LISBON SCHOOL OF ECONOMICS & MANAGEMENT
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MASTER

ACTUARIAL SCIENCE

MASTER'S FINAL WORK

INTERNSHIP REPORT

ON THE TECHNICAL ASPECTS AND PRACTICAL APPLICATION OF THE IFRS 17 RISK ADJUSTMENT

CATARINA PEREIRA OLIVEIRA

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Abstract

The accounting standard IFRS 17 was released on 18 May 2017 with the purpose of increasing comparability between insurance contracts globally. The Risk Adjustment (RA) is introduced by the new standard as the element reflecting the compensation required by an entity for bearing the uncertainty that arises from non-financial risk regarding the amount and timing of cash flows.

Being *principles-based*, IFRS 17 does not prescribe a calculation method for the RA. This internship report explores the technical aspects underlying the RA and aims to assess commonly found computational methods, from quantiles measures – like the Value-at-Risk, Tail-Value-at-Risk and the Proportional Hazard Transform – to existing risk measuring techniques, such as the Cost-of-Capital approach.

From illustrative examples for both non-life and life products, it is possible to conclude that insurance contracts with more volatile cash flow trends have wider probability distributions of future losses, given an increase in uncertainty, which result in higher RA estimates. For the non-life product, the Bootstrap method is also applied - prior to the risk measures - to stochastically generate a probability distribution function of losses.

Keywords: IFRS 17, Risk Adjustment, Risk measures, Cost-of-Capital, Quantile techniques, Stochastic methods, Bootstrap.

Resumo

A norma contabilística IFRS 17 foi publicada a 18 de maio de 2017 com o objetivo de aumentar a comparabilidade entre contratos de seguros por todo o mundo. O Ajustamento de Risco (AR) é introduzido no novo requisito como o elemento que reflete a compensação requerida pela entidade para suportar a incerteza associada a riscos não financeiros quanto ao montante e *timing* dos fluxos de caixa.

Sendo *principles-based*, a IFRS 17 não estabelece um método específico para calcular o AR. Este relatório de estágio explora os detalhes técnicos subjacentes ao AR e procura avaliar os possíveis métodos de computação, desde técnicas de quantis, como o *Value-at-Risk*, o *Tail-Value-at-Risk* e o *Proportional Hazard Transform*, bem como outras medidas de risco utilizadas presentemente, como o método do *Cost-of-Capital*.

A partir de exemplos ilustrativos para produtos de não-vida e vida, é possível concluir que contratos de seguro com tendências de fluxos de caixa mais voláteis tendem a gerar distribuições de probabilidades de fluxos futuros mais “largas”, dada uma maior incerteza sobre os mesmos, o que resulta num maior valor de AR. Para o produto de não-vida, foi utilizado o método de *Bootstrap* para gerar estocasticamente a distribuição de probabilidades de fluxos futuros.

Palavras-chave: IFRS 17, Ajustamento de Risco, Medidas de risco, *Cost-of-Capital*, Técnica dos quantis, Métodos estocásticos, *Bootstrap*.

Acronyms and Abbreviations

RA	Risk Adjustment
AR	Ajustamento de Risco
M&RC	Management and Risk Consulting
IFRS	International Financial Reporting Standards
IASB	International Accounting Standards Board
FCF	Fulfilment Cash Flows
CSM	Contractual Service Margin
VaR	Value-at-Risk
TVaR	Tail-Value-at-Risk
PHT	Proportional Hazard Transform
CoC	Cost-of-Capital
LoB	Line of Business
GMM	General Measurement Model
BBA	Building Block Approach
VFA	Variable Fee Approach
LRC	Liability for Remaining Coverage
LIC	Liability for Incurred Claims
PAA	Premium Allocation Approach
P&L	Profit and Loss Statement
MCMC	Markov Chain Monte Carlo
SCR	Solvency Capital Requirement
CTE	Conditional Tail Expectation
WACC	Weighted-Average Cost of Capital
EVA	Economic Value Added
EIOPA	European Insurance and Occupational Pensions Authority
BEL	Best estimate of the liability
IFIE	Insurance finance income or expenses

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1. Introduction

The present report discloses the activities and content developed within the scope of projects of the Management and Risk Consulting (M&RC) department, throughout a six-month internship at KPMG Lisbon. This paper explores in detail the element of Risk Adjustment (RA), introduced by the new International Financial Reporting Standards (IFRS) 17 [1].

Following the creation of the Insurance project in 1997, the International Accounting Standards Board (IASB) [2] set out to develop the IFRS for the insurance industry in two phases. Phase I consisted on the development of the IFRS 4 [3], a preliminary standard, which was released in 2004. Then, in May of 2017 the IASB issued IFRS 17, which would be the last phase of the project. After being postponed two years from the original date, the effective date for the transition is now set for 1 January 2023.

Under the new standard, companies are expected to quantify and disclose the level of non-financial risk underlying their liabilities. IFRS 17 defines the RA as an adjustment to the estimate of the present value of cash flows, in order to "reflect the compensation that the entity requires for bearing the uncertainty about the amount and timing of the cash flows that arise from non-financial risk" [IFRS 17.37].

IFRS 17 is a *principles-based* standard, which implies a certain level of subjectivity underlying some of its concepts. Although the concept of the RA is defined in the norm, there are no prescribed methods for its calculation. Consequently, insurers are expected to develop techniques that best fit their degree of risk aversion. In order to construct useful and comparable information about the financial performance of companies, IFRS 17 requires insurers to disclose their approaches in an auditable fashion.

During the present internship, it became key to approach the upcoming challenge that insurers face when determining the RA for their insurance contracts. Thus, the main goal

[1] [15] https://www.ifrs.org/issued-standards/list-of-standards/ifrs-17-insurance-contracts/
[2] https://www.ifrs.org/groups/international-accounting-standards-board/
[3] https://www.ifrs.org/issued-standards/list-of-standards/ifrs-4-insurance-contracts/

of this study is to introduce explainable and suitable estimation techniques for the RA, given the criteria proposed by the norm and expected results.

For a better understanding of this new element and its main impacts, one must first understand the grounding concepts proposed by IFRS 17. Thus, in Chapter 2, insights are provided regarding the so-called Fulfilment Cash Flows (FCFs - which include the expected future cash flows, discount rates and the risk adjustment for non-financial risks) and the Contractual Service Margin (CSM). Furthermore, IFRS 17 measurement models are also briefly introduced and discussed, as the choice of model may impact the calculation of the RA.

Chapter 3 focuses on the theoretical background regarding the RA. It closely follows what is expected of this element, according to what is proposed in the norm. In fact, despite not giving precise guidelines on the calculation techniques, IFRS 17 introduces relevant criteria to be followed when estimating the RA, relating for instance to the sensitivity of results to any possible variable that might alter the certainty of cash flows.

Having a practical perspective in mind, potential estimation techniques are explored in Chapter 4. Using risk measures as selection methods, this report discusses the applicability of the Value-at-Risk (VaR), Tail-Value-at-Risk (TVaR) and the Proportional Hazard Transform (PHT) to determine the RA. All of these rely on a distribution of discounted FCFs, which will require generating methods to be obtained. Additionally, the Cost-of-Capital (CoC) method is studied whilst taking the opportunity to analyse the viability of synergies between the Solvency II's Risk Margin and the RA.

Chapter 5 focuses on methods for quantifying and allocating diversification benefits for a given RA estimate, as explicitly required in the norm. Given the accounting aim of the IFRS 17, further detail on the presentation of the RA in the statement of financial position is presented in the last section of the chapter.

To sum up, this report is the emerged combination of the mathematical and accounting knowledge acquired throughout the master at ISEG with the practical experienced gained in internship at KPMG Lisbon. It explores one of the most pressing topics for insurers, the RA for non-financial risk, as the industry meets IFRS 17's transition date.

2. Overview of the norm

2.1 Scope and key features of the IFRS 17

The main aim of the new standard is to create a common level-playing field, therefore allowing for unconstrained competitiveness between entities within and across borders. *Transparency*, through increased comparability and the quality of the financial information, *accountability*, through the narrowing of the information gap, and *economic efficiency*, by leading to sounder investment decisions, and thus to more efficient capital allocation, are the three key concepts underlying the development of the IFRS 17 [3].

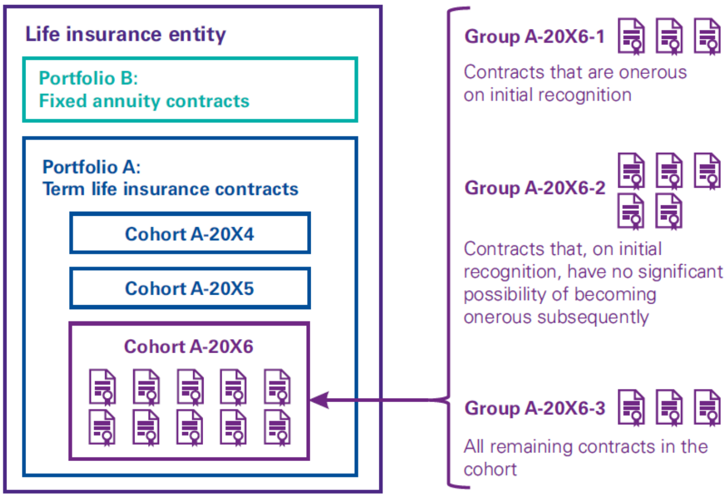
Many firms within the Portuguese market have taken the past years to implement Solvency II, the current European regulation for capital requirements, and thus are looking for possible ways to use similarities between this regime and IFRS 17, to take in the changes that the new norm will impose. However, one must first look into what makes these regimes diverge before potentially using Solvency II inputs. The main differences in requirements between Solvency II and IFRS 17 are greatly due to the distinct purposes of the two regimes. Whilst Solvency II has an economic focus, that is, it releases information relating to the financial health of the insurer on a balance sheet date, IFRS 17 is also focused on analysing the state of the firm throughout a given period, having more of an accounting view.

IFRS 17 starts by defining insurance and reinsurance contracts whilst setting several criteria to assess each particular contract - which will be determinant when applying the norm - highlighting the importance of separating components within contracts, concerning the type of underlying risks. Specific types of contracts, such as self-insurance, are stated and ruled out from the application of the norm [IFRS 17. B27].

It also defines the level of aggregation at which the measurement of contracts must be performed – illustrated in Figure 1. In a nutshell, what is expected is that companies should first separate contracts at a portfolio level, considering contracts with similar risks and that are managed in the same way. Then, one must separate contracts within the same portfolio into cohorts, that is, each group of contracts must only comprise contracts that were underwritten within a period of 12 months, maximum.

Finally, to reach the level established by IFRS 17, and to define a group of contracts according to the norm, one must split the previous level according to the performance of the contracts. For such, one should separate the contracts at initial recognition into a minimum of three groups: (1) onerous; (2) with no significant possibility of becoming onerous subsequently; (3) and the remaining contracts [IFRS 17.16]. Understanding these first concepts will be important when we discuss the level of aggregation of the RA.

Figure 1 - Example of a possible aggregation of contracts into groups.

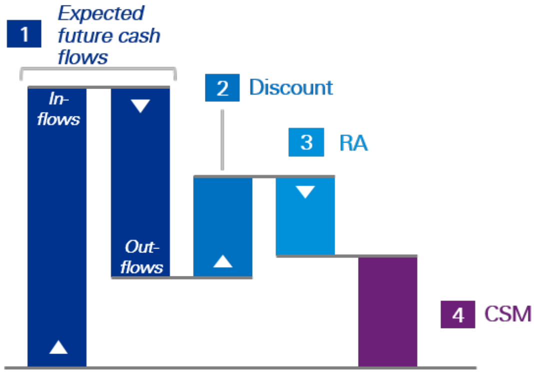


Source: KPMG (2017) First Impressions

The norm then provides information regarding the initial recognition of the previously defined insurance contracts – and by recognition it means the process of assessing a group of contracts and giving it a value in terms of responsibilities and expected profit. For that, one must first understand the technical terms and the key elements used in this initial measurement, as well as how the impacts are correlated. At this point, the concept of Fulfilment Cash Flows is introduced as the probability-weighted average of the future insurance contract's cash flows, discounted to the present time and adjusted for non-financial risk.

