LISBON SCHOOL OF ECONOMICS & MANAGEMENT
UNIVERSIDADE DE LISBOA

MASTER

ACTUARIAL SCIENCE

MASTER'S FINAL WORK

INTERNSHIP REPORT

RISK ADJUSTMENT IN A LIFE INSURANCE PORTFOLIO

ANDREIA SIMÕES PEREIRA

NOVEMBER – 2020

MASTER
ACTUARIAL SCIENCE

MASTER'S FINAL WORK
INTERNSHIP REPORT

RISK ADJUSTMENT IN A LIFE INSURANCE PORTFOLIO

ANDREIA SIMÕES PEREIRA

SUPERVISION:
CARLA SÁ PEREIRA
ONOFRE SIMÕES

TUTOR:
HUGO BORGINHO

NOVEMBER – 2020

Abstract

Since IFRS 17 was issued, the study and understanding of all its components have been a critical task in the insurance framework, particularly the components of the liability's measurement. Its complexity and principle-based approach represent a challenge for all insurance companies, regulators, consultants, and other stakeholders.

With that in mind, this internship had the foremost goal of understanding one of its components, the Risk Adjustment, which has some similarities with Solvency II's Risk Margin. The Risk Adjustment represents the compensation an entity requires for bearing the uncertainty regarding non-financial risks.

Therefore, this report aims to understand and illustrate two potential methods to compute the Risk Adjustment in a Life Insurance Portfolio. The first one uses the Standard Formula of Solvency II to a specific life insurance group. The second uses the Maximum Likelihood Estimation Approach to find the parameters of the distributions of the present value of the cash flows of non-financial insurance risks to find the Value at Risk and the Tail Value at Risk, and posteriorly, the Risk Adjustment.

KEYWORDS: IFRS 17, Risk Adjustment, Value at Risk, Tail Value at Risk, Cost of Capital, Life Insurance.

Resumo

Desde que a IFRS 17 foi emitida, o estudo e compreensão de todas as suas componentes tem sido uma tarefa desafiante para o quadro segurador, principalmente o cálculo das componentes do passivo. A sua complexidade e abordagem baseada em princípios representa um desafio para todas as companhias, consultores e outros *stakeholders*.

Com isso em mente, este estágio teve como objetivo principal a compreensão de uma das suas componentes, o *Risk Adjustment*, que pode ser comparado à Margem de Risco de Solvência II. O *Risk Adjustment* representa a compensação que uma entidade requer para suportar a incerteza dos riscos não financeiros.

Assim, este relatório pretende perceber e ilustrar dois potenciais métodos para calcular o *Risk Adjustment* numa carteira de Vida. O primeiro usa a Fórmula *Standard* de Solvência II num específico grupo de seguros de vida. O segundo usa o Método de Estimação de Máxima Verossimilhança para calcular os parâmetros das distribuições do valor atual dos fluxos de caixa dos riscos não financeiros, para encontrar o *Value at Risk* e o *Tail Value at Risk*, e posteriormente, o *Risk Adjustment*.

PALAVRAS-CHAVE: IFRS 17, Risk Adjustment, Value at Risk, Tail Value at Risk, Cost of Capital, Seguro de Vida.

Acknowledgments

Firstly, I would like to thank Carla Sá Pereira, Dora Leal, and Vanessa Serrão, for the help and motivation given throughout this six-month internship, specially through this pandemic time, and for given me the opportunity for continuing to expand my knowledge. This report is finished mostly because of your support and guidance.

To my team, for the patience and help provided. A special thanks to João and Daniela for making the work more fun.

To my tutor, Professor Hugo Borginho, for the help and feedback provide in times in need.

To my faculty supervisor, Professor Onofre Simões, for all the help regarding bureaucratic issues. And for all his kind words over these last two years.

To my friends, for all the amazing times spent together.

To Tuna Económicas, for making everything more difficult and worthwhile.

A huge thanks to my parents, Jorge, and Celeste. You made all this possible. Thank you for supporting me, even at rough times. And, specially, for your enormous patience.

To my incredible sisters, Daniela, and Joana, for the all the laughs, memorable times, and discussions that helped me to be a better person, but mostly thank you for the sisterhood.

To my beautiful nephew Francisco. For getting my life brighter and happier with your contagious laugh.

And, finally, to Filipe. You have been my rock over these years, and I cannot thank you enough for all your support and for, even far, being always present.

Contents

List of Figures

List of Tables

Acronyms and Abbreviations

ASF	Autoridade de Supervisão de Seguros e Fundos de Pensões
BBA	Building Blocks Approach
CF	Cash Flow
CoC	Cost of Capital
CSM	Contractual Service Margin
DB	Diversification Benefit
EUT	Expected Utility Theory
EY	Ernst & Young, S.A.
FCF	Fulfilment Cash Flow
FSO	Financial Services Organization
GAAP	Generally Accepted Accounting Principles
HRG	Homogeneous Risk Group
IAA	International Actuarial Association
IASB	International Accounting Standards Board
IFRS	International Financial Reporting Standard
LIC	Liabilities for Incurred Claims
LoA	Level of Aggregation
LoB	Line of Business
LRC	Liabilities for Remaining Coverage
MLE	Maximum Likelihood Estimation
P&L	Profit & Loss
PAA	Premium Allocation Approach
PCES	Plano de Contas para as Empresas de Seguros
PVCF	Present Value of the Cash Flows
RA	Risk Adjustment
RM	Risk Margin
RRA	Relative Risk Aversion
SCR	Solvency Capital Requirement
TMV	Time Value of Money
TVaR	Tail Value at Risk
VA	Volatility Adjustment
VaR	Value at Risk
VFA	Variable Fee Approach
WACC	Weighted Average Cost of Capital

Introduction

The present report results of the work of a six-month internship at Ernst & Young, S.A. (EY) in the Financial Services Organization (FSO) Consulting team. During this time, I had the opportunity to be part of different projects and work with a phenomenal team that helped me to grow as an actuary and a professional.

Throughout the internship, one of the main topics of work and formation was the new Standard that the International Accounting Standards Board (IASB) developed over almost twenty years for the insurance business, the International Financial Reporting Standard (IFRS) 17 – Insurance Contracts. Due to its importance in the insurance framework and, therefore, in EY, it looked important to me and to my team to choose one aspect of the Standard as main topic of my report, so I chose to study and focus on one of the four components of the general measuring model, the Risk Adjustment (RA). Hence, the main goal of this report is to understand more practically some methodologies recommended by the Standard to compute the RA, and more specifically in a Life Insurance business.

In chapter one there is an overview of IFRS 17, its history, and some basic concepts and the three measurement models are also introduced.

In chapter two a deep dive into the RA is done, and what the main methodologies that companies can use to compute this component are. It also intends to give the theoretical background behind it, and some advantages and disadvantages.

In chapter three two practical examples of the RA calculation that were done during the internship are shown. It also presents the portfolio used, its features, some initial assumptions, and the steps to compute the RA.

Finally, to conclude, in the last chapter the results are discussed and possible future work regarding the RA is suggested.

1. IFRS 17 – Insurance Contracts

1.1. Overview and Scope

IFRS 17 is the new Accounting Standard, which sets new principles of recognition, measurement, presentation, and disclosure of insurance contracts liabilities.

IFRS 17 was developed by the IASB to replace the previous standard, the IFRS 4 *Insurance Contracts*, an interim standard launched in 2004, also considered as the first phase of IASB's project started in 1997. IFRS 4 does not prescribe the measurement of insurance contracts and allows companies to use local accounting standards (local Generally Accepted Accounting Principles (GAAP)) or variations of those requirements, for the measurement of their contracts issued. However, over the years, IFRS 4 showed some problems, such as the difficulty of the investors to analyze and compare different Insurer's results caused by the wide non-GAAP measures used in the various jurisdictions and industries and also to the other recognitions in time of profitability. In Portugal, it was not mandatory the use of this interim Standard, which led to the Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF) not implementing the IFRS 4 in the national accounting framework, the Plano de Contas para as Empresas de Seguros (PCES). Mainly because IFRS 4 was a transitory standard, only the classification of the contracts was adopted.

In May of 2017, IASB issued IFRS 17 *Insurance Contracts*, the second phase of the project, that gathers standard principles that insurance companies must follow when preparing and publishing their financial performance reports according to IASB, IFRS 17 addresses many inadequacies in the existing wide range of insurance accounting practices. IFRS 17 requires all insurers to reflect the effect of economic changes in their financial statements in a timely and transparent way. A significant characteristic of this new Standard is that it makes a distinction between two different types of profitability: Insurance Service Results and Investment Results.

Under the scope of IFRS 17 are insurance contracts, reinsurance contracts, and investment contracts with discretionary participation features. Investment contracts or other goods and non-insurance services are covered by IFRS 9 *Financial*

Instruments and IFRS 15 *Revenue from Contracts with consumers*, respectively, as seen in the *Figure 1*.

Companies must separate the different components and exclude from the scope of IFRS 17 investments, embedded derivatives, and other goods or non-insurance services, if possible. There are cases where the correlations between these components become impossible to work separately, in which case the separation is not required.

