MASTER OF SCIENCE IN
FINANCE

MASTERS FINAL WORK
PROJECT

INVESTMENT POLICY STATEMENT:
LUSITANIA SEGUROS

WORKMAN´S COMPENSATION PORTFOLIO

PEDRO AIRES DOS SANTOS

PROFESSOR RAQUEL MEDEIROS GASPAR

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Abstract

This master's Final Work is an Investment Policy Statement aimed to govern a liabilities portfolio, namely liabilities attributed to worker´s compensation insurance, medical expenses insurance, and income protection insurance. These three types of liabilities are blended into a single liability portfolio.

Lusitania Seguros is a subsidiary of Montepio Geral- Associação Mutualista, the largest portuguese mutual association, which initiated activity in 1986.

As the goal is to cover their future liabilities, it is imperative that the portfolio yields sufficient returns. As such, an expected annual return of at the least 2,5% above the risk-free rate is one of the attainable goals, as well as maximum expected volatility of 7,5%, per year.

Due to the portfolio´s goal of covering liabilities, it is thus imperative that enough cash is yielded each year from the portfolio´s assets. As such, the investment philosophy relies on a portfolio immunization strategy, englobing both cash flow matching and duration matching, to mitigate potential credit and interest rates risks.

Because of this, the asset allocation strategy should be based on predictable cash flows, which means building a portfolio mainly composed of fixed income securities, and also including real estate and a fair percentage of cash.

This ensures better accuracy when matching both cash flows and durations from the asset portfolio and the obligations portfolio. The asset portfolio focuses mostly on government and supranational bonds, but also includes some corporate and covered bonds, to mitigate potential defaults, while maintaining reasonable returns prospects.

Also, the majority of the securities are ETFs, as investing in them provides considerable diversification at low costs, while trying to increase returns (optimization portfolio). More specifically, 65% of the portfolio is composed of fixed income and real estate indices, and 35% is related to the immunization portfolio, which is only constituted by individual securities, in order to perform cash flow matching.

In terms of risk management and analysis, value at risk and expected shortfall are computed for 99% and 99,9% confidence levels, using both the historical method and a Monte Carlo simulation.

JEL classification: C63; G11; K22; G28; G2

Keywords: Asset Management; Portfolio Theory; IPS; Portfolio Immunization; Cash Flow Matching; Duration Matching; Fixed Income.

Resumo

Esta tese consiste na construção de uma Política de Investimentos, cujo objetivo é governar a carteira de ativos financiados pela Lusitania Seguros, nomeadamente seguros de acidentes de trabalho, seguros de vida, seguros de despesas médicas e seguros de proteção de rendimentos. A Lusitania Seguros é detida pela Montepio Geral-Associação Mutualista, a maior associação mutualista portuguesa, e iniciou atividade em 1986.

Com a meta de cobrir os passivos, é imperativo para o fundo obter rentabilidade suficiente para tal. Por esse motivo, uma taxa de retorno anual esperada de pelo menos 2,5% é um dos objetivos a ter em conta, bem como como uma volatilidade máxima esperada de 7,5% ao ano.

Para além disso, dado que tem de se cobrir um passivo num período específico futuro, é necessária previsibilidade nos fluxos de caixa do portefólio. Assim, a filosofia de investimento irá basear-se numa estratégia de imunização de portefólio, englobando Cash Flow Matching e Duration Matching, para mitigar potenciais riscos de crédito e de movimentações de taxas de juros.

Ou seja, o portefólio em questão depende de uma alocação estratégica de ativos com fluxos de caixa previsíveis, o que significa um portefólio composto principalmente por títulos de renda fixa, garantindo assim uma melhor precisão na estratégia de imunização de portefólio.

O portefólio de imunização é principalmente composto por obrigações governamentais e supranacionais, mas também incluirá algumas obrigações de empresas e covered bonds para mitigar possíveis falhas ou atrasos em pagamentos, mantendo perspectivas de retornos razoáveis.

A maioria dos ativos são ETFs, uma vez que investir neles proporciona uma diversificação considerável a baixos custos, enquanto é possível maximizar os retornos (optimization portfolio). Mais especificamente, 65% do portefólio é composta por índices de rendimento fixo e imobiliários, e 35% será composta pelo immunization portfolio, que é constituída apenas por obrigações, com o objetivo de realizar cash flow matching.