The FCFs comprise three main elements: expected future cash flows, discount rates and the RA, illustrated in Figure 2. A description of these elements, along with the concept of *Contractual Service Margin* will be introduced next.

Figure 2 - FCFs at Initial Recognition according to IFRS 17.



Source (adapted): KPMG (2017) First Impressions

i. Expected future cash flows

The expected future cash flows of the insurance contract are the probability-weighted estimates of the future cash outflows less the future cash inflows that arise with the fulfilment of the contracts strictly within its boundaries [IFRS 17.33]. Paragraph 33 of the norm also states that the estimates may be calculated at a "*higher level of aggregation*", for example, at each Line of Business – and afterwards the resulting FCF's would be allocated to individual groups of contracts, as defined previously.

In practical terms, all the cashflows of a period $]t-1,t]$ are reported to the end of the period. An insurer may have, for instance, some of the following cash flows:

$$CF_t = Surr_t + Claim_t + Mat_t + Comm_t + Exp_t - Prem_t - Inv_t \tag{1}$$

In (1), CF_t stands for the expected cash flows at time t, $Surr_t$ stands for the expected value of surrenders, $Claim_t$ is the expected claim payments, Mat_t stands for expected value of maturities, $Comm_t$ represents the expected value of commissions, Exp_t stands for the expected value of expenses, $Prem_t$ is the expected premium and Inv_t stands for the expected value from investments' returns.

ii. Discount Rates

The discount rates shall adjust future cash flows in order to reflect the time value of money and the underlying financial risks, to the extent that these are not included in the calculation of the estimates of the cash flows. Indeed, the estimates of cash flows alone are required to exclude any adjustment for both financial and non-financial risk. [IFRS 17.33d)]

The discount rate is set such that it mirrors the main characteristics of the cash flows in terms of both currency and liquidity features of the contract. In order to diminish mismatches between the insurer's liabilities and the instruments underlying the discount rates, the rates must be consistent with current observable market prices for financial instruments. This implies excluding factors that affect the market prices but do not influence the liability of the contracts and including features that characterise both [19].

Once one has CF_t, cf. (1), and the discount rate in force for period $[t-1, t[$, let it be r_t, $t = 1, \dots, T$, *T* being the maturity of the contract liabilities, it is now possible to calculate the present value of the expected future cash flows, defined by the variable P in the equation below:

$$P = \sum_{t=1}^{T} \frac{CF_t}{(1+r_t)^t} \tag{2}$$

iii. Risk Adjustment for non-financial risk

The third element of the, so-called, *building block* is the RA for non-financial risk. This element is defined as the compensation that the entity requires for bearing the uncertainty about the amount and timing of the cash flows that arises from non-financial risk, as defined in IFRS 17.37. Further explanation can be found in the Appendix B86-B92 of the norm.

However, besides this definition and some criteria concerning the expected results, there are neither prescribed calculation techniques for the Risk Adjustment nor a model to account for diversification benefits. There is, however, a requirement to disclose the implied confidence level of the method used to calculate the RA. If the entity uses an alternative technique to the confidence level technique, IFRS 17 requires it to describe the method used and disclose the corresponding confidence level underlying the results of the chosen method [IFRS 17.119]. Finally, there is also the implicit requirement that the method should be comfortably interpretable and efficient in its purpose.

Having defined the RA as a liability, we use equation (2) to set the equation for the FCFs in (3):

$$FCF = P + RA \tag{3}$$

That is, at initial recognition, the FCFs of the group of contracts under measurement is the present value of future expected cash flows combined with the Risk Adjustment that is calculated for that group of contracts. Thus, even though the estimates of the future expected cash flows are explicit, the FCFs are adjusted for financial risk through the discount rate and for the remaining risks through the RA.

iv. Contractual Service Margin

Finally, after having estimated the FCFs, one can now set a CSM if there is an expected profit (depending on how it is defined, it could be when we have a negative liability i.e. FCF < 0). The CSM is seen by practitioners as the most innovative element introduced by the norm, since there is no similar concept in the current standards, making its calculation a challenging step as insurers transit to IFRS 17. It is defined in IFRS 17.43 as "the profit in the group of insurance contracts that has not yet been recognised", that is the unearned profit that is expected at initial recognition, after the calculation of the FCFs, but that (according to IFRS 17) must not be immediately recognised.

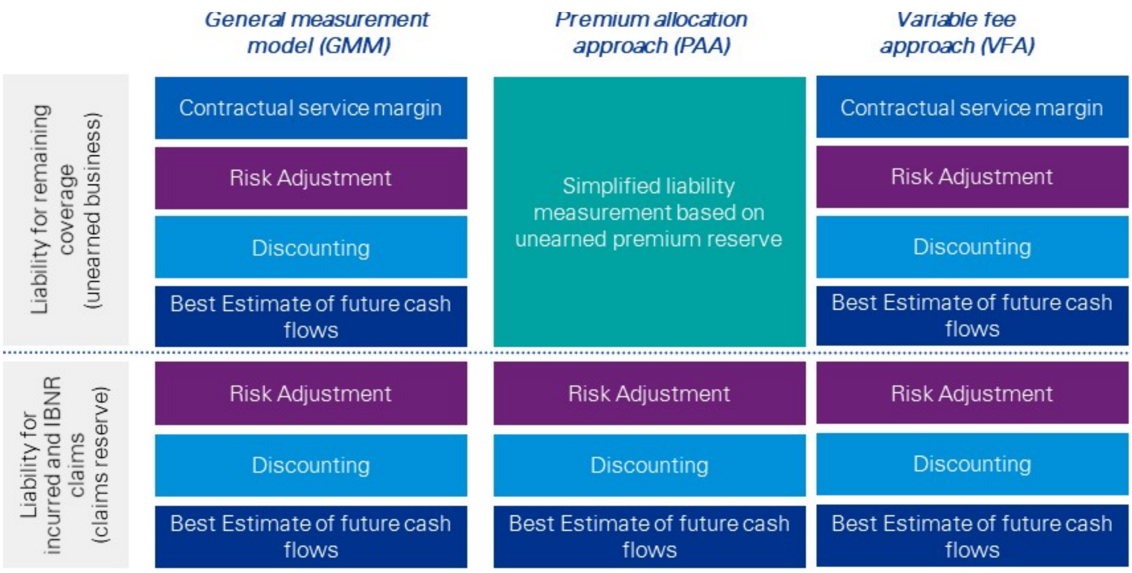
Indeed, the release of the CSM shall be done as the insurance service is provided in each period. To determine the release of the CSM, the norm requires the calculation of *coverage units*, which are illustrative values that should represent the pattern of the release of risk. Once again, there is no specified method for the calculation of *coverage units*, but the norm states that these must reflect the quantity of benefits – which relates to the amounts that can be claimed by the policyholder under the contract – and the expected coverage period, including expected lapses and terminations as well as the probability of insured events that would affect duration of the contract [19].

v. Measurement models of the liabilities under IFRS 17

So that one may later understand when the RA is applied, and for what type of contract liabilities, we must first briefly resume the three possible measurement models under IFRS 17 – illustrated in Figure 3. IFRS 17 base model is set as the General Measurement Model (GMM), also known as the Building Block Approach (BBA). It can be applied to almost all types of contracts, except the ones with *direct participation features*[4], which will fall into the Variable Fee Approach (VFA). The VFA is rather close to the GMM, except in the calculation of the CSM[5].

It is important to retain that both methods separate the measurement of liabilities into Liability for Remaining Coverage (LRC) and Liability for Incurred Claims (LIC). As per IFRS 17.40, the LRC corresponds to the entity's obligation concerning insured events related to the unexpired portion of the coverage period, whereas the LIC relates to the entity's obligation to investigate and pay claims for insured events that have already occurred, which includes events that have occurred but have not been reported and other incurred insurance expenses [19].

Figure 3 - Measurement models for liabilities under IFRS 17.



Source: Author's, based on an internal KPMG document.

Additionally, the norm presents a third model referred to as the PAA (Premium Allocation Approach) to be applied mostly to short-term contracts (12 months). This method is seen as operationally less complex and closer to current IFRS 4 reserving, particularly as it allows the firm to hold the unearned premium as a simplification for the LRC, whilst the LIC is constructed analogously to the GMM. Thus, for non-life products, as they are typically short-term, the PAA can be applied and so the RA will be only calculated for the

[4] Defined generally in the norm as "insurance contracts that are substantially investment-related service contracts under which an entity promises an investment return based on underlying items". Typically includes contracts with unit-linked features. For more detail see IFRS 17.B101.
[5] Detail on this difference is not relevant for the topic of the RA.

LIC – which will notably simplify the calculation. In fact, given that the LRC will be calculated as a simplification of the unearned premium reserve, a risk adjustment is not explicitly calculated [9].

2.1 Main impacts

Having introduced the grounding concepts of IFRS 17, it is relevant to start looking at the possible direct and secondary impacts that the introduction of this new accounting standard will have on the sector and globally on the whole economy. According to the IFRS Foundation's Fact Sheet [14], it is estimated that more than 450 insurers listed in the stock market worldwide will be using the new standard, which is expected to have an impact on their total assets of 13 trillion USD.

IFRS 17 will determine how comparability between firms can be achieved, providing some perception into the financial strength of the insurer. This is because the norm will mostly impact the accounting for the financial performance within each firm in the sector; how they interpret the standard will be vital to how they reach their financial results.

The most concerning consequence of the norm is strongly related to its intrinsic subjectivity, which will allow for heterogeneity in financial results and equity. Indeed, this will occur mostly due to the lack of requirements (only *principle based*) and properly defined methods to calculate discount rates. This will have a direct effect on the valuation of Balance Sheet and Profit or Loss Statement (P&L) items. There might be a need to reallocate investments and redesign products so as to align assets and liabilities – as mismatches become noticeable. Furthermore, the insurer's perspective concerning its investments will additionally change, as premiums are no longer recognized as revenue at an initial moment, but instead are released over time.

3. Theoretical background on the Risk Adjustment

3.1 The Risk Adjustment

The IFRS 17 standard defines the RA by stating that “an entity shall adjust the estimate of the present value of the future cash flows to reflect the compensation that the entity requires for bearing the uncertainty about the amount and timing of the cash flows that arises from non-financial risk" [IFRS 17.37].

Therefore, the RA is the extra amount of liabilities that it is added to the present value of all expected future cash flows, such that the sum is enough to cover the present value of all expected future cash flows in case of a shock. As stated previously, there is no prescribed method for the calculation of the RA, nevertheless there is a set of criteria to which the chosen RA must comply, see Section 3.1.1 for more details.

Additionally, it is necessary to disclose the confidence level corresponding to the RA, in order to increase transparency and allow comparability between financial reports of insurers using different estimation methods. The choice of the confidence level relates to the amount of compensation that an entity requires, given the non-financial risk that it is undertaking for each group of contracts. Being *principles-based*, the norm also leaves an area of uncertainty regarding the risks and the contracts in scope.