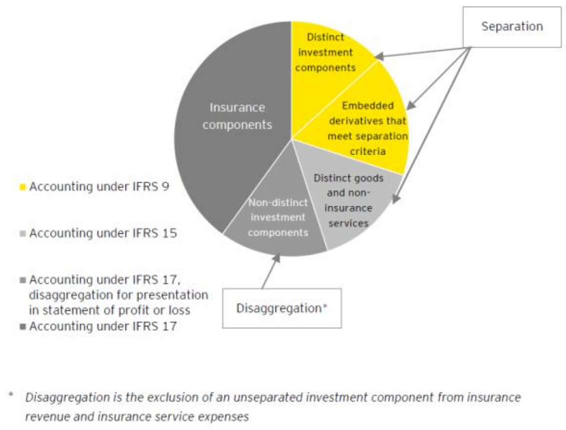

Figure 1 - Component Separation, Source: EY

Together with IFRS 9 and IFRS 15, IFRS 17 aims to increase transparency, consistency, and comparability between different insurers implementing a uniform accounting system for all insurance contracts, using updated, relevant, and transparent information.

In June of 2020, IASB issued new amendments to IFRS 17 Insurance Contracts due to the feedback from Stakeholders, that, among other changes, deferred the effective implementation date to January 1st of 2023. The IFRS 9 was also deferred for the companies which had temporary exemption.

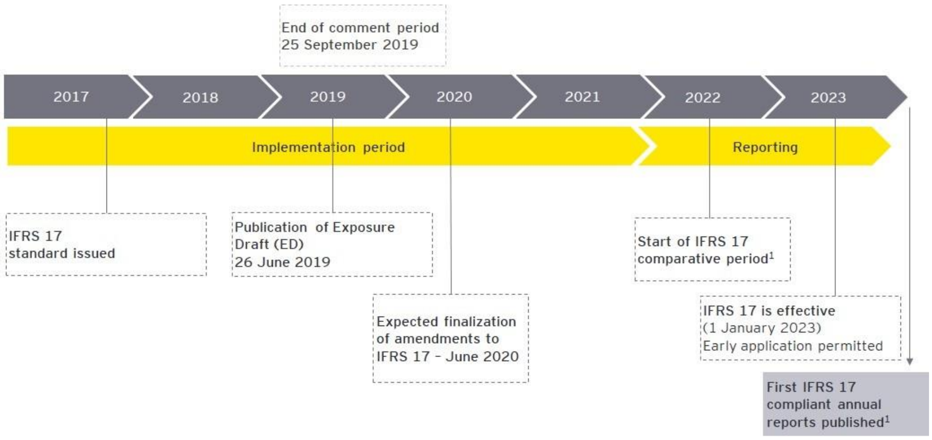

Figure 2 - IFRS 17 Timeline, Source: EY

1.2. Level of Aggregation and Initial Recognition

Because IASB recognizes the requirements at policy level with the purpose of calculating the Contractual Service Margin (CSM), the standard introduces guidelines to companies to aggregate the policies into groups of contracts. This process is called the Level of Aggregation (LoA). It is a crucial step because it affects how profitability is reported in the financial statements, since it is the unit of account used to do the measurement. It also allows companies to determine the fulfillment cash flows (FCF) at a granular level. Moreover, it mandates early recognition of losses, determining which contracts are onerous. This early recognition is essential because, in IFRS 17, profits originated by future services are dealt with different from losses.

Companies must divide their insurance contracts into three minimum groups. At initial recognition, the first level of grouping contracts is to separate them into portfolios with similar risks and characteristics to be managed together. After that, they are separated into cohorts with a maximum interval of 12 months. And, finally, they are divided into these three buckets – onerous, no significant possibility of becoming onerous and remaining. An onerous contract is an accounting term for a contract that will cost a company more to fulfill than the company will receive in return. In the Figure 3 it is shown an example of the three levels of aggregation.

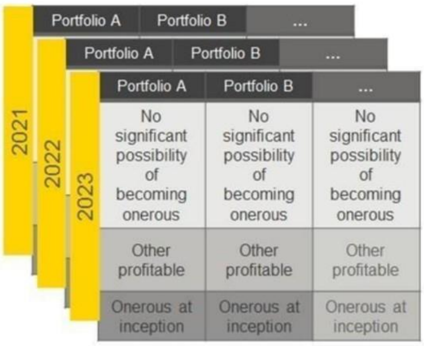

Figure 3 - Segmentation Example, Source: EY

The grouping is an essential component in IFRS 17 since it provides more useful information about insurance activities than measured only in an individual contract level as seen in different IFRS's, like IFRS 9 *Financial Instruments* or IFRS 15 *Revenues.* It is also important to refer that the LoA could be done at an individual level; entities have the freedom to choose what suits them.

The initial recognition of a group of insurance contracts is considered the earliest date between these three situations:

- The beginning of the coverage period of the group;
- The date on which the first payment of the policyholder is due; and
- For a group of onerous contracts, when the group becomes onerous, or a group of contracts becomes onerous.

Even if contracts had already been recognized, they could still join a group of contracts, but only if those insurance contracts are no more than one year apart, considering their initial recognition date. Consequently, the entity must adjust the groups' components, for instance, the FCF and Contractual Service Margin (CSM).

1.3. Measurement Models

When measuring liabilities, IFRS 17 presents some models that the entity must follow, which will depend on the characteristics of the portfolio. The total liabilities of the entity are divided into two liabilities: The Liabilities for Incurred Claims (LIC) and the Liabilities for Remaining Coverage (LRC). The first type of liability represents the Insurer's obligations to pay amounts related to services provided. The second one represents the Insurer's obligation to provide insurance contract services. To calculate these amounts, the Standard proposed three models: The General Model, also known by

Building Blocks Approach (BBA), the simplified model also named by Premium Allocation Approach (PAA), and the modified model, known as Variable Fee Approach (VFA). These methods will be discussed in more detail in the subsequent sections.

1.3.1. Building Blocks Approach

The BBA is the default valuation model and uses the concept of building blocks to measure the Insurer's liabilities mentioned above. The blocks are: The estimate of future cash flows, the discount rates, the RA for non-financial risks, and the CSM, as shown in Figure 4. The first three blocks are known as the Fulfilment Cash Flows (FCF).

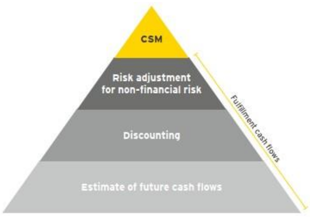

Figure 4 - The four Building Blocks, Source: EY

The FCF are composed of three components, as state above. One of them is the unbiased, explicit, and probability-weighted expected value of future cash flows, which includes the claims paid and the premiums collected, as well as the benefits and expenses. These estimates are adjusted to consider current cash flows and amounts within the contract boundary. The second component of FCF is the RA for non-financial risk. It is viewed as the adjustment for the uncertainty arising from non-financial risks, and more details will be discussed throughout this report.

To obtain the current cash flows that entities need, one should use the discount rates, the third element of the FCF, to reflect the Time Value of Money (TMV) and use yield curves that show the characteristics of the cash flows and the liquidity of the insurance contracts. They also must be consistent with the market prices of the financial instruments that are consistent with those insurance contracts, which means that the discount rate used must exclude the influence of the market variables that do not influence the group and their own credit risk. Due to the significant variety of insurance contracts, there is not a single yield curve that fits the characteristics of all insurance contracts. However, companies may choose to use only one yield curve to simplify the process. This is more common in non-life insurance than in life-insurance.

There are two general approaches to determine these discount rates, the Top-Down Approach, and the Bottom-up Approach. The Top-Down Approach starts with considering the yield of the actual or expected reference asset portfolio, and then it must deduct the credit risk. This deduction is called the credit adjustment, and it is done in two steps, estimating the expected credit loss, and then adjusting for the unexpected losses, such as the losses associated with the credit risk premium.

The Bottom-up Approach consists of using a risk-free rate for the foundation. After that, an illiquidity adjustment is added, as seen in Figure 5.

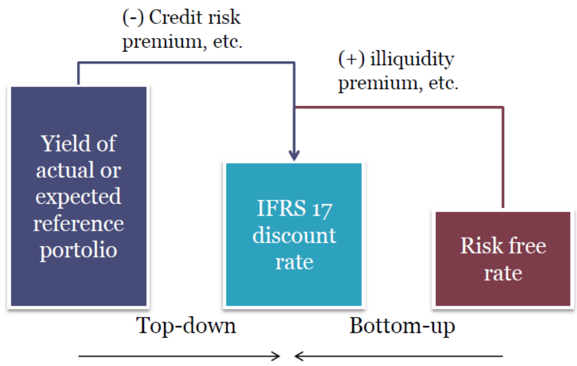

Figure 5 - Top-Down & Bottom-up Approach, Source: Solvency Models course, Slides 2019

The fourth block of the general model, the CSM, at initial recognition, is the expected unearned profits of the insurance contracts and is the difference between the PVCF and the RA, which represents the profit that the entity will recognize for the future services of the group of insurance contracts. For onerous contracts, the CSM is recognized as a loss.

