_{i,s}^{(n+k)}$, are currently distinguished for each simulation s, when k=0, re-reserving procedure of CDR provides $\hat{R}_{i,s}^{(n+1)}$ and , $\hat{U}_{i,s}^{(n+1)}$, providing the beginning amounts needed for estimating $CDR_{i,s}^{(n+1)}, when\ k = 1$. Again, note that the payments that emerge across each calendar period, $I_{i,s}^{(n+2)}$ are available from bootstrapping Mack's model, so to complete the estimation of $CDR_{i,s}^{(n+2)}$, it is only essential to estimate $\hat{R}_{i,s}^{(n+2)}$ and , $\hat{U}_{i,s}^{(n+2)}$. To achieve this, another iteration of the re-reserving procedure is conducted. The original claims triangle is augmented by a second payments diagonal (generated through bootstrapping Mack's model), and the reserves (or ultimate cost of claims) are estimated using the chain ladder model for each simulation, based on the claims that have emerged over the two-year period.

To estimate $\mathrm{CDR}_{i,s}^{(n+k+1)}$ for the remaining values of k, the re-reserving procedure is repeated recursively. Each iteration augments the original claims triangle with an additional triangle generated from bootstrapping Mack's model. The chain ladder model is then used for each simulation based on the emerged claims. This recursive technique produces a distribution of the CDR for each future calendar period, allowing for the estimation of any risk measure. (Diers, 2009) also employ the multi-year re-reserving approach to estimate the cumulative emergence of the CDR, rather than the incremental one-year movements.

Table 3:The motor comprehensive simulated standard deviations for one year ahead CDRs for the ultimate period

Acc.year	CDR(1)	CDR(2)	CDR(3)	CDR(4)	CDR(5)	Sqrt SS
2017	0	0	0	0	0	0
2018	717,461	0	0	0	0	717,461
2019	1,192,653	619,800	0	0	0	1,344,088
2020	747,397	1,011,776	537,444	0	0	1,367,896
2021	7,172,764	584,683	929,014	516,217	0	7,274,610
2022	15,048,571	7,681,148	602,976	997,117	547,314	16,944,524
Overall	17,487,199	7,966,408	1,485,271	1,172,902	547,314	19,317,015

Source: The researcher based on R.

Table 3 has shown the standard deviations (RMSEP) of the simulated motor comprehensive CDRs for each future calendar year through the recursive re-reserving approach in addition to the square root of the sum of squares in the last columns. in comparison with table 2 illustrates that the standard deviation of the bootstrapped CDRs are relatively close to the standard deviations from bootstrapping Mack's model across the lifetime of the liabilities, It confirms that Mack's model can divide the lifetime perspective of risk into a series of one-year perspectives.

3.2. Solvency II Risk Margins using the Cost-of-Capital Approach

The Solvency II framework mandates that risk margins be determined using a cost-of-capital method. The process is straightforward: as reserves decrease over subsequent years, the risk margin is computed by aggregating the discounted costs of capital. These costs are calculated by multiplying the capital requirements by a predetermined and constant cost-of-capital rate. Both the cost-of-capital rate and the discount rates used in these calculations are predefined and fixed. The main challenge lies in securing the initial required capital and accurately forecasting future capital needs as liabilities diminish over time.

The initial capital of Solvency II can be estimated using internal model or from standard formula. The VaR at 99.5% of the overall CDR across one year can be used as a proxy. The future capital can be estimated using various approximations (Best estimate, Standard deviation, variance and Value at risk at 99.5%). According to (Verrall, 2019), the commonly used proxy involves estimating future capital requirements as a fraction of the initial capital, with this fraction determined by the rate at which the best estimate of reserves decreases over time. Although the popularity of the best estimate method, Prudential Regulation Authority (Authority, 2014) Warns the insurers from using the best estimate method unless it has been thoroughly demonstrated that this methodology does not result in significant inaccuracies in the determination of technical provisions.