3.1.1 Criteria and requirements

Despite the lack of estimation techniques for the RA, IFRS 17 prescribes a set of characteristics - from paragraphs B86 to B92 in the norm’s Annex – which should be considered as part of its determination. Most importantly, for the calculation of the RA it is paramount that the results reflect the degree of uncertainty and risk underlying the insurance contracts’ liabilities. Paragraph B88 in the norm’s Appendix states two important requirements that estimates of the RA must attend to:

a) *“the degree of diversification benefits the entity includes when determining the compensation it requires for bearing that risk; and*
b) *both favourable and unfavourable outcomes, in a way that reflects the entity’s degree of risk aversion.”*

In the following paragraphs, five criteria are discussed with the aim of summarising the required implicit characteristics [18].

Criteria 1: Diversifiable

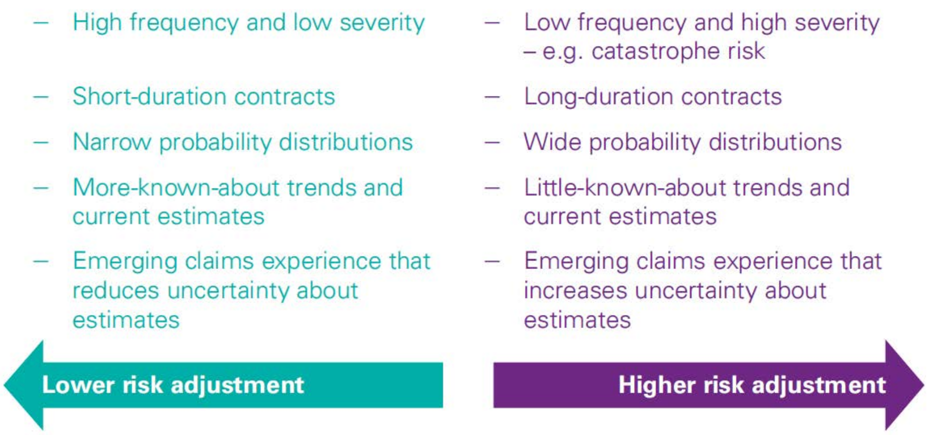
The first requirement is paramount, as the concept of diversification is very much present in former legislation, such as in Solvency II. As insurers' portfolio of risks widens, and more correlated risks are pooled, then the expected value of outflows in case of a shock will likely be smaller than if the risks were to be covered separately. These changes in the adjustment of the liabilities, as the portfolio gets diversified, shall be reflected in the estimate of RA. See Chapter 5 for further detail on how to measure and allocate possible diversification benefits.

Criteria 2: Technically sound

The second requirement is again a familiar concept for insurers everywhere. As expected, the considered "risk" must correctly consider favourable and unfavourable outcomes and should be set such that it reflects the risk appetite of the insurance company.

Additionally, and promoting technically sound results, the norm also states that, given that the measure aims to reflect the compensation that the entity requires for bearing non-financial risks, then the outcome of its calculation shall mirror the relationships and effects of variables on non-financial risks [IFRS 17.B91] displayed in Figure 4.

Figure 4 - Risk Adjustment results' criteria.



Source: KPMG (2017) First Impressions.

Thus, regardless of the method that each company chooses to calculate the RA, what is required by the norm is that, given certain changes in the characteristics of the input data (that is, variations that impact the level of uncertainty on the amount and timing), the outcome should also change accordingly.

So, for example, if a Portuguese insurance company has a group of contracts covering the damage by an earthquake (low frequency, high severity), its RA should be higher than the RA for damage by rain, if both risks yield the same expected future cash flows. The same for the RA for contracts with durations of 20 years versus two years, as the timing of the payments is less certain in long-term contracts, such as in life insurance. In terms of probability distributions, for example, if the risk of getting disabled for insured people in Portugal follows a normal distribution and in the UK this risk follows a student-t distribution (wider), then the RA for disability risk in Portugal should be lower than in the UK. Also, if there is more data available for the timing of becoming disabled in Lisbon than in Porto, for instance, then the RA for disability risk for insured people in Lisbon should be lower. Finally, as more data becomes available about the timing of disability, the RA for this risk should decrease.

Criteria 3: Consistent

Paragraph B53 of the norm describes the relationship between market and non-market variables. In fact, it is common to observe a correlation between, for example, lapse rates (a non-market variable) and the interest rates (market variable), as illustrated in the concept of the illiquidity premium. Thus, the RA must be consistent with the observed market prices and market variables which it depends on.

Criteria 4: Allow for comparability

Paragraph B92 states that an entity should choose a technique for the calculation of the RA such that it "*provides concise and informative disclosure so that users of financial statements can benchmark the entity´s performance against the performance of other entities*". This requires entities to either use confidence level techniques or, if they choose not to, to disclose the chosen technique and the corresponding confidence level for that technique. Therefore, it might be preferable to choose a well-known method, for example the VaR, which is already in use in Solvency II, since its interpretation is familiar for both internal and external stakeholders.

Criteria 5: Calculated only for non-financial risks

According to Paragraph B86, the RA shall only be calculated for non-financial risks, i.e. "*risk arising from insurance contracts other than financial risk*". Note that the concept of risk relates to how the entity perceives uncertainty regarding the amount and timing of future cash-flows, compared to the expected amount.

It follows that non-financial risks are the risks that might affect the expected future cash flows (*and are not financial risks*[6]), meaning it is expected to include mortality, disability, longevity, expense, revision, lapse, catastrophe and premium and reserve risk. Each group of contracts will be exposed to only a subset of these risks as illustrated in Table 1.

Table 1 - Non-financial risks for insurance products.

Insurance product	Mortality	Longevity	Disability	Expense	Lapse	Catastrophe	Premium and reserve
Life annuities		X		X			
Deferred annuities		X		X			
Term life single premium	X		X	X	X	X	
Universal life	X		X	X	X	X	
Savings	X	X		X	X	X	
Term assurance	X		X	X	X	X	
Pure endowment	X		X	X	X	X	
Endowment	X	X	X	X	X	X	
Liability insurance					X	X	X

Source: Author's, based on an internal KPMG document.

3.2 Relationship between the elements of the building block and the RA

The FCFs together with the CSM constitute the value of an insurance contract. Indeed, the CSM is defined such that no initial expected profit is recognised. Hence, the CSM at initial recognition must be set symmetrically to the FCFs, given that it can never be less than zero. That is, at initial recognition:

$$CSM = -Min\{FCF, 0\} \tag{4}$$

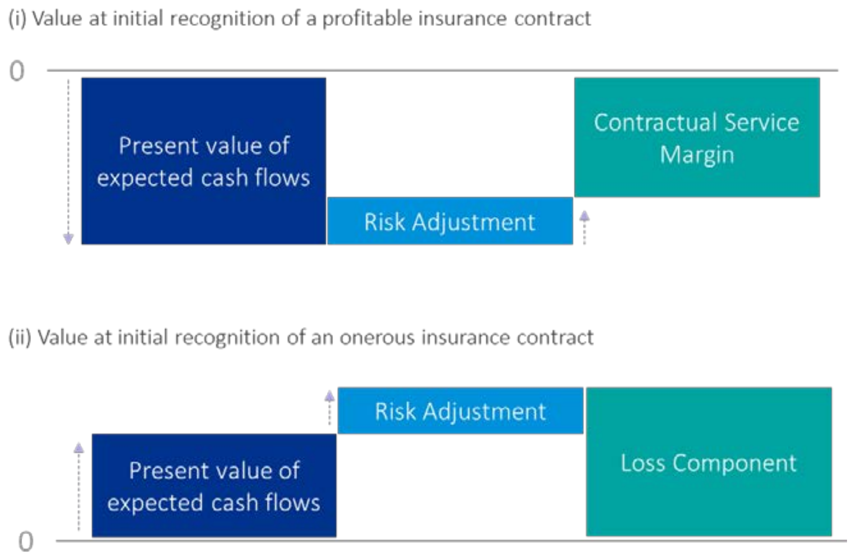
The negative sign comes from the fact that there will only be a CSM when $FCF < 0$, i.e. there is an expected profit. If the FCF s are positive i.e. when $(P + RA)$ is greater than

6 Financial risk is "the risk of a possible future change in one or more of a specified interest rate, financial instrument price, commodity price, currency exchange rate, index of prices or rates, credit rating or credit index or other variable" [IFRS17. Appendix A Defined Terms].

zero, there is no CSM and there is a *Loss component* for that group of contracts - now considered *onerous* - which is immediately recognised in the P&L.

Hence, it is possible to understand that, at inception, the RA will impact the CSM directly, since a higher RA will decrease the CSM, as it increases liabilities. Contrarily, if there is instead a *Loss Component* for the given group, the RA will be positively related to it, meaning that the *Loss Component* will increase with the RA (see Figure 5).

Figure 5 - Relation between the elements of the FCFs and its impact on the initial valuation of insurance contracts.



Source: adapted from Koetsier (2018)

Notwithstanding, in subsequent measurements, as both the RA and the CSM are recalculated, the RA will impact the CSM through changes that only relate to future services, since the changes in the RA relating to past and current services will be released through P&L.

Thus, the RA will impact the accountability of the financial performance of the group of contracts throughout their lifetime, either through the *release of risk* or through the adjustments to the CSM on each subsequent period. Considering the lack of prescribed method to perform its calculation, combined with the disclosure requirements present in the norm, one can foresee the possible implications that such element may bring to insurers, as they interpret and make choices regarding possible estimation techniques for the RA, and how it might greatly impact their financial results and overall industry comparability.

4. Estimation Techniques for the Risk Adjustment

4.1 Probability distribution generating methods

If an entity chooses to calculate the RA using confidence level techniques, as suggested in IFRS 17.119, through the application of a risk measure to a given risk profile, it is important to separate two main moments. First define the risk profile which can be obtained by generating a probability distribution of the discounted fulfilment cash flows. Second, after the risk profile is defined, apply a preferred risk measure.

The process of obtaining a probability distribution of a given random variable X requires simulation techniques, such as the bootstrap method, and can be summarized in the four main steps below [17], where n is the (preferably large) number of simulations:

1. Construct a model for X that depends on random variables Y, Z, …, where their distributions and any dependencies are known;
2. For $j = 1, \dots, n$ generate pseudorandom values y_j, z_j, … and then, using the model from step 1, compute x_j;
3. The probability distribution function may be approximated by $F_n(x)$, the empirical probability distribution function based on the pseudorandom samples $x_1, x_2, \dots, x_n$;
4. Calculate quantities of interest, like the mean, variance, quantiles or probabilities using the empirical probability distribution function.

There are several stochastic approaches that insurers may use to model the fulfilment cash flows. The Monte Carlo simulation, for instance, consists in repeatedly simulating a random process for risk variables given an underlying distribution. Consider we are trying to simulate mortality and lapse decrements for a Life product in a given year, assuming binomial distributions. Then, according to the Monte Carlo simulation, a random number is generated and compared to the existing mortality rate to check whether this policy is terminated by death. If this year the policy is not to be terminated by death, then another random number is simulated and compared to the existing lapse rate, to check whether this policy is terminated by lapse. This algorithm is then performed repeatedly to generate a distribution for the risk relating claims [16].

Additionally, insurers could use methods such as the Bootstrap or Mack resampling, or even the MCMC (Markov Chain Monte Carlo) simulation method, to generate the probability distribution required for the calculation. However, and for the rest of this report, we will focus on the Bootstrap method of replication, as many insurers are already familiar with the bootstrapping of non-life triangles. The Bootstrap is a resampling procedure where historical information is used to generate scenarios stochastically. Instead of using a hypothetical distribution to start with, this method uses historical observations, in order to compute possible future observations. It is mostly used in stochastic generating scenarios for capital market related variables – such as interest rates, equity index prices, etc. This method provides a good approximation to the real probability distribution of the risks for large samples and it relies mostly on the fact that each sampled *pseudorandom* variable is independent from another. In terms of disadvantages, it might provide a poor approximation for small samples. Also, historical observations might not adequately represent the volatility of outcomes for future cash flows, which is especially critical for high severity, low frequency outcomes [16].