This component was created to identify profitability over time of a group of insurance contracts. Hence, in the coverage period, profits are released in the Profit & Loss (P&L) for past services based on the coverage units of the group. The CSM is adjusted in the case of future services, to reflect the future profit. An important concept to determine the release of the CSM in the P&L is the coverage units. Coverage units in a group are the quantity of coverage that the group of insurance contracts provided. This is computed considering the coverage of each contract belonging to that specific group and their coverage duration. So, the CSM release in the P&L is determined by the following equation:

$$Release\ of\ CSM = \frac{Coverage\ units\ in\ the\ period}{Total\ coverage\ units}. \tag{1.1}$$

At initial recognition, the group of insurance contracts is measured by the sum of the FCF and the CSM. At inception, it is equal to zero, because CSM is equal to the PV CF plus the RA. After that, the amount of liabilities is the sum of the LRC, which, as mentioned above, is the future services regarding that group at that date and if it falls in the onerous' category, does not have CSM; and the LIC, which is the past service at that date. Furthermore, it does not have the CSM. Figure 6 illustrates this process.

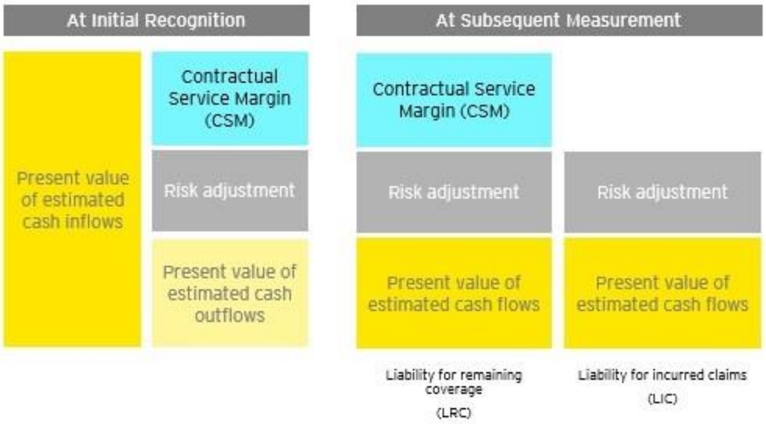

Figure 6 - BBA Measurement, Source: EY

1.3.2. Premium Allocation Approach

Another approach that entities can use to measure the LRC that is relatively closer to the current practice and more straightforward than the general model is the PAA. This one is optional, and it is only used if the group matches some criteria. It does not use the CSM concept. Instead, it is based on the premium received. For onerous contracts, the PPA will be equally calculated as in the BBA, and the loss component will be that value calculated for the liability minus the FCF.

Firstly, this approach is used for groups that have a coverage period of one year or less, and for that reason it is most common in non-life insurance contracts, particularly when it produces a liability that is not materially different from the one produced by the BBA.

To measure insurance contracts, the PAA replaces the building blocks for the calculation of the LRC. The LRC, at inception, is equivalent to the premium received less acquisition costs, so it gives the measure of insurers' liability for the coverage period of that contract. The LIC are the recognized in the same way as in the BBA.

In Figure 7 we can see the representation of LRC and LIC using PPA.

Figure 7 - PPA Measurement for LRC & LIC, Source: EY

1.3.3. Variable Fee Approach

The last approach proposed by the IFRS standard is the VFA. The VFA only can be used for insurance contracts with Direct Participation Features. The Standard requires that an insurance contract be an insurance contract with DPF if it meets all the following criteria:

1." The contractual terms specify that the policyholder participates in a share of a clearly identified pool underlying items.

2. The entity expects to pay to the policyholder an equal to a substantial share of the fair value returns underlying items.

3. The entity expects a substantial proportion of any amounts to be paid to the policyholder to vary change in the fair value of the underlying items."[1]

Therefore, an obligation is created to the insurer to pay the policyholder an amount equal to the underlying items less a "variable fee" for the service.

Initially, the VFA is very similar to the BBA, but, subsequently, there is the adjustment of the fair value of the underlying items in the CSM each period, that will be recognized in the P&L. One of the main differences between the BBA and this approach is in the subsequent measurement and the accrual of interest in the CSM. In the BBA is used, as said before, a locked-in discount rate, and in the VFA the aggregation is based on a current rate included in the balance sheet. This type of approach is used in traditional life profit-sharing policies with direct participation and is very embrace in the insurance industry.

[1] IFRS 17 Insurance Contracts, Paragraph B104

2. Risk Adjustment

2.1. Definition

As seen in the previous chapter, the Risk Adjustment for non-financial risk is one of the components of the BBA introduced by IFRS 17. And, since it will be the main topic of this report is essential to give a more in-depth look at this component.

Let us start with the definition given by the IASB. The RA is defined as:

"The compensation an entity requires for bearing the uncertainty about the amount and timing of the cash flows that arise from non-financial risk as the entity fulfills insurance contracts."[2]

The RA's definition is very similar to the Risk Margin (RM) in Solvency II.

RA is the amount added to the Present Value of Cash Flows (PV CF) to incorporate the uncertainty raised by the non-financial risks within the group of insurance contracts held by the company. These non-financial risks that are contemplated in the RA are the ones directly related to insurance contracts.

Hence, RA should correspond to the amount required by the company that would make it indifferent between fulfilling a liability that:

a) "has a range of possible outcomes arising from non-financial risk," and

b) "will generate fixed cash flows with the same expected present value as the insurance contracts";[3]

Since the RA is the part of the FCF that reflect the uncertainty arising from non-financial risks, the Standard stipulates that the RA must reflect:

a) "the degree of diversification benefit the entity includes when determining the compensation, it requires for bearing that risks", and

b) "both favourable and unfavourable outcomes, in a way that reflects the entity's degree of risk aversion";[4]

[2] IFRS 17 Insurance Contracts, Paragraph 37

[3] IFRS 17 Insurance Contracts, Paragraph B87

[4] IFRS 17 Insurance Contracts, Paragraph B88

2.2. Methodologies

Even though the IFRS 17 does not prescribe a method for entities to follow when computing the RA, the Standard requires that the approach follows these five characteristics:

a) "*Risks with low frequency and high severity will result in higher risk adjustments for non-financial risk than risks with high frequency and low severity.*

b) *For similar risks, contracts with a longer duration will result in higher risk adjustments for non-financial risk than contracts with a shorter duration.*

c) *Risks with a wider probability distribution will result in higher risk adjustments for non-financial risk than risks with a narrower distribution.*

d) *The less that is known about the current estimate and its trend, the higher will be the risk adjustment for non-financial risk; and*

e) *To the extent that emerging experience reduces uncertainty about the amount and timing of cash flows, risk adjustments for non-financial risk will decrease, and vice versa.*"[5]

In the following section, some of the suggested methodologies given by the IASB will be discussed. Also, examples will be shown in the next chapter, with a practical case.

2.2.1. Value at Risk

Probably the most known technique among companies, the Value at Risk (VaR) is one of the methods proposed by the Standard. And even though it is not a prescribed or required approach, the entities are required to disclose the level of confidence at which they calculate the RA. So, one of the main advantages is that VaR will directly satisfy the disclosure requirements. Moreover, its use is very familiar among companies, since it is the method used for the Solvency Capital Requirement (SCR) calculation under Solvency II, based on Standard Formula. In Solvency II, the SCR is calculated at a $99{,}5^{th}$ percentile considering a 1-year time horizon. However, in the SCR, it is regarded as all risks, not only non-financial risks.

[5] IFRS 17 Insurance Contracts, Paragraph B91

The VaR is a quantile method and can be used to determine the amount of capital required to bear an adverse outcome. In other words, it allows companies to measure, with high certainty, the amount of capital needed for projects to not become insolvent. Moreover, it is in the choice of the level of confidence that entities can gain Diversification Benefits (DB).

The VaR method is defined as:

Definition 2.2.1: Consider a random variable X that represents a loss. The VaR of Xat the level $100p\%$, $VaR_p(X)$ or π_p, is the $100p$ quantile of the distribution of X.

For continuous distributions, we can simplify and consider $VaR_p(X)$ is π_p such that:

$$P[X > \pi_p] = 1 - p. \tag{2.1}$$

However, even though the VaR is commonly used, it is not a coherent risk measure since it does not obey one of the four criteria of coherence [16]. The four criteria are:

1.Monotony: if $x \leq y, then\ f(x) \leq f(y)$;

2.Sub-additivity: $f(x + y) \leq f(x) + f(y)$;

3.Homogeneity: $\forall\ a > 0$: $f(ax) \leq f(x)$;

4.Translation invariance: $\forall\ a\ constant$: $f(x + a)\ =\ f(x)\ +\ a$.

VaR fails the second criteria, which may make it hard to use when considering lower-level allocations.

This method uses the risk profile of companies to create a distribution. Once the risk profile is obtained, companies can easily simulate outputs and compute the RA. There are some approaches to generate this distribution, which include the fitting of the future present value of the cash flows for non-financial risks into known probability distributions. For instance, fitting the cash flows into a normal distribution. However, when choosing this fit, it could be considered a simplifying assumption about the behavior of the cash flows. For portfolios or groups of contracts that show some skewed properties, it should consider other distributions with that property.