Table 4: Motor comprehensive VaR at 99.5% of simulated on year ahead CDRs for all future years

Acc.year	CDR(1)	CDR(2)	CDR(3)	CDR(4)	CDR(5)
2017	0	0	0	0	0
2018	1,704,979	1,704,979	1,704,979	1,704,979	1,704,979
2019	3,028,536	3,325,350	3,325,350	3,325,350	3,325,350
2020	1,928,104	3,133,745	3,387,019	3,387,019	3,387,019
2021	18,607,138	18,681,974	18,685,597	18,845,854	18,845,854
2022	38,747,717	43,662,117	43,910,533	43,594,194	43,665,292
Overall	45,617,943	49,124,856	49,920,590	49,732,973	49,465,163

Source: The researcher based on R

Table 4 has shown that the VaR calculated at 99.5% of simulated one year ahead CDRs for all future years. The result of first column can be used as a proxy to the initial capital as required in CoC technique.

Table 5: Motor Comprehensive cost of capital risk margin

future Time	Disc Fut Res	Capital	Capital Profile	Cost of Capital	Disc CoC
1	196,011,743	45,617,943	100.00%	2,737,077	2,380,067
2	23,914,527	5,565,644	12.20%	333,939	252,506
3	7,491,097	1,743,408	3.82%	104,604	68,779
4	1,512,523	352,010	0.77%	21,121	12,076
5	0	0	0.00%	0	0
Risk Margin					2,713,427

Source: The researcher based on R

Table 5 has shown the calculation of CoC risk margin for motor comprehensive line of business. The second column contains the projected reserves discounted at the start of each year at 15%. The third column begins with the initial (opening capital) as a proxy using VaR at 99.5% and the future capital requirement as the same ratio of reserves run off. The fourth column represents the ratio of each future capital to the initial capital (capital profile using "best estimate" basis). The fifth column provides the calculation of CoC, is calculated as the multiplication of 6% (The CoC rate is determined by Solvency II) and the capital requirements. The final column represents the calculation of risk margin by the summation of CoC discounted at 15%, giving the risk margin for Motor Comprehensive 2,713,427.

3.3. Estimating the confidence level of the CoC risk margin:

The Egyptian insurers are expected to be obliged to comply with Solvency II and IFRS 17.While the usage of CoC approach are commonly approved for risk margin calculation under Solvency II and IFRS 17, IFRS 17 additionally requires that the risk margin's confidence level be disclosed.

The probability of sufficiency is a confidence level measurement used by (Kravavych & Dal, 2017) to quantify the distribution-free reserve risk. The approximation for POS depends on the risk profile (the Coefficient of Variation (CoV), skewness in terms of CoV and Kurtosis if available) of reserve risk using Cornish-Fisher (C-F) and Bohman-Esscher (B-E) approximations. The concept of PoS can be described in figure 1 and can be expressed mathematically, as following:

$$PoS = P[x \leq BE_x.(1 + \eta_x)] = \alpha \quad (8)$$

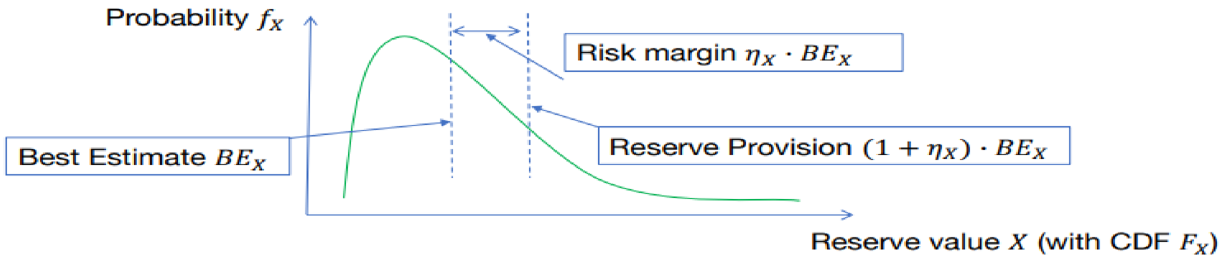
Where:

BE_x: *is the best estimate of reserve value x.*

η_x: *is the risk margin.*

α: *is PoS (required confidence level)*

Figure 1: PoS as a measure of confidence level



Source: (Kravavych & Dal, 2017)

According to (Kravavych & Dal, 2017), there are a pair of approaches to estimate the POS formula mentioned above. The first approach is to use distribution inverse (finding $VaR_{\propto}(x)$) requires perfect knowledge of the distribution of X. The second approach is the information theory (distribution-free approach) that depends on using centralized and normalized copy of X,

$$\tilde{X} = \frac{X - BE_x}{BE_x - CoV_x} \text{ and, } \tag{9}$$

$$X = BE_x.\left(1 + CoV_x.\tilde{X}\right) \tag{10}$$

$$VaR_{\propto}(x) = BE_x.(1+\eta_x) = BE_x.(1 + CoV_x.VaR_{\propto}(\tilde{X})) \tag{11}$$

So,

$$VaR_{\propto}(\tilde{X}) = \frac{\eta_x}{CoV_x} \tag{12}$$

$\mathrm{VaR}_{\propto}(\tilde{\mathrm{X}})$ Carriers unique statistical characteristics of reserve risk profile. The key components of the statistical makeup of the reserve distribution are coefficient of variation (CoV), Skewness-to-CoV (SC) ratio, and Kurtosis-to-CoV ratio, as they can provide a vital topology for characterizing distributions and explain quintiles of $\tilde{\mathrm{X}}$. Additionally, it shows the so-called Coefficient of Riskiness (CoR), which is the standard deviation of the underlying reserve risk profile expressed in terms of the quintile's distance from the mean.

In insurance, the most widely used distributions for loss modelling and reserving are Single Shape Parameter (SSP) distributions. SSP are distributions where:

- Two-parameter distributions where scale and shape parameters are distinct.
- The shape of the distribution is entirely elucidated by its shape parameter.

SSP distributions can be split into categories: (Kravavych & Dal, 2017)

- Moderately skewed distributions ($1.5 < SC \le 3$) : Gamma, Inverse-Gaussian (Wald);
- Significantly skewed distributions ($3 < SC \le 4$): Log-Normal, Suzuki, Exponentiated-Exponential (Verhulst) and Dagum
- Extremely skewed distributions ($SC > 4$) : Inverse-Gamma (Vinci), Birnbaum-Saunders, Exponentiated-Frechet, Reciprocal Wald and Log-Logistic.

To estimate the confidence level using B-E approximation or C-F approximation, the CoV and skewness of motor comprehensive has to be calculated, as following:

Table 6: Coefficient of variation and skewness for motor comprehensive

	CoV	Skewness
Motor comprehensive	8.80%	-32.46%

Source: The researcher based on R

3.3.1. Bohman-Esscher (B-E) Approximation:

The B-E approximation of the confidence level α is based on the inversion of $\mathrm{VaR}_{\propto}(\widetilde{\mathrm{X}})$ to α using the incomplete Gamma function, as following:

$$\alpha \approx \frac{1}{\Gamma(s)} \int_0^{s+\sqrt{s}.q} y^{s-1}.e^{-y}\, dy \tag{13}$$

Where,

q= $\mathrm{VaR}_{\propto}(\widetilde{\mathrm{X}}) = \frac{\eta_x}{CoV_x}$ $and\ s = \frac{4}{\gamma_x^2}$, which is equivalent to applying a Gamma distribution $F_Y(y)$ with $Y \sim Gamma(s, 1)$ evaluated at $y = s + \sqrt{s}\, q$

Estimating the confidence level using (B-E) Approximation

Table 7: Estimating the confidence level using (B-E) Approximation

	discounted Best estimate	CoC risk margin	CoC risk margin%	Confidence level
Motor comprehensive	196,252,644	2,713,427	1.38%	58%

Source: The researcher based on R

Table 7 shows the estimated confidence level using (B-E) Approximation. The first column represents the discounted best estimate of the reserve discounted at 15%. The second column is the values of CoC risk margin for Motor comprehensive . The third column represents the CoC risk margin as a proportion of discounted best estimate. The last column represents the estimated confidence level for the CoC risk margin as an objective of the research.