The Bootstrap method is currently performed by insurers to validate reserves estimates calculated using the Chain Ladder approach. For this purpose, this method is used to simulate random outcomes of both past and future claims (i.e. the so-called *pseudorandom* samples) using a sample of Chain-Ladder residuals to which it is applied the prediction method (in this case, the Chain-Ladder method). It is then possible to compare the simulated outcomes of future claims with the simulated predictions to assess its reasonability [21]. We will see a practical application of the Bootstrap method in the calculation of the RA in Section 4.4.1.26

It is important to note that traditional approaches to reserve risk, like the bootstrapping of a paid loss triangle, usually only consider paid or incurred amounts. For IFRS 17, it is necessary to consider all fulfilment cash flows, which also include premiums and expenses. A possible way to mitigate this could be to perform traditional stochastic methods for loss amounts and then simply adjust for premiums and expenses.

Alternatively, one could first try to obtain a single triangle of the fulfilment cash flows for the group of contracts under consideration, and then apply the traditional stochastic reserving techniques. Or, for a more sophisticated approach, users could attempt at determining distributions of all component cash flows and then combine them using an appropriate dependency structure, such as copulas [14].

4.2 Risk measures as selection methods

Once obtained the probability distribution of the present value of future cash flows, the risk associated to these cash flows can be measured using a chosen risk measure, for a given confidence level. Finally, the RA will be the difference between the value obtained by the measure and the probability's mean.

First let us introduce two important definitions to further study risk measures. The definition of a *coherent* risk measure in Artzner et al (1999) [1] is the following:

Definition 1: Consider a statistical measure $f: F \rightarrow \mathbb{R}$, where $F \in \Omega$ is the set of all risks. A statistical measure is defined as *coherent* if it satisfies the following properties:

i. *Monotonicity*. For all $X \, and \, Y \in F$ with $X \leq Y$, $f(X) \leq f(Y)$;
ii. *Sub-additivity*. For all $X \, and \, Y \in F$, $f(X + Y) \leq f(X) + f(Y)$;
iii. *Positive homogeneity*. For all $\lambda > 0$ and all $X \in F$, $f(\lambda X) = \lambda f(X)$;
iv. *Translation invariance*. For all $X \in F$ and all $\alpha \in R$, $f(X + \alpha) = f(X) + \alpha$.

Now, let us provide the definition of a quantile [6]:

Definition 2: The *p*-th quantile of a given random variable X (or of its corresponding distribution function F_X) is denoted as π_p and it is defined as any value such that:

$$F_X(\pi_p^-) \leq p \leq F_X(\pi_p), 0 < p < 1 \tag{5}$$

4.2.1 Value-at-Risk (VaR)

The Value-at-Risk technique is used under Solvency II for the calculation of the Solvency Capital Requirement (SCR) according to its Standard Formula. Following Definition 2, the VaR's definition is [6]:

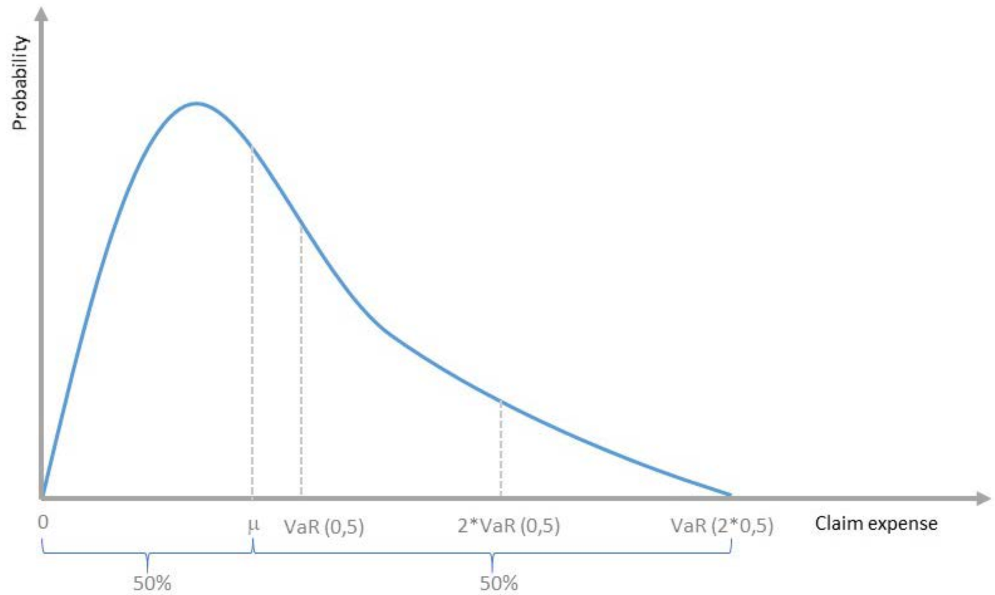
Definition 3: Given a risk X and a probability level p, the corresponding VaR, denoted as $\boldsymbol{VaR_p(X)}$ is the *p*-th quantile of X.

Then, the RA is the difference between the future cashflows in case of shock and the average future cashflows. In practical terms, for a given confidence level p, it is calculated as follows:

$$RA = VaR(p) - \mu \tag{6}$$

where μ is the mean of the probability distribution, which is only equivalent to the $VaR(0{,}5)$ for symmetric distributions. See Section 4.4.1 for a practical example of this calculation. In terms of its properties, the VaR is cash-invariant, positively homogenous and monotone. However, it is not sub-additive, hence it is not a statistically *coherent* measure, according to Definition 1 (Figure 6).

Figure 6 - Properties of the VaR.



Source: Author’s.

4.2.2 Tail-Value-at-Risk (TVaR)

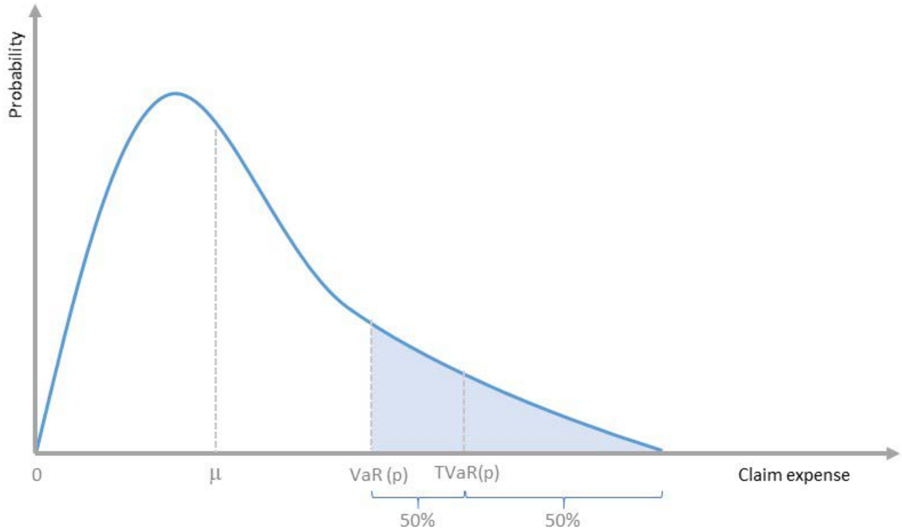
An alternative to the VaR would be to use the Tail-Value-at-Risk, which satisfies all the properties of a *coherent* risk measure. The formula is given by the following definition [6]:

Definition 4: The Tail-Value-at-Risk of a risk X, at confidence level $0 < p < 1$, is:

$$TVaR = \frac{\int_p^1 VaR_u(X)\,du}{1-p} \tag{7}$$

Thus, as illustrated in Figure 7, TVaR risk measure is the probability-weighted average of all amounts of VaR above the confidence level p.

Figure 7 - Properties of the TVaR.



Source: Author's.

Again, since the RA is the extra amount that the insurer would have to pay in case of shock, it is given by the formula:

$$RA = TVaR(p) - \mu \tag{8}$$

For a continuous random variable X, the TVaR can also be called as the Conditional Tail Expectation, $CTE_p(X)$, as it is possible to derive:

$$TVaR_p(X) = CTE_p(X) = E\left[X|X > \pi_p\right] \tag{9}$$

4.2.3 Proportional Hazard Transform (PHT)

Current references [4] present the Proportional Hazard Transform[7] as a third possible risk measure to calculate the RA. The PHT is seen as particular case of the Risk Adjusted Premium Principles, in Risk Theory [6]. Thus, the formula for the risk adjusted premium, under the PHT, for a given $p \geq 1$, is the following:

$$Risk\ Adjusted\ Premium = \int_0^{\infty} [1 - F_x(u)]^{1/p} du \tag{10}$$

[7] Wright (1997) introduced the idea of using the PHT developed by Shaun Wang in 1996 for measuring a prudential margin, such as the RA.

Once again, for the calculation of the RA, one would have to take the difference between the Risk Adjusted Premium, that is, the future cash flows in case of shock and the average future cash flows.

Take, for example, an insurance product with a distribution of claims to which we would like to fit a Pareto distribution. Using the method of moments, given that we have the mean and the variance of a sample of claims – that is, $E(X)$ and $Var(X)$, respectively - we could solve the following equations to find the parameters for the $Pareto(\alpha, \theta)$:

$$E(X) = \frac{\theta}{\alpha - 1} \tag{11}$$

$$Var(X) = \frac{\theta^2 \alpha}{(\alpha - 1)^2(\alpha - 2)} \tag{12}$$

Then, since the probability distribution function of the Pareto is given by $F_X(x) = 1 - \left(\frac{\theta}{\theta + x}\right)^\alpha$, we could calculate the Risk Adjusted Premium, for a given level p, as follows:

$$Risk\ Adjusted\ Premium = \int_0^\infty \left(\frac{\theta}{\theta + x}\right)^{\alpha/p} dx = \frac{\theta}{\frac{\alpha}{p} - 1} \tag{13}$$

Then, the RA is calculated as the difference between the Risk Adjusted Premium and the expected value of the distribution of claims, $E(X)$. For insurers using the PHT, it would be necessary, not only to disclose the level p used for the method, but also what the equivalent level would be in terms of confidence levels, that is, what would be equivalent in percentage if we were using a percentile method.

4.3 Cost-of-capital method

4.3.1 Description and interpretation of the method

As an alternative to the confidence level techniques, one can consider the Cost-of-capital method. The CoC approach is based on estimating starting and successive capital requirements over the lifetime of the product's obligations. Thus, the RA would be the compensation the entity would require in order to meet a targeted return on that capital. The elements required for this calculation, as per Article 77(5) of Directive 2009/138/EC (Solvency II directive), are the following:

- *Future estimated capital amounts* to project non-financial risk for the duration of the liabilities;
- *CoC rate (s)*, which reflects the relative compensation that the external entity requires for acquiring the capital at risk;
- *Discount rates* to bring the future required compensation to its present value.

These three components are combined in the CoC general formula from which one can calculate the RA in the following way:

$$Risk\ Adjustment = \sum_{t \geq 0} \frac{r_t \times C_t}{(1 + d_t)^t} \tag{14}$$

Where:

- r_t is the CoC rate for period t;
- C_t is the estimated capital amount for period t;
- d_t is the discount rate for period t.

Notice how the numerator of the fraction, $r_t \times C_t$, represents the compensation needed by an entity for holding the capital at risk in period t [7]. Nonetheless, even for a reasonably simple formula, there is a great amount of intricacy involved in the determination of its input elements.