Another general approach that can be used is the Monte Carlo Simulation. The Monte Carlo Simulation is a stochastic approach. The main idea here is to use a random number of generated samples from the population to simulate a more complicated process. Doing that allows entities to get some insights about the random behavior of some more critical variables. Companies should project or simulate multiple cashflows scenarios based on some stochastic input parameters, to obtain the entities' aggregate risk and, consequently, the risk target quantile. Other modelling approaches can be used, such as resampling techniques, like Bootstrapping. Once the distribution is generated, the VaR can be easily computed.

If it is impossible to use stochastic approaches to model the relevant VaR, companies can use the calibration and correlation method. A stress test is done at the required level of confidence, and in the VaR's calculation, margins of different scenarios are added and then combined using the correlation matrix with appropriate risks factor. One of the advantages of this method is that it is easily operated, even when information and modelling resources are scarce. The challenge here is to choose the appropriate scenario for each group of contracts.

Another approach that can be used is the method of the standard formula to calculate the SCR under Solvency II, which is also the calibration and correlation methodology discussed above. However, it's previously set at the $99{,}5^{th}$ confidence level, and then recalibrated at the IFRS 17 confidence level and chosen the relevant sub-model correlation matrix. Nonetheless, one should acknowledge that there is no guarantee that the EIOPA stress tests correspond to a 99.5% confidence level for a particular insurer, as the calibration was performed at a European-wide perspective.

The RA is determined as the VaR_p less the mean of the discounted value of the best estimate future cash flows, that would be represent as $E[PVCF]$ onward. The RA can be represented as:

$$RA = VaR_p - E[PVCF] \tag{2.2}$$

2.2.2. Tail Value at Risk

Another quantile method used is the Tail Value at Risk (TVaR). This method also uses the confidence level, but considers the expected value given an extreme event, i.e:

$$TVaR_p(X) = \mathrm{E}[X \mid X > \pi_p],. \tag{2.3}$$

where X mostly still represents the random variable of loss and π_p the VaR_p, but here it is considered the threshold.

This approach is better at catching skewness and extremes behaviors, and, unlike the VaR approach, it obeys to the subadditivity property. For that reason, it is considered a superior risk measure and reflects the shape of the tail after the threshold, which the VaR cannot. However, it may be difficult for companies to implement this method since it requires a full risk distribution, only achieved by stochastic models.

Figure 8 illustrated an example of the representation of the VaR and the TVaR.

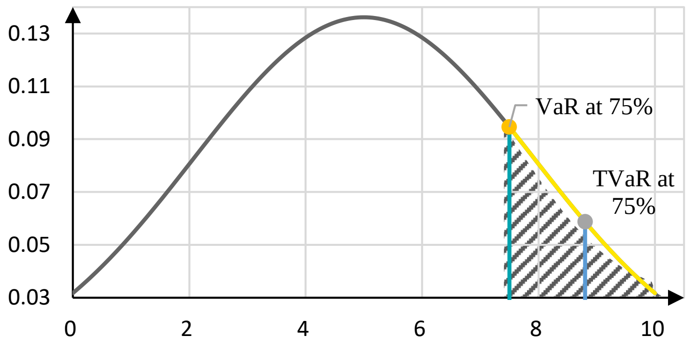

Figure 8 - VaR and TVaR Representation

2.2.3. Cost of Capital

The last approach proposed to compute the RA is based on the same idea of the process behind the RM under Solvency II, to assess the cost or the compensation that the entity would be required to cover non-financial risks over a period time. Three elements must be used in this methodology:

-Solvency Capital Requirement amounts for non-financial risks at time t (SCR_t):

-Cost-of-Capital (CoC);

-Discount Rate at time t (i_t);

Given this, the RA would be defined as:

(2.4)
$$RA = CoC \times \sum_{t \geq 0} \frac{SCR_t}{(1 + i_{t+1})^{t+1}},$$

I. Solvency Capital Requirement amounts

These future capital requirements, for a given group of contracts, can be obtained using a variety of methods. Possible methods include the simulation based on capital models [3], the use of the Standard Formula under Solvency II, or even the use of a proxy.

Moreover, these amounts should reflect only risks that belong in the scope of the RA, the non-financial risks. And it should also reflect the DB using the methodologies that will be discuss further.

II. Cost-of-Capital and Discount Rate

The CoC represents here the relative compensation that is required by the entity for having the capital. It is commonly represented as the weighted average cost of capital (WACC) minus the rate that could be earned on surplus. It's probably the hardest component of this methodology to define since it will depend on the risk aversion of entities.

The discount rate used in this approach will depend on the risk capital arising from the portfolio choice and the same discount rate used by the Standard could be accepted. This risk-free rate could include an illiquidity premium or not, depending on the investment strategies.

III. Solvency II Parallelism

One of the advantages of this method is the fact that most companies already use it for other purposes. For instance, as pointed before, in the calculation of the RM under Solvency II. Therefore, using this method, entities can save time and resources and make use of the experience gained through the years.

However, there are adjustments to be made and significant differences between these two concepts. These differences are highlighted in the following table:

Table I - Risk Adjustment & Risk Margin Differences

Characteristic	Risk Adjustment (IFRS 17)	Risk Margin (Solvency II)
Definition	Compensation that the entity would require for bearing non-financial risks	The additional return required by a third party to accept the transference of the liability portfolio
Methodology	No method prescribed, only necessary to disclose the associated confidence level	Cost-of-Capital method
Parameters	Confidence level and a methodology according to the risk profile of the company	The cost-of-Capital rate is set as 6%, prospective SCRs, and a 99,5% confidence level implicit in the calculation of the SCRs
Duration	Equal to the duration of the liabilities	One-year period
Granularity	Portfolios and groups of contracts	Lines of business (LoB) or homogeneous risk groups (HRG)

As mention before, in Portugal, the IFRS for insurance contracts was not implemented due its transitory property. Hence, the current accounting regime in force still corresponds to the rules of Solvency I regime. This regime has significantly different measurement rules of Solvency II and to those foreseen for IFRS 17. This led to significant changes in the value of the provisions calculated in the economic balance sheet of Solvency II, when compared to those which are accounting recognized. Therefore, and since the regulator (ASF) aims to change the PCES to include this new standard, with the implementation of IFRS 17, the gap between the accounting regime (now SI, then IFSR 17) and the prudential regime (SII) it is expected to be reduced.

2.3. Disclosure

Regarding the disclosure requirements, IFRS 17 requires that the entity discloses the RA and confidence level used to calculate it, considering here the aggregate RA (at entity -level). The confidence level is seen as the price that entities will be willing to accept the non-financial risks.

If the VaR technique, which was discussed above, is not used, the entity must disclose the one that is used, as well as the confidence level that corresponds to the method applied. This provides to stakeholders and other companies more concise and informative information to be used as a benchmark. Moreover, it is also required the financial and accounting analysis carried out to compute the RA over each reporting period. IFSR 17 also outlines that the chosen technique should provide concise and informative disclosure to be used as a benchmark.

2.4. Important Properties and Characteristics

2.4.1. Types of Risk

The type of risks that entities include in the RA is one of its most meaningful characteristics. As mentioned in the previous chapter, the RA must reflect the uncertainty for bearing non-financial risks. Non-financial risks are risks associated with the management of the insurance contracts itself. These risks do not include credit risks or market risks, since the financial risks which are relevant for the liabilities being measured are already included in the discount rates. So, to avoid double count, the Standard excludes these risks.

Depending on the HRG or LoB, the risks incorporated in the RA are different. For non-life insurance contracts, it can be considered, for instance, the lapse risk, the non-life catastrophic risks, or the Premium and Reserve Risk. In Life insurance, the most common are mortality risk, longevity risk, expenses risk, lapse risk and Disability/Morbidity risk.

For IFRS 17, the operational risk is expressly excluded from the RA since it is not directly connected to the insurance contracts. Hence, it is essential, when entities are choosing these risks, not to consider the same risk more than once.

2.4.2. Diversification

As mentioned in the previous chapter, one of the characteristics that the RA must reflect it is DB. The way entities choose to approach this problem will affect the level of RA and the confidence level disclosed.

We can achieve diversification through the interaction between risks or groups of insurance contracts. Diversification between risks can be achieved by pooling one type of risk or pooling different types of risks. Consequently, the benefit happens when the correlation between risks or groups of contracts is less than the perfect positive correlation between them, i.e., total risk, as shown in the equation below.

$$DB = Total\ Risk - Aggregated\ Risk, \qquad (2.5)$$

where Total Risk $= \sum_i Risk_i$.

However, the Standard does not prescribe any process that entities must follow. The Canadian Institute of Actuaries [3] introduces two concepts to calculate this DB, the Entity-Level Approach, and the Unit-of-Account.

The Entity-Level Approach is based on the calculation of the RA at a higher aggregation level between all risks.

Before introducing some of the techniques to calculate the diversification through this approach, let us discuss what risk aggregation is.

Definition 2.4.1: Let us consider a portfolio with N policies and $\{X_i\}_{i=1,2,\dots,N}$ as the random variable that represents the risk of the i^{th} policy.

Now, let us consider the following:

$$S = X_1 + X_2 + \cdots + X_N \ , \qquad (2.6)$$

where S represents the aggregate risk.