3.3.2. Cornish-Fisher (C-F) Approximation

The C-F approximation of the confidence level α is based on the standard normal quintiles, as following:

$$\mathrm{VaR}_{\propto}(\widetilde{\mathrm{X}}) \approx z_{\propto} + \gamma_x \frac{z_\alpha^2 - 1}{6} + C_1\left(\iota_x \frac{z_\alpha^3 - 3z_\alpha}{24} - \gamma_x^2 \frac{2z_\alpha^3 - 5z_\alpha}{36}\right) + C_2(-\gamma_x \iota_x \frac{z_\alpha^4 - 5z_\alpha^2 + 2}{24} + \gamma_x^3 \frac{12z_\alpha^4 - 53z_\alpha^2 + 17}{324}) \tag{14}$$

Where,

The coefficients C_1 and C_2takes values from 0 to 1 representing special cases of C-F approximation, as following:

- C_1=0,C_2=0 representing second-order Cornish-Fisher (or, equivalently, first-order Normal Power) approximation utilizing only skewness γ_x of X;
- C_1=1,C_2=0 representing third-order C-F (or, equivalently, second-order Normal Power) approximation utilizing skewness γ_x and kurtosis ι_x of X; and
- C_1=0,C_2=1 representing fourth-order C-F approximation utilizing skewness γ_x and kurtosis ι_x of X; here, the PoS level, α, is recovered by solving a C-F polynomial equation for standard normal quintile $z_\propto$ and mapping it to $\alpha = \Phi(z_\propto)$

Estimating the confidence level using C-F approximation

The Cornish-Fisher expansion is contingent upon the initial three moments of the reserve risk distribution: the estimated value derived from the Chain-Ladder projection, the standard deviation according to Mack, and the distribution's skewness.

Table 8: Estimating the confidence level using (C-F) Approximation

	$\mathrm{VaR}_\propto(\tilde{\mathrm{X}})$	**Z (Risk margin)**	**Confidence level**
Motor comprehensive	16%	0.11	54%

Source: The researcher based on R

Table 8 shows the estimated confidence level using first-order Normal Power (second-order C-F Approximation). The $VaR_\alpha(\tilde{X})$ in the first column is calculated by dividing the risk margin percentage by CoV. The second column represents the calculated z by solving a C-F polynomial equation for the standard normal quintile. The last column represents the estimated confidence level for the CoC risk margin as an objective of the research.

4. Conclusions and recommendations

The research reveals that the cost of capital approach is valid for estimating the Risk margin under Solvency II and the risk adjustment under IFRS 17there is one additional requirement of IFRS 17 to disclose confidence level. The CoC approach is more complex and requires additional variables, assumptions and sensitivities about the opening and future capital requirements in addition to the cost of capital rate. If the cost-of-capital approach is applied for IFRS 17 risk adjustments, the insurer has to choose between the one-year and lifetime perspectives of risk when determining capital requirements. Solvency II depends on the one-year perspective of risk, whereas IFRS 17 depends on the lifetime perspective of risk. This research has used the VaR at 99.5% of the overall CDR across one year as a proxy for initial (opening) capital and estimates the future capital requirements as a proportion of the opening capital, where this proportion is estimated as rate of reduction in the best estimate of reserves across time.

The research recommended that For insurers already using a CoC technique for other objectives e.g. (Solvency II), a logical starting point for the IFRS 17 risk adjustment may involve maximizing the recycle of existing calculations. This approach not only aims to streamline reporting processes, minimize expenses, and conserves resources but also maintains coherence with current regulatory or internal capital and profit metrics. The insurers have to- periodically-review and adjust the discount rate and the CoC rate in case of using CoC technique.

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