Capital amount (C_t)

First, we will focus on obtaining the initial capital amount. A practical approach could be through simulations-based capital modelling, as it is done under Solvency II. That is, apply Solvency II Standard Formula to generate a shocked cashflow for the given product risks and then take the difference to its best estimate [7].

Then, to obtain future estimates construct the cashflows of capital requirements from the initial amount in proportion to the pattern of the best estimate. This method has the advantage of being operationally easy to implement but could be less accurate. In fact, according to the publications made by the Bank of England on the matter [2], SCRs used to derive the Risk Margin can be approximated as proportional to the projected best estimate, only if no significant misstatement of technical provisions has been shown. In

Section 4.5.2, we will develop this approach with a practical example, assuming proportionality.

An alternative to deriving a proxy is to run the model used for the opening amount (which could be just the Standard Formula for Solvency II) repeatedly, changing the assumptions as the reserves run-off. This approach has the advantage of being more coherent but less easy to perform.

Cost-of-capital rate (r_t)

Traditionally, the CoC rate is set as the Weighted-Average Cost of Capital (WACC) which reflects the rate at which the company is willing to invest its capital or enter in new business. It should reflect the shareholders risk aversion – if the firm requires different compensation for identical risks in different sectors of the business, this difference shall not be reflected in the capital amount, but on the CoC rate [7].[8]

Discount rate (d_t)

According to the standard, the discount rates to be applied to the RA are set internally by each firm. What is important to remember when using the Cost-of-Capital for the RA is that, regardless of the approach used to calculate de discount rates, these must be consistent with the rates that are used to calculate the present value of future cash flows [15].

4.3.2 Comparison between the Risk Margin and the Risk Adjustment

The Solvency II regime describes[9] the calculation of regulatory capital requirements for various classes of assets held. It is important to recall that the main objective underlying this norm is the protection of policyholders and beneficiaries. Solvency II requires technical provisions to be consistent with the amount an entity would have to pay if it transferred its contractual obligations and rights to an external undertaking, effective immediately. It should be based on observable market values and credible and current

8 Under the Solvency II regime, it is defined as the "the additional rate, above the relevant risk-free interest rate, that an insurance or reinsurance undertaking would incur holding an amount of eligible own funds".

9 In Delegated Regulation 2016/467.

information, concerning the financial guarantees and options underlying its insurance contracts [22].

In Article 77.3 of the Solvency II-Directive, the Risk Margin is defined as the amount such that the value of technical provisions matches the amount required by an external entity if it was to take over and meet the obligations underlying its insurance contracts over the lifetime thereof [22]. Article 37 in the Delegated Regulation 2015/35 outlines its exact formula, that is, discounting and valuing all future SCR [10]:

$$Risk\ Margin = \sum_{t\geq 0} \frac{6\% \times SCR_t^{reference\ entity}}{(1+\ r_{t+1})^{t+1}} \tag{15}$$

So far, we notice how the RA and the Risk Margin are different elements but with very similar elemental concepts, according to their definitions. Table 2 summarises the main comparable concepts between the RA and the Risk Margin, in order to evaluate the appropriateness of using the Cost-of-Capital method for the calculation of the RA [12].

In terms of the definitions, both concepts seem to be strongly linked. However, as we interpret the prescribed formula of the Risk Margin, we can point out some important gaps between the two. For example, for the risks in scope, the definition seems to be wider for the Risk Margin as it only filters for non-*hegeable* risks. This will include operational risk, which is specifically excluded for the RA under IFRS 17. Furthermore, financial risks occurring in the long-term might be included if they are not *hegeable* beyond a 30-year time period.

Even though the capital used in the cost of capital is set at the 99.5th percentile over a one-year time horizon, the resulting Risk Margin does not correspond to a 99.5th percentile, as the 6% cost-of-capital rate is applied. Hence, if a firm were to "recycle" this method to calculate the RA, it is important to determine and disclose the resulting quantile. However, obtaining equivalence between the CoC method and confidence level methods certainly adds complexity to this method.

[10] Solvency II-Directive states that the SCR shall correspond to the VaR of the basic own funds of an entity subject to a confidence level of 99,5% over a one-year period [11].

Intense debate has arisen around the propriety of the 6% CoC rate set under Solvency II for the calculation of the RA [12]. Still, there are other metrics that the insurance company could use, depending on its purpose, such as, the economic value added (EVA) which uses an internally defined cost of capital.

In terms of differences arising from the discount rates, for the RA they are to be defined by the firm and the Risk Margin uses EIOPA[11]'s risk free rates.

Table 2 - Risk Adjustment versus Risk Margin.

Caption: Low gap Medium gap High gap

	Risk Adjustment	Risk Margin	Gap
Definition	Compensation that a company requires for bearing the uncertainty about the amount and timing of cash-flows that arise as the entity fulfills the insurance contract	Amount, in addition to the present value of future cash-flows, which would be required by another insurer to take over and meet the insurer's obligations	
Risks in scope	Only includes non-financial risks	It includes all non-hedgeable risks and this ordinarily includes all non-financial risks, including operational risk	
Percentile and time horizon	Level of confidence that relates to the entity's appetite for risk, through the lifetime of the insurance product´s obligations	Although the SCR is calculated using a 99.5th percentile, after applying the cost-of-capital, the Risk Margin will no longer reflect the same percentile.	
Cost-of-capital rate	Not defined	CoC rate at 6%, calibrated to reflect the spread over the risk-free rate for a BBB entity looking for market funding	
Discount rate	Two approaches were introduced for the derivation of the rates. The bottom-up explicitly refers to the risk-free rate, as a starting point.	EIOPA prescribes the risk-free rate to be used under Solvency II	

Source: Author's.

Resuming, since firms are already using the CoC method, it seems like a natural starting point for the calculation of the RA, under IFRS 17. Recycling this method not only reduces reporting efforts but also assures some consistency between the existing regulatory capital and profit accountability. However, the parameters being "recycled" might not be in line with the RA requirements. Plus, it is possible that the disclosing requirements for this method will make the "recycling" more costly.

[11] European Insurance and Occupational Pensions Authority (EIOPA).

4.4 Comparison between estimation techniques

To further complete our analysis, it is important to compare the risk methods, given their intrinsic features. Table 4 organizes the methods' properties into advantages and disadvantages [20].

Table 3 - Comparison between calculation methods for the RA

	Advantages	Disadvantages
VaR	• Easy to compute and understand; • Allows for consistency of results given it is also a risk measure used in Solvency II; • The confidence level is defined at outset, facilitating disclosures.	• Values after the defined threshold are not considered (less fit for skewed distributions with heavy right tales); • Discourages diversification benefits, since it is not a *subadditive* risk measure (not *coherent*); • Relies on the existence of a probability distribution function.
TVaR	• Potentially more efficient at capturing skewness [12]; • *Coherent* risk measure (thus is potentially useful for allocations at lower levels).	• For distributions with a more volatile - or even unpredictable - tail, the TVaR technique is less preferable since it takes all tail values into account; • More complex to compute and less interpretable compared to the VaR; • Relies on the existence of a probability distribution function.
PHT	• Potential to reflect the risk appetite explicitly in a more sophisticated way; • Efficient at capturing skewness; • *Coherent* risk measure (thus is potentially useful for allocations at lower levels).	• May be difficult to explain to non-actuaries and users of financial statements; • Relies on the existence of a probability distribution function of discounted FCFs.
CoC	• Potential to leverage Solvency II techniques and interpretation; • Useful as a benchmarking tool across different firms; • Does not require a probability distribution.	• Requires the determination of the implied confidence level to meet disclosure requirements; • The capital measure and rate of return are not defined under IFRS 17; • Dependent on the SCR if used as capital measure, as in Solvency II.

Source: Author's, based on [20].

Overall, for distributions with heavy and stable tails, the TVaR might be an efficient risk measure to use, as it is coherent and not so complex to understand its interpretation, compared to the PHT. However, to allow for consistency with current solvency practices, the VaR may also be a possible choice as it is not accounting for shape of the tail, that is,

[12] The skewness of a distribution measures the asymmetry of the probability distribution about its mean.

it is efficient as a measure of risk for volatile or more unpredictable tails. Plus, insurers are already familiar with the VaR under Solvency II - one just must be aware for skewed distributions. On the other hand, the CoC method could be the most practical for companies that are able to adjust existing Solvency II techniques – however, determining the implied confidence level to meet disclosure requirements might complicate the process.

4.5 Practical application for non-life and life products

To construct illustrative examples of the methods we have been discussing, it is paramount to first distinguish between non-life and life products, as their intrinsic statistical features greatly impact the possible computing methods.

4.5.1 Non-life product

For illustrative purposes, we shall consider groups of contracts for two insurance products (X and Y). The contracts are assumed to have contract boundaries of 12 months; thus, we can apply the PAA to measure the contract. As explained in Section 2.1, we shall only calculate an explicit estimate for the RA concerning the LIC, given that the LRC is calculated using simplifications. We will discuss group X first and then will move to group Y. Assuming that premiums are all paid in the beginning of each contract, consider the cumulative triangle of payments and attributable expenses as seen in Figure 8.

Figure 8 - Cumulative losses triangle for product X

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
2006	4 702	6 748	6 952	6 996	7 020	7 037	7 039	7 042	7 042	7 042	7 042	7 042	7 042	7 042
2007	4 368	6 151	6 377	6 444	6 480	6 493	6 495	6 496	6 496	6 496	6 496	6 496	6 496	
2008	4 579	7 078	7 316	7 394	7 433	7 485	7 510	7 515	7 515	7 515	7 515	7 515		
2009	4 967	7 540	7 854	7 939	7 978	7 998	8 008	8 013	8 013	8 013	8 013			
2010	5 300	8 215	8 572	8 706	8 767	8 815	8 847	8 857	8 857	8 857				
2011	5 478	7 916	8 278	8 386	8 447	8 480	8 518	8 568	8 568					
2012	6 525	9 987	10 511	10 779	10 897	10 984	11 103	11 136						
2013	7 395	10 904	12 445	13 134	14 152	14 600	14 913							
2014	4 891	9 049	10 025	10 994	11 308	11 546								
2015	6 141	9 573	10 730	11 442	11 876									
2016	6 419	8 888	9 504	9 823										
2017	6 863	10 881	12 301											
2018	5 020	7 846												
2019	5 203													

Source: Author's calculations.

For a simple reserving exercise, we would like to forecast the future claims development, that is, the bottom right corner of the triangle. As we immediately see from looking at the cumulative triangle - and also looking the incremental triangle (Figure 13) - the pattern of losses for this type of product is considerably stable as incremental amounts decrease gradually throughout development years, for all accident years. Plus, cumulative amounts become constant from the 8th development year onwards, thus reflecting a very stable business tail.

Using the Chain Ladder method [13], we calculate age-to-age factors in order to determine an expected loss development pattern (Figure 19). Then, with the obtained development pattern, we can calculate estimates for each next development period and thus find the *ultimate loss* [14]. Then, the *outstanding reserve* (which is an estimate of future payments) is obtained by taking the difference between the *ultimate loss* and the known historical losses (that is, the last diagonal on the cumulative triangle). For this example, we obtain 7167 as our *outstanding reserve*. Now, for the bootstrapping part of this technique, in R, we used the function:

$> \ BootChainLadder(triCum, R = 10000, process.distr = "gamma")$ [15]

Essentially, this function applies a two-stage bootstrapping approach as per England and Verrall (2002) [10]. First, the Chain Ladder technique is applied to the cumulative triangle of losses. Then, using the Chain Ladder results, it calculates the scaled Pearson residuals, which are bootstrapped R times to obtain estimates of future incremental losses, again using the Chain Ladder method. Then, the probability distribution of future losses is obtained by ordering the set of reserves estimated. From this distribution, we can further derive summary statistics of interest [5]. As explained, the RA is calculated by taking the difference between the VaR or TVaR at a chosen confidence level and the mean. Results are shown in Figure 9.