The study of the aggregate risk S distribution allows the measuring and allocation of the risks across groups and risk types. Furthermore, it allows for a better understanding of their business and helps companies with the decision-making regarding expansions, reductions, or eliminations of business lines.

Although the Standard does not prescribe any aggregation or allocation method, there are common techniques to find these benefits of diversification, and they are mostly based on statistical procedures. These procedures are discussed in the subsequent sections.

I. Correlation Matrix

The first technique and the most common is using a correlation matrix to aggregate two or more risks. The correlation coefficient is the classical measurement of dependency and is defined as:

$$\rho(X_i, \mathrm{X_j}) = \frac{COV[X_i, \mathrm{X_j}]}{\sqrt{\sigma^2[X_i] \cdot \sigma^2[\mathrm{X_j}]}}, \tag{2.7}$$

where $\mathrm{X_i}$ and $\mathrm{X_j}$ are two random variables that represent the risks i and j, respectively, with finite variances, $\mathrm{COV}[\mathrm{X_i}, \mathrm{X_j}]$ denotes the covariance between X and $\mathrm{X_j}$ and $\sigma^2[\mathrm{X_i}]$ and $\sigma^2[\mathrm{X_j}]$ denote the variance of X_i and $\mathrm{X_j}$, respectively.

One of the advantages of using this technique is that it is easy to calculate and commonly understandable. Moreover, for bivariate distributions the second moments, i.e variances and covariances, are easy to compute. And for the risks used in insurance, there are some known correlation matrixes. For instance, the one's use in Solvency II.

On the other hand, using a correlation matrix can bring some problems when we want to deal with multivariate distributions due to its linearity.

II. Copulas Based Approach

Another technique for computing the DB within the aggregate risk is using copulas. Copulas addressed the issue of dependencies between risks and resolved some fallacies that appear when using only correlation. This approach creates multivariate models from known marginal distributions when there are two or more risks that are assumed not to be independent. In other words, copulas are joint distributions functions and are defined as the following:

Definition 2.4.2 Let $X_1, X_1, \dots, X_n$ be a random variable with distribution functions $F_1(x_1), F_2(x_2), \dots, F_n(x_n)$. A multivariate copula C is a non-decreasing and right-continuous function, mapping $[0,1]^n$ into $[0,1]$ such that, for all $\{u_1, u_2, \dots, u_n\}$:

i) $C(u_1, \dots, u_{i-1}, 0, u_{i+1}, \dots, u_n) = 0, i = 1, 2, \dots, n$ (C is grounded)

ii) $C(1, \dots, u_i, 1, \dots, 1) = u_i, i = 1, 2, \dots, n$

iii) $C - volume([\boldsymbol{u}, \boldsymbol{v}]) \geq 0$, for $[\boldsymbol{u}, \boldsymbol{v}] = [u_1, v_1] \times \dots \times [u_n, v_n]$

In 1959, Sklar [8] introduced the notion and the name copula that led to the most important theorem regarding copulas, the Sklar's Theorem:

Theorem 2.4.1: Let X_1, X_2, …, X_n be random variables with distribution function $F_1(x_1)$, $F_2(x_2)$, …, $F_n(x_n)$, respectively. Then, there exists a copula C such that, for all $(x_1, x_2) \in \mathbb{R}^2$:

(2.8) $$F_{\boldsymbol{x}}(x_1, x_2, \dots x_n) = C(F_1(x_1), F_2(x_2), \dots, F_n(x_n)).$$

Conversely, if C is a copula and $F_1(x_1)$, $F_2(x_2), \dots, F_n(x_n)$ are distributions of X_1, X_2, …, X_n respectively, then the function $F_{\boldsymbol{x}}(x_1, x_2, \dots x_n)$ defined above is a multivariate distribution function with margins F_1, $F_2, \dots, F_n$.

This new notion helped understanding the non-linear dependence, unlike the measure used in the technique above, the correlation matrix, and to develop new measures of dependency, that it will present above.

The first measure present is Kendall's tau, τ_k, and it is defined as:

(2.9) $$\tau_k(X_1, X_2) = P[(X_1 - \widetilde{X_1})(X_2 - \widetilde{X_2}) > 0] - P[(X_1 - \widetilde{X_1})(X_2 - \widetilde{X_2}) < 0],$$

where (X_1, X_2) and $(\widetilde{X}_1, \widetilde{X_2})$ are independent and identically distributed continuous bivariate random variables with marginals F_1 for X_1 and $\widetilde{X_1}$, and F_2 for X_2 and $\widetilde{X_2}$.

In terms of copula function, we have the simplification:

(2.10) $$\tau_k = 4\int_0^1 \int_0^1 C(u, v)dC(u, v) - 1 = 4E[C(U, V)] - 1,$$

The second dependency measure is the Spearman's rho, ρ_S, and it is defined as:

(2.11) $$\rho_S(X_1, X_2) = \rho\big(F_1(X_1), F_2(X_2)\big),$$

where (X_1, X_2) are continuous bivariate random variable, $F_1(X_1)$, and $F_2(X_2)$ are its marginal distributions, and ρ is the linear correlation.

In terms of copula function, we also have the simplification for the Spearman's rho and is the following:

(2.12) $$\rho_S = 12\int_0^1 \int_0^1 C(u, v)dudv - 3 = 12\mathrm{E}[UV] - 3,$$

In the monograph issued by the International Actuarial Association (IAA) [11] in 2018 about the RA, some copula models to compute the aggregated distribution are described. The more common are the Gaussian copula, the t copula and, for marginal distributions that present asymmetry, the Clayton copula.

After the estimation of the RA at a higher aggregation level, since it is required by the Standard that the CSM must be computed in a contract group level, it is needed the allocation of the RA to the unit-of-account level. This allocation can be done using a range of techniques, from direct approaches, like the proportional method, to indirect approaches. The main idea is that the aggregate RA should be equal to the RA for the unit of accounts.

The second approach to assessing the DB is made at a granular level, which means that it is assessed at the contract group level directly. However, this approach may not reflect fully the diversification between group of contracts, since the aggregate RA of the entity will be the sum of the unit-of-account RA. One of Moody’s article about the RA [18] refers one way to get through this problem, that uses the entity-level approach at each contract group.

2.4.3. Risk Profile

Since the IFRS 17 is a principle-based standard, it does not prescribe a method for the calculation of the RA, which gives companies and entities the freedom to calculate this value according to their internals' perspective towards risk. For that reason, and according to what was said above, it is essential to assess the company's risk profile because it will tell how much the company will be willing to pay to hedge the liability.

In general, insurance companies want to mitigate unfavourable outcomes and reduce its losses. Therefore, it is assumed that entities are risk-averse and will require compensation for bearing risks, meaning that the RA will be positive. In the case of the entity being risk-seeking or risk-neutral, the RA would be negative or zero, respectively, which, theoretical, is not very common. Therefore, the challenge holds on to know the extent of their aversion to risk.

3. Practical Case

In this chapter, three practical examples to determine the RA using a dataset from a life portfolio, provided by EY, will be run. The first example consists in using the Solvency II SCR shocks to find the VaR, and then, the RA. The second example uses the distribution function for the PV CF of non-financial risks to find the VaR and TVaR values. The third, and last example run in this report, is using the CoC as methodology. Some of the features mentioned in the previous chapter will be included. The results were computed using the software R Studio and Excel.

For confidentiality proposes, the data, the initial assumptions and any information about the company data are modified or are not presented in this report. Some of the inconsistencies in the results can result from that.

3.1. Dataset

For the examples run in the following subchapters, data from a life insurance portfolio is used, which was transformed to be consistent with the Standard. The portfolio is divided into three contract groups: Traditional, Term Assurances, and Annuities.

The Traditional group includes policies such as whole life insurances and pure endowments, which totals 193 762 policies. The Term Assurance group includes 27 954 policies of 1-year renewal term assurance. The Annuities group have 393 policies of whole life annuities.

To calculate the base projected future cash flows for the examples below, the following assumptions were used:

- GKM 80 and GKF 80 mortality tables;
- Future inflation rate of 2,15%;
- Lapse rate of 6,74%;
- Management cost under a unit cost by policy varying by the group considered;
- The CF are projected depending on the contract boundary of each group.

The contract boundary of each group is displayed in Table II .

Table II - Contracts Boundaries

Group	Contract Boundary
Traditional	15-years
Term Assurance	1-year
Annuities	30-years

The risks considered in each group vary between four risks: mortality risk, expenses risk, lapse risk, and longevity risk. The Traditional group is exposed to the first three, Term Assurance group to the mortality and expenses risk, and Annuities to longevity and expenses risk.

Regarding the discount rate to apply in the projected future cash flows, the Bottom-up approach is used. It is added to the risk-free rate the Volatility Adjustment (VA) as a proxy for the illiquidity adjustment. It is used the relevant interest rate term structure published by EIOPA for the Euro currency at the reference date of 30.09.2020, which is negative for shorter maturities. It can be found in the Annex.

3.2. Illustrative Examples

3.2.1. VaR: Using Solvency II

As stated in chapter 3, there are some methods to compute the RA using the VaR approach. In this chapter, an example using the shocks and calibrations under the Solvency II SCR is run to find the RA at a chosen confidence level. Here we considered that the Solvency II shocks correspond to the confidence level of 99.5%. Additionally, as diversification mechanism, the life correlation matrix taken from the SCR Standard Formula will be used. This matrix can be found in the Annex. The RA will correspond to a 80% confidence level.