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[13] More details on the Chain Ladder method can be found in the Annex.
[14] The concept of ultimate loss, used in the Chain-Ladder method, refers to the estimate of total payments on a claim. It is the sum of past payments on the claim and its *outstanding reserve*.
[15] The detailed results can be found in the Annex.

Figure 9 - Proposed estimates of the RA under the Bootstrap method for product X

Mean	Confidence level, p	VaR(p)	RA	% (RA / Mean)
6967	60,0%	7 202	234	3,4%
	70,0%	7 538	570	8,2%
	75,0%	7 735	768	11,0%
	80,0%	7 940	973	14,0%
	90,0%	8 549	1 582	22,7%
	95,0%	9 064	2 097	30,1%
	99,5%	10 483	3 516	50,5%

Confidence level, p	TVaR(p)	RA	% (RA / Mean)
60,0%	8 142	1 175	16,9%
70,0%	8 402	1 435	20,6%
75,0%	8 555	1 588	22,8%
80,0%	8 735	1 768	25,4%
90,0%	9 249	2 282	32,8%
95,0%	9 713	2 746	39,4%
99,5%	11 095	4 128	59,3%

Source: Author's calculations.

Now, take the group of contracts Y with the triangle of cumulative losses produced in Figure 10, where we no longer see a regular tail for the losses and the cumulative amounts are no longer steadily decreasing but have big or smaller random jumps – see incremental amounts triangle in Figure 18 of the Annex.

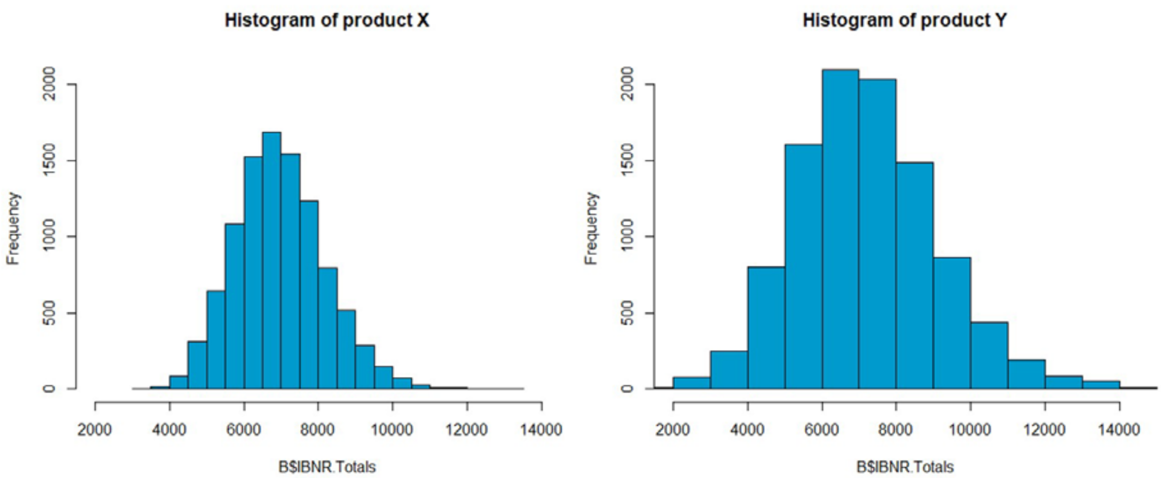
Figure 10 - Cumulative losses triangle for product Y

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
2006	6 271	8 316	8 710	8 722	9 055	9 084	9 108	9 111	9 148	9 153	9 160	9 171	9 197	9 197
2007	5 228	8 380	8 578	8 698	8 814	8 977	9 007	9 014	9 024	9 051	9 066	9 068	9 068	
2008	5 344	6 842	7 234	7 612	7 650	7 832	7 971	8 133	8 168	8 217	8 229	8 230		
2009	5 470	7 865	8 894	9 470	9 643	9 746	9 806	9 886	9 915	9 918	9 918			
2010	5 455	5 994	6 868	8 001	8 086	8 167	8 253	8 318	8 370	8 371				
2011	5 299	11 611	12 634	12 897	13 130	13 230	13 351	13 380	13 382					
2012	6 535	6 374	6 705	6 973	7 090	7 179	7 281	7 302						
2013	7 676	9 618	10 647	11 331	11 411	11 494	11 519							
2014	7 005	10 152	11 128	11 550	11 864	11 902								
2015	6 700	10 155	11 312	11 611	11 684									
2016	4 193	6 376	7 411	7 694										
2017	2 839	4 092	6 191											
2018	5 020	7 845												
2019	4 928													

Source: Author's calculations.

For product Y, when applying the Chain Ladder method, a lower value of *outstanding reserve* is reached, i.e. 7162. However, when one applies the Bootstrap, it is possible to notice a different shape in the probability distribution of payments, compared to the one for the first (more regular) triangle – see Figure 11. Indeed, the probability distribution of product X is narrower when compared to a wider distribution of product Y.

Figure 11 - Comparing probability distributions of product X and Y



Source: Author's.

Thus, even if product Y has a lower value of outstanding reserve by the Chain Ladder method, because the Bootstrap generated distribution for product Y has wider tails, we can expect higher quantile estimates, and consequently, a higher RA, in relative terms. [16]

Figure 12 - Proposed estimates of the RA under the Bootstrap method for product Y

Mean	Confidence level, p	VaR(p)	RA	% (RA / Mean)
7203	60,0%	7 547	344	4,8%
	70,0%	8 059	856	11,9%
	75,0%	8 388	1 185	16,4%
	80,0%	8 709	1 505	20,9%
	90,0%	9 713	2 510	34,8%
	95,0%	10 538	3 335	46,3%
	99,5%	13 309	6 106	84,8%

Confidence level, p	TVaR(p)	RA	% (RA / Mean)
60,0%	9 062	1 859	25,8%
70,0%	9 483	2 280	31,7%
75,0%	9 736	2 533	35,2%
80,0%	10 034	2 831	39,3%
90,0%	10 909	3 706	51,4%
95,0%	11 751	4 547	63,1%
99,5%	14 264	7 060	98,0%

Source: Author's calculations.

[16] Since the means of the distributions are different, it is not possible to compare RA estimates directly. Instead, it is possible to look at the histograms of the two distributions or at the proportion of RA estimates to the mean to compare their significance.

As expected, we obtain higher estimates of the RA for product Y (Figure 12), where the pattern of costs is more irregular, despite the lower estimate of *outstanding reserve*, relatively. This example supports the idea that emerging claims experience reduces uncertainty regarding estimates which will lead to lower results for the RA. That is, the more accurate one can predict future costs, the lower the underlying risk and the less capital is required to adjust future cash flows to non-financial risk – in line with Figure 4.

4.5.2 Life product

For a life product, as it is not appropriate to construct a triangle with the losses cash flows, the generation of a probability distribution will not be so direct. Instead, to generate a distribution of the factors that create uncertainty in the cashflows, such as mortality, other approaches need to be considered. However, this process becomes complicated since there is not much existing research on the distribution of these risks.

For example, for a product with mortality risk, such as a term life insurance, the factor creating uncertainty is the mortality rate applied to the cashflows, that is, the probability that a life dies at a given age. EIOPA suggests fitting a normal distribution or log-normal distribution (real data suggests a skewed distribution) to the mortality risk.

For this example, we will adapt the CoC approach to the calculation of the RA under IFRS 17, gross for mortality risk before diversification with other life risks. The method is performed according to the proposed steps (see Table 3 for results):

1. Calculate the best estimate of the liability (BEL):
    a. Compute the cashflow for each risk – in this case, for the mortality payments – according to the population adjusted mortality table;
    b. Discount the cashflows using a curve that reflects the contract's liability features.
2. Calculate the RA:
    a. Adjust the cashflow for the risk given a required capital level chosen by the entity. In our example, we choose 99,5% and so we apply a mortality shock[17], as prescribed by the Standard Formula under Solvency II;

[17] Shocked mortality parameter = mortality parameter x 1,15.

b. Calculate the "shocked-BEL" (present value of cashflow);
c. Calculate the required capital amount by taking the difference between the BEL and the "shocked-BEL";
d. Determine a driver to project the required capital. In this example, we use the BEL as the driver basis and apply it to each future value for the BEL;
e. Calculate future BELs;
f. Calculate future required capital by projecting the required capital;
g. Determine the CoC rate (management decision);
h. Apply the cost-of-capital to each required capital over the lifetime of the contract;
i. Calculate the RA (present value of cost of required capital).

3. Determine the implied corresponding confidence level. This step requires fitting a distribution to the liability. In our example, we assume a normal distribution with $\mu = 437{,}5$ and $\sigma = 15$. We then compute the confidence level:

$$Z = \frac{X - \mu}{\sigma} \tag{16}$$

$$Confidence\ level = \Phi(Z) \tag{17}$$

Where:

- $X = BEL + RA$;
- $\Phi(x)$ is the cumulative distribution function of the standard normal.

Table 4 - CoC example for the calculation of the RA of a life product

		0	1	2	3	4	5
1	**BEL**	437,5					
1.a	Cashflows		108,67	95,95	90,89	85,57	81,80
1.b	Discount factor	1,0	0,98	0,96	0,94	0,92	0,91
2	**RA**	11,0					
2.a	Shocked_CF		125,0	110,3	104,4	98,3	93,9
2.b	Shocked_BEL	502,7					
2.c	Required Capital	65,2					
2.d	Driver % Required Capital	14,9%					

2.e	BEL at period t		331,0	238,9	153,5	74,8	0,0
2.f	Required Capital		49,3	35,6	22,9	11,1	0,0
2.g	CoC rate	6%					
2.h	Cost of required capital	3,9	3,0	2,1	1,4	0,7	0,0
2.i	CoC = RA	11,0					
3	**Confidence level**	76,9%					
3.a	Mean	437,5					
3.b	Standard Deviation	15,0					

Source: Author's calculations, based on an internal KPMG document.

Remark that the examples must not be considered as complete modelling prescriptions for the calculation of the RA under IFRS 17. They indicate required inputs, possible calculation approaches and steps and include many simplifications in comparison with IFRS 17 reporting requirements. For instance, they do not relate to the level of groups of contracts, there are possible differences in discounting, interim reporting, higher level measurements allocation and the separation between LIC and LRC (for the life product example).

5. Allocating and disclosing results

5.1 Allocation and Diversification

According to the norm's paragraph 24, on initial recognition, the RA must be measured at contract group level. Additionally, the standard expects insurers to allocate risk diversification benefits accordingly. By *diversification* it is meant the pooling of different risks, such that together result in a single risk which is smaller than the sum of all risks. In fact, it is this dynamic of an insurer of decreasing risks by combining those which are correlated together that brings value to a society. [13].

It is fair to assume that the suitable RA for a combination of contract groups must be smaller than the sum of the RA for each group of contracts. This benefit arises from the fact that some risks are correlated, such that if one occurs, the other might be less likely to occur. This idea is clear when one considers a life insurance portfolio of contracts that combines both term life insurance contracts, affected by mortality risk, and immediate annuity products, affected by longevity risk. Thus, the combined risk of these contracts will be less than their individual sum, since mortality and longevity are negatively correlated, i.e. when one risk is aggravated the other is expected to decrease [18].

Under the new IFRS 17, two important steps become paramount: first, insurers shall have a method for calculating the benefits that arise from diversification; and second, they need also to have a method for allocating those benefits to their estimated RA, while meeting the proper requirements.

It is key that, regardless of the method chosen to calculate the diversification benefits, these should be disclosed clearly for an efficient interpretation of the approach from the users of the financial statements. Most importantly, the approach chosen must not lead to instability of the RA as it is calculated for each subsequent period.

In this report, we will introduce two distinct approaches for the calculation of the RA at a contract group level, whilst taking into the consideration possible diversification effects: the bottom-up and top-down approaches [13].

5.1.1 Bottom-up

The bottom-up approach consists on computing the RA for groups of contracts by aggregating RA estimates calculated at lower levels, say at risk level. This approach comes naturally when the calculations for the RA are already in place as part of the present value of future cashflows. Aggregation, if material, can be performed using the following proposed methods [18].

Simple sum

The most straightforward method of merging the different estimates of RA is by summing them. Note that no diversification benefit is considered. Take for example a group of contracts for each we have separately calculated the RA for each risk, where each risk's RA is denoted as RA_{mor}, RA_{long}, RA_{lap} and RA_{disab} that is, the RA for mortality risk, longevity risk, lapse risk and disability risk. Then, the estimate of the RA for that contract group is given by:

$$RA = RA_{mort} + RA_{long} + \ RA_{lap} + RA_{disab} \tag{18}$$

Correlations

Another familiar aggregation approach is through correlation matrices. We can apply the correlations used under Solvency II and then simply apply the following formula, to compute the aggregated RA:

$$RA = \sqrt{\left(RA_{mor} + RA_{long} + RA_{lap} + RA_{disab}\right)\begin{pmatrix} 1 & -0{,}25 & 0 & 0{,}25 \\ -0{,}25 & 1 & 0{,}25 & 0 \\ 0 & 0{,}25 & 1 & 0 \\ 0{,}25 & 0 & 0 & 1 \end{pmatrix}\left(RA_{mor} + RA_{long} + RA_{lap} + RA_{disab}\right)^t} \tag{19}$$

Copulas

For a more sophisticated approach, recent literature has introduced the possibility of using copulas to compute the aggregated RA, since they are structures used to describe the dependence between different random variables [18]. However, given the complexity involved in such a theoretical method, the adoption of such structures will be less likely by entities (as they will also be of difficult interpretation by users of financial reports), thus we will not further develop this approach in our analysis.

5.1.2 Top-down

If instead the RA is calculated in aggregate for different combined contracts groups, then a top-down approach shall be used. This could be the case for companies that wish to recycle existing processes to compute the IFRS 17 RA, in order to save time, reduce the additional effort and increase consistency with current metrics – which also have the advantage of being familiar and easily interpreted by users of financial information [13].

Scalar allocation

The scalar allocation method is a simple method of allocation, also known as the pro-rata allocation. It determines a reference measure that reflects the relative size of each non-financial risk at the contract group level. A possible proxy could be the weight of the present value of future cash flows [18] or of guaranteed benefits. It is important to check for the appropriateness of the chosen reference measure – for instance, the uncertainty related to the cashflows may change over time, making it a proxy relevant initially but not so relevant in the future. An appropriate proxy should be related to (or the same as) the coverage units. Ideally, it must also allow for comparability between groups of contracts for different types of products and be comfortably interpretable [13].

5.2 Presentation in the statement of financial position

Concerning the presentation in the statement of financial position, the RA will be recognized for each measurement period according to a release pattern to be defined by the entity. The RA will be released as the risk in the group of contracts decreases, which is expected to happen gradually as the contract covered risks expire. Therefore, the company shall recognise as *insurance revenue* for the period the changes in the risk adjustment during that period, excluding [IFRS17.B124.b]:

- changes included in insurance finance income or expenses;
- changes that adjust the CSM as it relates to future service;
- amounts allocated to the loss component of the liability for remaining coverage.

[18] Similar to EIOPA's simplification 3 for the Risk Margin (Solvency II).

As established by the norm, the amounts to be disclosed in the statement of financial position must be disaggregated into *insurance service result* (which is the result of combining *insurance revenue* and *insurance service expenses*) and IFIE (insurance finance income or expenses). One particularly interesting and important note regarding the disclosure of the change in the RA in each period, stated in paragraph 81 of the norm, is that the entity may choose to disaggregate (or not) the *insurance service result* and the IFIE for the RA in the statement of financial position. If the company chooses not to disaggregate, then there will be no IFIE for the RA, and the *insurance service result* will contain all the change in the RA for that period [19].

6. Conclusions

Throughout the present internship at the M&RC department, at KPMG Lisbon, it became clear the importance of studying IFRS 17's RA, given its strong statistical component and imminent relevance for its clients. Indeed, as the transition date for IFRS 17 approaches, companies need to prepare for a *principles-based* accounting standard whilst considering their own risk appetite and business goals.

This risk measuring variable, together with the expected future cash flows and discount rates, constitute the FCFs, the new standard's elementary notion. Furthermore, IFRS 17 introduces three measuring models: the GMM, the VFA and the PAA. For the RA, it is important to understand that under the PAA, unlike the other two, the calculation of this element will only concern liabilities relating to expired risk, that is, LIC, since the calculation of the LRC is performed as a simplification of the unearned premium for that group of contracts.

The estimated RA will have a considerable effect on insurers' financial performance and may be used for steering some of the financial results. This is mainly due to the negative impact that the RA has on the CSM, IFRS 17's unearned profit variable. In fact, users of financial statements will compare disclosures on the RA of distinct insurance companies to infer on their financial performance.

Despite the lack of a defined estimation technique and confidence level, the norm states five criteria that estimates of the RA must follow. The RA must be diversifiable, technically sound, consistent, allow for comparability and calculated for non-financial risks. Under Solvency II, non-financial risks present in insurance products are mortality, longevity, lapse, disability and premium and reserve.

To meet the main goal of this report, it is important to discuss the more commonly found estimation method. In terms of applicability, one can conclude that the CoC method would be the most operational for companies that would prefer to adjust existing Solvency II techniques to reach an estimate for the RA. On the other hand, risk measures such as the VaR and the TVaR have the advantage of having the confidence level defined at outset, facilitating the disclosure of interpretable results – see summary in Table 4.

From the practical examples provided throughout this research, it is also possible to substantiate higher results for the RA, given a more uncertain pattern of future cash flows. For the non-life illustration, the RA is allocated at higher levels for a product with a volatile run-off throughout the years, compared to a product with a stable run-off of costs. This relationship applies for both the VaR and the TVaR and is as expected per paragraph B.91 in the norm. Stochastically generating a distribution of the discounted FCFs for a life product, given the various risks underlying it, can be challenging. Hence, insures might prefer adapting current techniques, like the CoC method, to calculate the RA – as explored in Section 4.4.2.

Since, at initial recognition, the RA is measured at contract group level (which combines contracts belonging to the same portfolio, cohort and profitability cluster), allocation approaches that also account for *diversification benefits* must be developed. In this research, two allocation methods are presented: the bottom-up and the top-down approach. The first relates to calculating the RA at contract group level using appropriate dependency structures between risks, such as correlations. The latter determines the RA at a higher aggregate level and then applies proxies or marginals to allocate amounts at a contract group level.

Concerning the presentation in the statement of financial position, the RA will be recognized for each measurement period according to a defined release pattern. Unlike the rest of the disclosing amounts, the entity may choose not to disaggregate the RA into *insurance service result* and the IFIE (Insurance Finance Income or Expenses).

To conclude, the new accounting norm IFRS 17 is set by the IASB with the main goal of creating a level playing field that generates financial stability for the insurance sector, around the globe. Contrasting to prudential regimes, IFRS 17 is a *principles-based* standard thus allowing for a business-specific judgment from each company. As the sector moves towards its implementation, mathematical elements, like the RA, shall be carefully studied and discussed, given their significant impact on the financial results of each company.

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Annex

The Bootstrap method explained – results in R

Presently, insurers recur to the Bootstrap method to validate the calculation of the reserve estimates under the Chain Ladder approach. For this purpose, this method is used to simulate random estimates of past and future claims, the so-called *pseudorandom* samples, using a sample of Chain-Ladder residuals to which it is then applied a prediction method. It is possible to compare the simulated outcomes of future claims with the Chain Ladder's simulated predictions to assess its reasonability.

In this report, a triangle of cumulative costs for a given non-life product X is provided (Figure 8). First, recall that a triangle of costs considers the payment pattern for a given group of insurance contracts, which include claims payment and attributable expenses, through several development years after the accident year. It is possible to construct a triangle of incremental amounts (Figure 13), which is simply the difference between costs in subsequent development years in the cumulative triangle.

Figure 13 - Incremental losses triangle for product X

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
2006	4 702	2 046	204	44	24	17	2	3	0	0	0	0	0	0
2007	4 368	1 783	226	67	36	13	2	1	0	0	0	0	0	
2008	4 579	2 499	238	78	39	52	25	5	0	0	0	0		
2009	4 967	2 573	314	85	39	20	10	5	0	0	0			
2010	5 300	2 915	357	134	61	48	32	10	0	0				
2011	5 478	2 438	362	108	61	33	38	50	0					
2012	6 525	3 462	524	268	118	87	119	33						
2013	7 395	3 509	1 541	689	1 018	448	313							
2014	4 891	4 158	976	969	314	238								
2015	6 141	3 432	1 157	712	434									
2016	6 419	2 469	616	319										
2017	6 863	4 018	1 420											
2018	5 020	2 826												
2019	5 203													

Source: Author's calculations.

The incremental triangle reflects a payment pattern with a development period of eight years, after which no further payments are expected to occur. Additionally, it is possible to conclude that the incremental amounts are gradually decreasing, making the payment pattern substantially regular. Thus, the emerging payments experience reduces the uncertainty about estimates of future costs. From Figure 4, and as stated in IFRS17.B91, one can expect such characteristics to decrease the RA estimate.

Formally, following the notation in [8], take $C_{i,j}$ to be the incremental amounts of the triangle - independent and identically distributed variables by model assumption - where the accident years and developments years are given by variables $i = 2016, \dots, 2019$ and $j = 0, \dots, 13$, respectively. Then, by the Chain Ladder method, development factors are calculated by looking at the pattern of payments for each development year. The results are provided in Figure 14 [19].

Figure 14 - Chain Ladder development factors

Development year	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Development factor	1,525	1,077	1,035	1,023	1,012	1,008	1,002	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Source: Author's calculations.

For the purpose of the Bootstrap approach, the Chain Ladder development factors are applied backwards, in order to re-estimate the incremental amounts for the given triangle, creating a *false history* triangle (Figure 15). The entries of the *false history* triangle are given by the variable $\hat{\mu}_{i,j}$ which represents the estimates of incremental amounts, i.e. $\hat{\mu}_{i,j} = E(C_{i,j})$.

[19] Note that the detailed calculation under the Chain Ladder method is not relevant for the purpose of this study.

Figure 15 – False history incremental triangle for product X

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
2006	3 964	2 080	466	229	157	80	52	13	0	0	0	0	0	0
2007	3 657	1 919	430	212	145	74	48	12	0	0	0	0	0	
2008	4 230	2 220	497	245	167	85	56	14	0	0	0	0		
2009	4 511	2 367	530	261	178	91	60	15	0	0	0			
2010	4 986	2 617	586	289	197	101	66	16	0	0				
2011	4 823	2 531	567	279	191	97	64	16	0					
2012	6 269	3 290	737	363	248	126	83	21						
2013	8 410	4 414	989	487	332	170	111							
2014	6 560	3 443	771	380	259	132								
2015	6 826	3 583	802	395	270									
2016	5 777	3 032	679	334										
2017	7 490	3 931	880											
2018	5 145	2 701												
2019	5 203													

Source: Author's calculations.