This approach will be used to find the RA for the Term Assurance group, since they have 1-year time horizon, and the time horizon considered does not need to be recalibrated.

The steps performed in this example are described below:

I. Find the PV CF of the homogeneous group;

II. For each risk find RA:

a. Find the shocked PV CF, which is computed following the specifications in the Delegated Regulation. The assumptions are displayed in Table III. This value will correspond to the $VaR_{99,5\%}$ at 1-year horizon;

b. Find the RA at the 99,5th percentile, which corresponds to the difference between the $VaR_{99,5\%}$ and the E[PVCF];

c. Adjust the 99,5th percentile to the chosen IFRS 17 confidence level using an appropriate scaling factor;

III. After finding the RA for each risk, use the correlation coefficients of the Life Correlation Matrix from Solvency II, that can be found in the Annex, to find the diversified RA. The computation was done using the formula below:

$$RA = \sqrt{\sum_{i,j \in \forall \, Non-financial\ Risks\ Riski} \rho\left(X_i, \mathrm{X_j}\right) * RA_i * RA_j}, \tag{3.1}$$

where $\rho\left(X_i, \mathrm{X_j}\right)$ corresponds to the entry (i,j) of the Life Correlation Matrix from Solvency II, that can be found in the Annex ,for the risk i and j.

Table III - Delegate Regulation Assumptions

Risk	**Assumption**
Mortality	Instantaneous permanent increase of 15 % in the mortality rates[6]
Expenses	a) An increase of 10 % in the amount of expenses taken into account in the calculation of technical provisions;
	b) An increase of 1 percentage point to the expense inflation rate (expressed as a percentage) used for the calculation of technical provisions.[7]

The scaling factor used in this example was based in a common, however simplistic practice, which consists in using the confidence interval tables of a Normal Distribution. This technique considers that the best estimates follow a Normal Distribution. And it is the following:

[6] Commission Delegated Regulation (EU) 2015/35, Article 137

[7] Commission Delegated Regulation (EU) 2015/35, Article 140

$$RA_{\alpha\%} = RA_{99,5\%} \times \frac{z(\alpha\%)}{z(99,5\%)}, \tag{3.2}$$

where $\frac{z(\alpha\%)}{z(99,5\%)}$ is the scaling factor, and $z(\alpha\%)$ corresponds to the $\alpha\%$ quantile of the Standard Normal Distribution. However, it is important to refer that this simplistic approach has some limitations, and it is recommended to add some prudential margin to the calculations to compensate the model's error.

It also important to refer that the correlation matrix used in Solvency II is calibrated to aggregate risks which correspond to the $VaR_{99,5\%}$. So, the use of this correlation matrix for $VaR_{80\%}$ presents some limitations.

In the following table it is shown the steps mentioned above.

Table IV - Risk Adjustment for Mortality and Expenses Risks

Step	0	1
1. a) PVCF	**- 628 266**	
CF	- 556 255	- 71 647
Discount Rate	0.000%	-0.505%
PV CF	- 556 255	- 72 011
2.1 RA Mortality at 80%	**27 692**	
b) $VaR_{99.5\%}$ PVCF	- 543 512	
CF	- 484 349	- 58 864
Discount Rate	0.000%	-0.505%
PV CF	- 484 349	- 59 163
c) $RA_{99.5\%}$=(b)-(a)	84 754	
d) $RA_{80\%}$	27 692	
z(99,5%)	2,576	
z(80)%	0.842	
%RA	32,67%	
2.2 RA Expenses at 80%	**3 577**	
b) $VaR_{99.5\%}$ PVCF	- 617 320	
CF	- 546 286	- 70 675
Discount Rate	0.000%	-0.505%
PV CF	- 546 286	- 71 034
c) $RA_{99.5\%}$=(b)-(a)	10 946	
d) $RA_{80\%}$	3 577	
z(99,5%)	2.576	
z(80)%	0,842	
%RA	32.67%	

Table V - Diversified RA at 80%

3. RA Diversified at 80%	**28 795**
Diversification Benefit	2 473
RA Mortality	27 692
RA Longevity	0
RA Disability/Morbidity	0
RA Lapse	0
RA Expenses	3 577
RA Revision	0

Given the results above, the RA for the Term Assurance, using the Solvency II shocks, is equal to 28 795 m.u, with DB of 2 473 m.u.

3.2.2. VaR and TVaR Method: Using Distribution Functions

To compute the RA through the VaR and TVaR methods, it is used, in this example, the fitting approach to find the risk distributions. The fitting is done to the present value of the future cash flows for non-financial risks and a few known distributions are considered. It is assumed that there is no new business.

It is also considered in this example the unit-of-account approach, mentioned above, to recognize the level of the DB. Using this approach, the RA of the portfolio will correspond to the sum of the RA for each insurance group. Copulas will also be used to find the aggregated distribution.

To find the best marginal distribution function to each risk, it is initially done a visual check, through a histogram, to understand the behavior of the PV CF for each risk. As we can see in the Figures below, Traditional, Term Assurance, and the expense risk of Annuities all show a skewed right tail and a non-normal behavior, so it is not wise to use the simplification approach and use a Normal Distribution. However, there are some known distributions that have skewed behavior. We will perform a goodness of fit test to the Gamma Distribution, the Pareto Distribution, and a Log-Normal Distribution. And, since for Annuities the longevity risk shows a more symmetric look, it will be added to these three distributions the Normal Distribution.

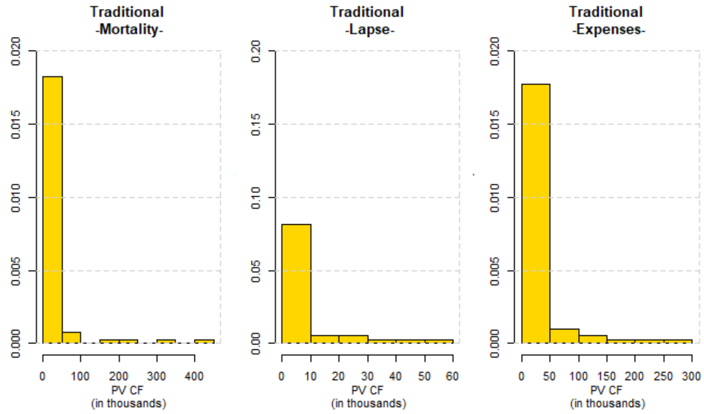

Figure 9- Histograms of Traditional' Risks PV CF

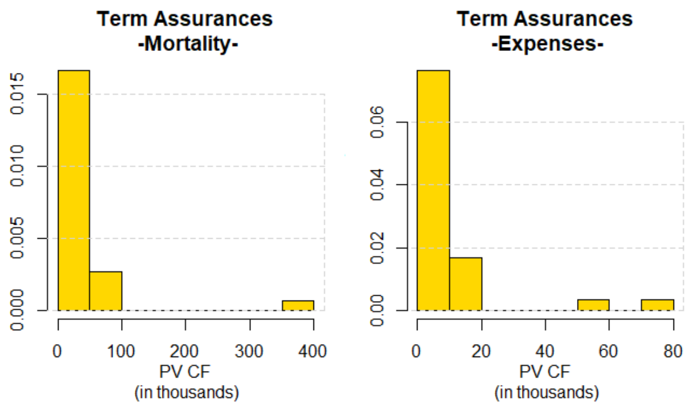

Figure 10 - Histograms of Term Assurance' Risks PV CF

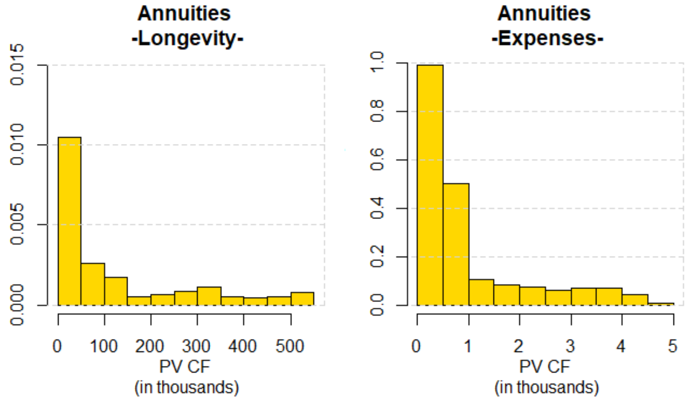

Figure 11 - Histograms of Annuities' Risks PV CF

To find the best fit between these four distributions, we initially found the sample parameters for each distribution using the Maximum Likelihood Estimation (MLE) method to find more efficient estimators. The R code learned in Risk Models lectures [20] was used to perform this calculus. The code and the respective estimated parameters can be found in the Annex.

The next step is to do a goodness fit test. And our test hypothesis is:

H0: X_i ~ stated distribution vs H1: X_i does not follow the stated distribution

Where X_i represents the PV CF for a given risk i.

Two goodness fit tests were performed: the Kolmogorov-Smirnov test and Cramer-von Mises test. R software provides a fast and efficient way to compute the critical value and the p-value for each test.