Then, having both incremental triangles – the real and the *false* – it is possible to calculate the *Pearson Residuals* as following:

$$r_{i,j} = \frac{C_{i,j} - \hat{\mu}_{i,j}}{\sqrt{\hat{\mu}_{i,j}}} \tag{20}$$

Additionally, the *Pearson Residuals* are adjusted to consider the degrees of freedom of the model, such that, the scaled Pearson Residuals are given by:

$$r^*_{i,j} = \sqrt{\frac{N}{N-p}}\, r_{i,j} \tag{21}$$

where N is the total number of observations, that is, the number of entries in the original triangle, and p is the number of estimated parameters, which is given by:

$$p = 2 \times (number\ of\ development\ years) - 1 \tag{22}$$

For the present example, given that N is 105 and p is 27, the scaled Pearson Residuals are calculated and presented in Figure 16:

Figure 16 - Scaled Pearson Residuals for product X

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
2006	14	-1	-14	-14	-12	-8	-8	-3	0	0	0	0	0	0
2007	14	-4	-11	-12	-10	-8	-8	-4	0	0	0	0	0	
2008	6	7	-13	-12	-12	-4	-5	-3	0	0	0	0		
2009	8	5	-11	-13	-12	-9	-7	-3	0	0	0			
2010	5	7	-11	-11	-11	-6	-5	-2	0	0				
2011	11	-2	-10	-12	-11	-8	-4	10	0					
2012	4	3	-9	-6	-10	-4	5	3						
2013	-13	-16	20	11	44	25	22							
2014	-24	14	9	35	4	11								
2015	-10	-3	15	19	12									
2016	10	-12	-3	-1										
2017	-8	2	21											
2018	-2	3												
2019	0													

Source: Author's calculations.

At this point in the calculation, it is possible to apply the Bootstrap approach, which is performed by repeating the next steps *k* times:

1. Create a new triangle of randomly selected scaled Pearson Residuals, allowing for replacement, from the original triangle of scaled Pearson Residuals, $r_{i,j}^{*(b)}$;
2. Given the random sample of residuals, $r_{i,j}^{*(b)}$, and the estimates for the incremental amounts, $\hat{\mu}_{i,j}$, calculate the *pseudo-random* variable for incremental amounts, $\hat{\mu}_{i,j}^{(b)}$:

$$\hat{\mu}_{i,j}^{(b)} = r_{i,j}^{*(b)} \sqrt{\hat{\mu}_{i,j}} + \hat{\mu}_{i,j} \tag{23}$$

3. Then, the Chain Ladder (or any other predictive method) is applied to the triangle with entries $\hat{\mu}_{i,j}^{(b)}$, and the lower triangle, that is, estimates of future payments are calculated;
4. The overall estimate of reserves is determined by summing the estimates of future payments for each development year.
5. The reserve results are saved, moving back to step 1.

The Bootstrap logarithm is applied to the costs' triangle of product X and 50 000 estimates for reserves are calculated. The procedure was conducted in R and the results are shown in Figure 17.

Figure 17 - Bootstrap method in R with results for product X

```
> B <- BootChainLadder(triCum, R = 10000, process.distr = "gamma")
> B
BootChainLadder(Triangle = triCum, R = 10000, process.distr = "gamma")

   Latest Mean Ultimate Mean IBNR IBNR.S.E  IBNR 75% IBNR 95%
1   7,042         7,042  0.00e+00     0.00  0.00e+00 0.00e+00
2   6,496         6,496 -8.76e-03     4.25  0.00e+00 3.69e-25
3   7,515         7,515 -2.26e-02     6.10 2.50e-120 1.45e-11
4   8,013         8,013 -8.81e-02     9.23  7.92e-71 1.94e-07
5   8,857         8,857  1.14e-01    12.84  1.33e-49 4.18e-05
6   8,568         8,568 -1.56e-01    11.66  2.08e-42 2.69e-04
7  11,136        11,136 -3.13e-01    13.13  3.41e-31 3.76e-03
8  14,913        14,937  2.38e+01    66.69  2.45e+01 1.45e+02
9  11,546        11,646  9.95e+01   119.49  1.45e+02 3.40e+02
10 11,876        12,111  2.35e+02   180.80  3.24e+02 5.84e+02
11  9,823        10,241  4.18e+02   240.80  5.48e+02 8.77e+02
12 12,301        13,270  9.69e+02   375.65  1.20e+03 1.66e+03
13  7,846         9,099  1.25e+03   420.51  1.52e+03 2.01e+03
14  5,203         9,173  3.97e+03   915.22  4.51e+03 5.60e+03

                 Totals
Latest:         131,135
Mean Ultimate:  138,102
Mean IBNR:        6,967
IBNR.S.E          1,209
Total IBNR 75%:   7,735
Total IBNR 95%:   9,064
```

Source: Author's calculations in R.

The results are ordered from smallest to largest so that relevant indicators such as quantiles, can be determined. The left histogram in Figure 11 shows the distribution function of reserves that is generated given the Bootstrap results. To calculate the VaR measure for product X, only the quantile results shown in Figure 9 are required. This can be done non-parametrically in R by calling the function *quantile:*

$$VaR\ <-quantile(B, c(0.50, 0.60, 0.70, 0.75, 0.80, 0.90, 0.95, 0.995))$$

Then, the RA is calculated by taking the difference between the VaR at a chosen confidence level and the mean of the simulated distribution. The TVaR is calculated by taking the average of results above a certain threshold using the following proposed R code, for instance, for the confidence level 80%:

$$sims\ <-B\$IBNR.Totals$$

$$tvar\_80\ <-mean(sims[sims\ >=\ quantile(sims, 0.8)])$$

With the purpose of comparing results and assessing the calculation method, product Y is also introduced. Figure 10 shows the triangle of cumulative costs for this group of contracts, which can be further analyzed by constructing the triangle of incremental amounts (Figure 18).

Figure 18 - Incremental losses triangle for product Y

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
2006	6 271	2 045	394	12	333	29	24	3	37	5	7	11	26	0
2007	5 228	3 152	198	120	116	163	30	7	10	27	15	2	0	
2008	5 344	1 498	392	378	38	182	139	162	35	49	12	1		
2009	5 470	2 395	1 029	576	173	103	60	80	29	3	0			
2010	5 455	539	874	1 133	85	81	86	65	52	1				
2011	5 299	6 312	1 023	263	233	100	121	29	2					
2012	6 535	-161	331	268	117	89	102	21						
2013	7 676	1 942	1 029	684	80	83	25							
2014	7 005	3 147	976	422	314	38								
2015	6 700	3 455	1 157	299	73									
2016	4 193	2 183	1 035	283										
2017	2 839	1 253	2 099											
2018	5 020	2 825												
2019	4 928													

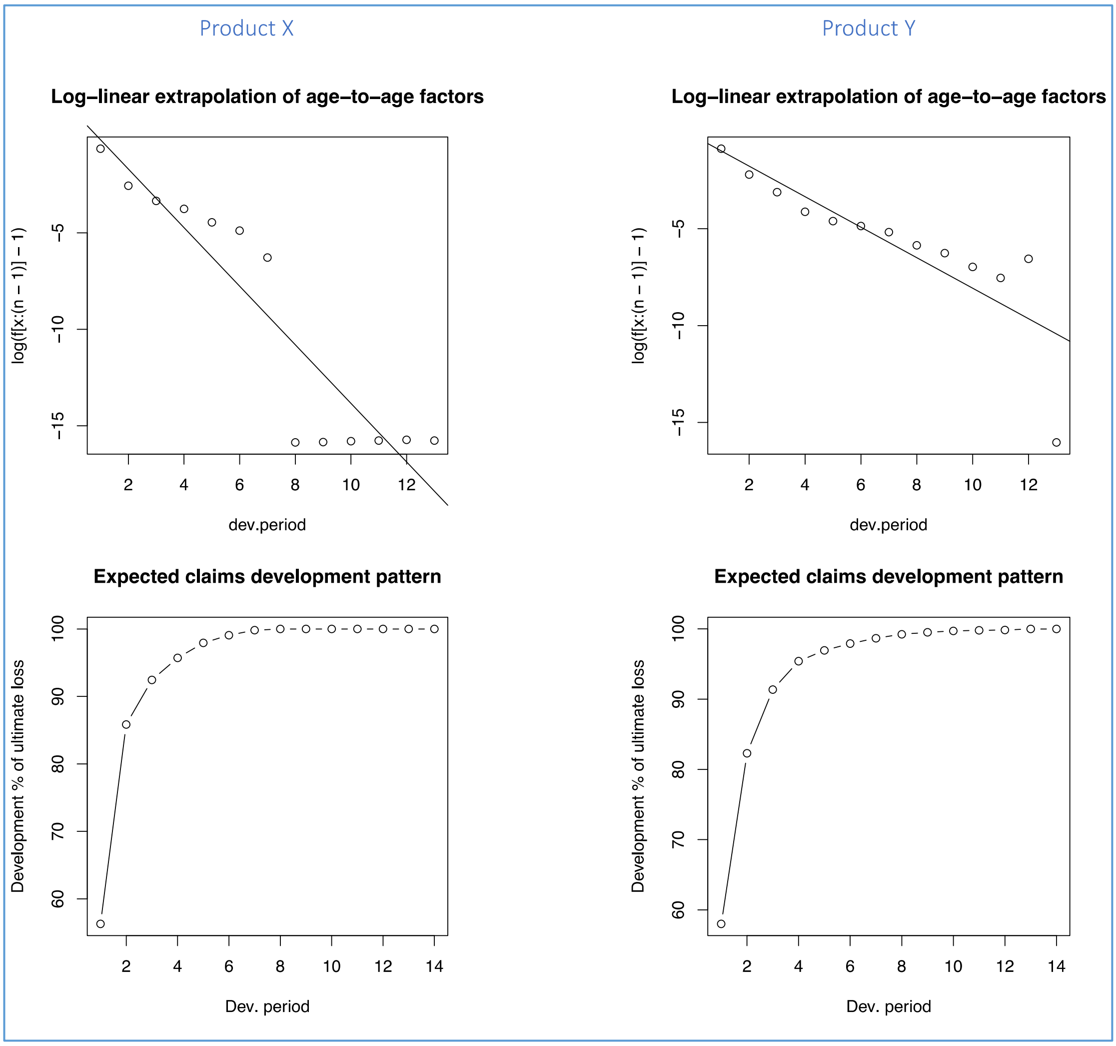
Source: Author's calculations.

By comparing Figure 13 and Figure 18, it is clear that the payment pattern of product Y is substantially more irregular. Indeed, the development period not only is longer than eight years but is also not stable, varying for each accident year. Moreover, the incremental amounts have an irregular trend, that is, incremental amounts are not gradually decreasing, like in product X, which brings further uncertainty to the projection of future cash flows.

These contrasting trends between product X and Y are reflected when comparing the different graphs in Figure 19. By looking at the log-linear extrapolation of age-to-age factors, it can be concluded that product X has shorter payment duration – eight years – with a gradually decreasing trend. By contrast, product Y's payment pattern is longer and the trend is not regularly decreasing. The expected claims development pattern seems to stabilize at year eight for product X, whilst it takes longer for product Y.

According to the definition of the RA and the criteria in Figure 4, the estimates for the RA are expected to be relatively higher for product Y, given the greater amount of uncertainty underlying its loss tendencies - reflected in the results in Figure 12. Despite having a lower Chain Ladder estimate for reserves, the RA amounts are considerably bigger for product Y. Also, it is possible to notice a different shape for the probability distribution of losses (Figure 11). Indeed, the probability distribution of product X is narrower when compared to a wider distribution of product Y, leading to lower quantile estimates for product X, relatively, and thus a lower need for an adjustment.

Figure 19 - Comparing historical trends and projections between product X and Y



Source: Author's calculations in R.