The results, for each risk, are shown in the tables below.

Table VI - Kolmogorov-Smirnov and Cramer-von Mises Tests for Traditional

	Normal Distribution			**Gamma Distribution**			**Pareto Distribution**			**Log-Normal Distribution**		
	Mortality	Lapse	Expenses	Mortality	Lapse	Expenses	Mortality	Lapse	Expenses	Mortality	Lapse	Expenses
Kolmogorov-Smirnov test												
Statistical Value	0.42	0.41	0.40	0.30	0.24	0.22	0.08	0.10	0.11	0.14	0.11	0.11
p-value	0.00%	0.00%	0.00%	0.00%	2.36%	0.10%	63.31%	85.38%	30.33%	7.39%	68.65%	29.38%
Cramer-von Mises test												
Statistical Value	4.43	1.78	3.86	1.64	0.44	1.17	0.05	0.08	0.12	0.19	0.07	0.21
p-value	0.00%	0.00%	0.00%	0.01%	5.48%	0.09%	88.72%	68.66%	49.16%	29.06%	76.47%	25.13%

Table VII - Kolmogorov-Smirnov and Cramer-von Mises Tests for Term Assurances

	Normal Distribution		**Gamma Distribution**		**Pareto Distribution**		**Log-Normal Distribution**	
	Mortality	Expenses	Mortality	Expenses	Mortality	Expenses	Mortality	Expenses
Kolmogorov-Smirnov test								
Statistical Value	0.34	0.30	0.18	0.14	0.07	0.09	0.07	0.08
p-value	0.16%	0.65%	26.61%	53.68%	99.76%	8.53%	99.51%	98.64%
Cramer-von Mises test								
Statistical Value	1.10	0.93	0.22	0.14	0.02	0.03	0.02	0.02
p-value	0.12%	0.32%	23.47%	41.12%	99.72%	97.14%	99.53%	99.16%

Table VIII - Kolmogorov-Smirnov and Cramer-von Mises Tests for Annuities

	Normal Distribution		**Gamma Distribution**		**Pareto Distribution**		**Log-Normal Distribution**	
	Longevity	Expenses	Longevity	Expenses	Longevity	Expenses	Longevity	Expenses
Kolmogorov-Smirnov test								
Statistical Value	0.23	0.22	0.08	0.07	0.12	0.12	0.09	0.12
p-value	0.00%	0.00%	7.09%	13.87%	0.05%	0.05%	1.46%	0.04%
Cramer-von Mises test								
Statistical Value	4.94	4.54	0.29	0.20	0.61	0.81	0.59	0.94
p-value	0.00%	0.00%	14.48%	27.07%	2.11%	0.71%	2.32%	0.33%

For choosing the distribution, we choose the ones with the lowest test statistics, criteria given in the Loss Models [15], and p-value higher than 1%.

As this exercise requires the existence of the mean for each risk, for those distributions which the tests above show that follow a pareto and its parameter θ is less than 1, it is chosen the second-best distribution. The estimated parameters can be found in the Annex.

Hence, given the criteria mentioned above, the distribution of the PV CF for a given risk are the following:

For Traditional:

- $X_{Mortality} \sim Log - Normal(\hat{\mu} = 6.62 , \hat{\sigma} = 2.61)$;
- $X_{Lapse} \sim Log - Normal(\hat{\mu} = 6.08 , \hat{\sigma} = 2.61)$;
- $X_{Expenses} \sim Log - Normal(\hat{\mu} = 6.28 , \hat{\sigma} = 2.92)$.

For Term Assurances

- $X_{Mortality} \sim Log - Normal(\hat{\mu} = 8.94 , \hat{\sigma} = 1.66)$;
- $X_{Expenses} \sim Log - Normal(\hat{\mu} = 7.71 , \hat{\sigma} = 1.68)$.

For Annuities:

- $X_{Longevity} \sim Gamma(\hat{\alpha} = 0.53 , \hat{\theta} = 224\,417)$;
- $X_{Expenses} \sim Gamma(\hat{\alpha} = 0.57 , \hat{\theta} = 1\,572)$.

After fitting and choosing all distributions, it is computed the E[PVCF], which is the mean of the PV CF, the VaR at the chosen confidence level, and the TVaR at the chosen confidence level. For this example, the 80% confidence level was chosen, and the results are displayed in the tables below. This RA corresponds to the total RA, without diversification.

Table IX - Risk Adjustment for Traditional' s Risks

	Mortality Risk			**Lapse Risk**			**Expenses Risk**		
	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR
RA		**3 972**	**116 076**		**2 321**	**25 385**		**3 938**	**74 833**
Value	2 761	6 732	118 837	1 612	3 933	26 997	2 302	6 240	77 135

Table X - Risk Adjustment for Term Assurance' s Risks

	Mortality Risk			Expenses Risk		
	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR
RA		**13 292**	**103 756**		**4 017**	**22 466**
Value	17 456	30 748	121 212	5 163	9 180	27 629

Table XI - Risk Adjustment for Annuities' s Risks

	Longevity Risk			Expenses Risk		
	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR
RA		**76 723**	**244 752**		**584**	**1 948**
Value	118 816	195 539	363 568	901	1 485	2 849

The Total RA for each group is the sum of the RA of their risks. In Table XII , the results are shown.

Table XII - Total Risk Adjustment at 80%

	Total Risk Traditional		Total Risk Term Assurance		Total Risk Annuities	
	RA with VaR	RA with TVaR	RA with VaR	RA with TVaR	RA with VaR	RA with TVaR
RA	10 231	216 294	17 309	126 222	77 307	246 700

To include the diversification, the copula approach is used to find the aggregated RA for each group, using the marginal distributions of their respective risks. The Clayton Copula was used, as the marginal distributions display asymmetry. The Clayton copula is defined as:

$$C(u_1, \dots, u_d) = \left(u_1^{-\theta} + \dots + u_d^{-\theta} - 1\right)^{-1/\theta} \quad (3.3)$$

To simulate the aggregated distribution using this copula, the algorithm present in the IAA's paper regarding the RA [11] was used. The R code can be found in the Annex. And the algorithm is the following:

1. "*Generate independent exponential variates (μ=1):*$v_1, \dots, v_d$*;*
2. *Generate a gamma variate z (with* $\beta = 1$*) independent of the exponential variates;*

3. *Set* $u_i = \left(1 + \frac{v_i}{z}\right)^{-1/\theta}$;

4. *The resulting vector is u=*$\begin{pmatrix} u_1 \\ \vdots \\ u_d \end{pmatrix}$ *and follows a Clayton copula with parameter* $\theta > 0$. *The mirrored copula is u`=*$\begin{pmatrix} 1-u_1 \\ \vdots \\ 1-u_d \end{pmatrix}$. *"*[8]

A Goodness Fit test is performed to understand which distribution the aggregated risk follows, using the same steps to find its marginal distributions. The table with the results regarding its test statics and p-value can be found in the Annex.

All aggregated risks follow a Log-Normal Distribution, and even though the best fit for the Annuities is a Pareto since the alpha estimated is less than 1, its mean does not exist and for the purpose of this report it is important to have a mean.

The tables below show the aggregated RA at 80%, using the copula-based algorithm, and the DB.

Table XIII - Aggregated RA at 80%

	Aggregated Risk Traditional			Aggregated Risk Term Assurance			Aggregated Risk Annuities		
	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR	E[PVCF]	VaR	TVaR
RA		**1 127**	**8 775**		**3 626**	**14 747**		**34 447**	**83 260**
Value	2 233	3 361	11 009	11 219	14 845	25 966	56 711	91 158	139 971

Table XIV - Diversification Benefit

	Traditional		Term Assurance		Annuities	
	VaR	TVaR	VaR	TVaR	VaR	TVaR
Diversification Benefit	9 104	207 519	13 682	111 475	42 860	163 440

To conclude, the RA of this portfolio will be sum of the RA for the Traditional, Term Assurance and Annuities. For the respective methodology, the results can be seen in the tables below. The RA using the VaR approach at 80% corresponds to 39 201 m.u, and for the TVaR approach at the same level of confidence to 106 782 m.u.

8 IAA (2018), Risk Adjustment for Insurance Contracts under IFRS 17

Table XV - Portfolio's VaR Risk Adjustment

RA VaR at 80%	**39 201**
Diversification Benefit	(65 645)
RA Traditional	1 127
RA Term Assurance	3 626
RA Annuities	34 447

Table XVI - Portfolio's TVaR Risk Adjustment

RA TVaR at 80%	**106 782**
Diversification Benefit	(482 434)
RA Traditional	8 775
RA Term Assurance	14 747
RA Annuities	83 260

In the Table XVII we can see the RA results for the Term Assurance group using the three methods run in this report:

Table XVII - Term Assurance RA Summary

Using Correlation Matrix - VaR SII		Using Copulas - VaR		Using Copulas - TVaR	
RA Diversified at 80%	**28 943**	**RA Diversified at 80%**	**3 626**	**RA Diversified at 80%**	**14 747**
Diversification Benefit	2 486	Diversification Benefit	13 682	Diversification Benefit	111 475
Total RA	31 429	Total RA	17 309	Total RA	126 222

Conclusion

Throughout this report, it was clear the challenges that IFRS 17 present to the insurance companies. As the many components of this Standard, the RA is still in study and has a lot of space to grow and be improved. Thus, it was useful to understand how the RA can be computed and the many aspects to consider.

The first example represents an advantageous method for companies since it uses the Solvency II shocks that they are already required to perform. However, simplistic assumptions were also used to change the confidence level of the VaR. For contracts with a lifetime higher than one year, it also demands a recalibration of the time horizon, which presents more work for companies. Some approaches to perform this recalibration can go from simplistic methods as the square root of time rule, which considers that the PV CF are independent and identical distributed, to a more complicated process, like a Monte Carlo approach. In Life Insurance, this is a critical aspect to consider since contracts tend to be very long.

The second example has used the distributions of the PV CF of the non-financial risks to find the VaR and the TVaR. These approaches need a lot of information about the risks and the risk profile of the company. And in terms of prudence, they are not comparable. In Table XV and Table XVI , we can see that the results of both methodologies are very different, considering absolute values. This results from the fact that the TVaR methodology is very sensitive to extremes values, which presents the advantage of better ability of catching skewness and outliers. Hence, all things equal, the TVaR is a more prudent measure than the VaR. It is also important to mention, that the fact that the VaR measure is not coherent can present problems with distribution with lower values.

In Table XVII we can see, when using the Solvency II shocks, that we get a higher RA for the Term Assurance group, compared with the other methodologies. The reason behind this can be the problems regarding the DB methodology and the simplifications used.

This report's main goal was to illustrate some examples of how to compute the RA for a given life portfolio dataset. Nevertheless, this component can be calculated using a wide range of methodologies, not only the ones described in this report. Some of the mechanisms were simplified, and consequently, there is a lot of material for future work, which can go from performing new methodologies, to improving the ones performed here with more accurate models and stronger assumptions. One interesting subject would be investigating the impact of the RA on the profitability indicators of a company. However, the complexity of this work demands a more profound knowledge of the methodologies.

Bibliography

[1] Abadi, M (2015), Analysis of New Techniques for Risk Aggregation and Dependence Modeling

[2] Borginho, H. (2019) Solvency Models, ISEG-ULISBOA

[3] Canadian Institute of Actuaries (2019, July), IFRS 17 Risk Adjustment for Non-Financial Risk for Life and Health Insurance Contracts, Retrieved from https://www.cia-ica.ca/docs/default-source/2019/219081e.pdf

[4] Commission Delegated Regulation (EU) 2015/35 of 10 October 2014 supplementing Directive 2009/138/EC of the European Parliament and of the Council on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II)

[5] Cruz, M.C (2019), Evaluation of the Technical Provisions of Insurance Contracts under IFRS 17

[6] EIOPA (2018), EIOPA’s analysis of IFRS 17 Insurance Contracts, Retrieved from https://register.eiopa.europa.eu/Publications/Reports/EIOPA-18-717_EIOPA_Analysis_IFRS_17_18%2010%202018.pdf

[7] EIOPA (September 2020), Risk-free interest rate term structures, Retrieved from https://www.eiopa.europa.eu/tools-and-data/risk-free-interest-rate-term-structures_en

[8] Embrechts, P., Lindskog, F., McNeil, A. (2001), Modelling Dependence with Copulas and Applications to Risk Management

[9] EY (2018), Applying IFRS 17: A closer look at the new Insurance Contracts Standard

[10] Gaspar, R.M (2018), Financial Markets and Investments, ISEG-ULISBOA

[11] IAA (2018), Risk Adjustment for Insurance Contracts under IFRS 17

[12] IFRS Foundation (2017), IFRS 17 Insurance Contracts

[13] IFRS Foundation (2017), International Financial Reporting Standards17 - Basis for Conclusions

[14] IFRS Foundation (2017), Project Summary- IFRS 17 Insurance Contracts

[15] Klugman et al (2012), Loss Models – From data to decisions, Fourth Edition, Wiley

[16] Manganelli, S, Engle, R.E (2001, August), Value at Risk Models in Finance

[17] Milliman (2017) IFRS 17: Risk Adjustment on IFRS 17 Insurance Contracts

[18] Moody's Analytics (2019), Aggregation and diversification of the IFRS 17 Risk Adjustment

[19] OSFI (2014), Quantitative Impact Study No. 4: General – Aggregation and Diversification, Supplementary Information, Retrieved from https://www.osfi-bsif.gc.ca/Eng/Docs/qis4_aggdiv.pdf

[20] Silva, J.A (2018) Risk Models, ISEG-ULISBOA

Annex

Table XVIII – EIOPA risk-free term structure (October 2020)

Year	Term Structure
1	-0.405%
2	-0.395%
3	-0.385%
4	-0.355%
5	-0.325%
6	-0.286%
7	-0.246%
8	-0.196%
9	-0.157%
10	-0.107%
11	-0.064%
12	-0.017%
13	0.018%
14	0.053%
15	0.085%
16	0.100%
17	0.106%
18	0.115%
19	0.134%
20	0.168%
21	0.218%
22	0.280%
23	0.349%
24	0.424%
25	0.501%
26	0.580%
27	0.658%
28	0.736%
29	0.813%
30	0.887%

Table XIX - Life Correlation Matrix

	Mortality	Longevity	Disability/Morbidity	Lapse	Expenses	Revision
Mortality	1.00	-0.25	0.25	0.00	0.25	0.00
Longevity	-0.25	1.00	0.00	0.25	0.25	0.25
Disability/Morbidity	0.25	0.00	1.00	0.00	0.50	0.00
Lapse	0.00	0.25	0.00	1.00	0.50	0.00
Expenses	0.25	0.25	0.50	0.50	1.00	0.50
Revision	0.00	0.25	0.00	0.00	0.50	1.00

Table XX - Maximum Likelihood Estimation Parameters

Traditional

	Normal Distribution		Gamma Distribution		Pareto Distribution		Log-Normal Distribution	
	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\theta}$	$\hat{\mu}$	$\hat{\sigma}$
Mortality Risk	20 355	67 040	0.22	92 697	0.47	166	6.62	2.61
Lapse Risk	6 175	12 895	0.27	23 253	0.42	70	6.08	2.61
Expenses Risk	17 152	46 722	0.21	81 488	0.35	47	6.28	2.92

Term Assurances

	Normal Distribution		Gamma Distribution		Pareto Distribution		Log-Normal Distribution	
	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\theta}$	$\hat{\mu}$	$\hat{\sigma}$
Mortality Risk	30 176	70 329	0.47	64 666	1.03	7 635	8.94	1.66
Expenses Risk	8 087	15 308	0.49	16 399	1.04	2 326	7.71	1.68

Annuities

	Normal Distribution		Gamma Distribution		Pareto Distribution		Log-Normal Distribution	
	$\hat{\mu}$	$\hat{\sigma}$	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\theta}$	$\hat{\mu}$	$\hat{\sigma}$
Longevity Risk	118 816	149 364	0.53	224 417	1.38	72 694	10.50	2.04
Expenses Risk	901	1 116	0.57	1 572	1.91	961	5.72	1.86

Table XXI - Kolmogorov-Smirnov and Cramer-von Mises Tests for Aggregated Distributions

Traditional

	Normal Distribution	Gamma Distribution	Pareto Distribution	Log-Normal Distribution
	Copula Aggregated	Copula Aggregated	Copula Aggregated	Copula Aggregated
Kolmogorov-Smirnov test				
Statistical Value	0.36	0.14	0.07	0.03
p-value	0.00%	0.00%	0.04%	18.53%
Cramer-von Mises test				
Statistical Value	43.28	6.73	1.41	0.36
p-value	0.00%	0.00%	0.03%	9.00%

Term Assurances

	Normal Distribution	Gamma Distribution	Pareto Distribution	Log-Normal Distribution
	Copula Aggregated	Copula Aggregated	Copula Aggregated	Copula Aggregated
Kolmogorov-Smirnov test				
Statistical Value	0.19	0.34	0.22	0.04
p-value	0.00%	0.00%	0.00%	9.63%
Cramer-von Mises test				
Statistical Value	13.81	39.05	19.74	0.25
p-value	0.00%	0.00%	0.00%	19.49%

Annuities

	Normal Distribution	Gamma Distribution	Pareto Distribution	Log-Normal Distribution
	Copula Aggregated	Copula Aggregated	Copula Aggregated	Copula Aggregated
Kolmogorov-Smirnov test				
Statistical Value	0.15	0.06	0.05	0.13
p-value	0.00%	0.18%	1.56%	0.00%
Cramer-von Mises test				
Statistical Value	5.91	0.84	0.59	5.47
p-value	0.00%	0.60%	2.32%	0.00%

R Code Maximum Likelihood Estimation [20]:

(Example for a Normal Distribution)

```
>library(actuar)

#Initial parameters:

>v0=c(1,1000)

#Creation of the function to minimize:

>distribution_function=function(parameter,x){

    alpha=parameter [1]; theta=parameter [2]

    -sum(dnorm(x,mean=alpha,sd=theta,log=TRUE))}

#Use of nlm function to find the minimum:

>result=nlm(distribution_function, v0, x=Dataset)
```