Em termos de gestão e análise de riscos, duas métricas chave foram calculadas: O "valor em risco (VaR)" e a "expected shortfall (ES)". Isto para níveis de confiança de 99% e 99,9%, utilizando tanto o método histórico quanto uma simulação de Monte Carlo.

Classificação JEL: C63; G11; K22; G28; G2

Palavras-Chave: Gestão de Activos; Teoria da Carteira; IPS; Imunização de Portefólio; Obrigações

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Thank you for all the support and encouragement,

Pedro Aires dos Santos

Índice

1. Executive Summary

1.1. Scope and Purpose

This IPS aims to govern the investments associated with Lusitania Seguros, a Portuguese company operating within the insurance sector. This investment policy statement governs the portfolio funding its liabilities concerning medical expenses insurance, income protection insurance, and workers' compensation (which represents the vast majority of the liabilities). The overall objective of the company is the preservation of capital while yielding sufficient returns considering an adequate level of risk.

1.2. Governance

The various units responsible for the execution and monitoring of procedures ensure the collection, analysis, processing, and production of high-level management information for strategic decision-making. The main responsibilities of the process are carried out by the following stakeholders: Board of Directors, Investment Committee, Financial Investment Office, Risk Management Department, Finance Department, Internal Audit Department and Compliance Office.

1.3. Investment Return and Risk

The main goal for the portfolio of assets under analysis is to cover the expected liabilities during the next 11 years. This means preservation of capital should be aimed for, and not necessarily return maximization.

However, returns cannot be neglected either. In fact, for a successful capital allocation, the returns should yield at least the discount rate of the liabilities from the EIOPA curve, ideally. Fixed income, government, and supranational bonds are necessary since they are the most aligned with the mentioned goals.

1.4. Risk Management

In terms of risk analysis, attention should go to two main metrics: The Value at Risk and Expected Shortfall.

With these ratios, two questions can be answered: "How bad can things get?", and "If things do get bad, how big of an impact will it have in terms of Expected Loss?".

The Value at Risk was computed through both the Historical Method and the Monte Carlo Simulation Method.

2. Investment Policy Statement

2.1. Scope and Purpose

This IPS aims to govern the investments associated with Lusitania Seguros, a Portuguese company operating within the insurance sector. Established in 1986 Lusitania has gained a strong foothold in the Portuguese market, providing a wide range of insurance products and services to individual and corporate clients, for non-life products. For individual clients these are mainly focused on the following liabilities:

- Motor vehicle liabilities (it includes motorcycles)
- Health insurance
- Property Insurance
- Family and Leisure Insurance (travel, personal protection, and children protection insurance)
- Hunting and Firearms Insurance
- Independent Worker Insurance

And for companies, the products available consist of the following:

- Motor Insurance
- Property & Casualty (Commercial, Industrial, Engineering, and Transportation Insurance)
- Workman´s Compensation
- Health Insurance
- Civil Liability Insurance

This investment policy statement governs the portfolio funding the liabilities concerning medical expenses insurance, income protection insurance, and workers' compensation (which represents the vast majority of the liabilities, as displayed below.

Units: euros	PORTFOLIO 2 - Portfolio of Expenses WComp - Cash Ouflows (Close Group)			Sum of CF
	Non Life Business			
Year	Medical expense insurance	Income protection insurance	Workers' compensation insurance	
1	4 070 713	144 574	12 459 404	16 674 691
2	432 239	46 378	3 194 091	3 672 709
3	216 531	23 316	1 628 718	1 868 565
4	130 564	12 297	997 424	1 140 284
5	91 430	2 695	601 254	695 379
6	65 506	829	469 797	536 132
7	48 693	741	415 234	464 669
8	45 276	164	346 737	392 178
9	51 083	0	280 363	331 446
10	862	0	264 981	265 843
11	0	0	232 025	232 025

In terms of the legal framework, Lusitania Seguros is a recognized and licensed insurance company operating under the jurisdiction of Portuguese regulatory authorities. As an insurance provider, Lusitania Seguros is subject to regulatory oversight by Autoridade de Supervisão de Seguros e Fundos de Pensões (ASF) and must comply with all applicable laws, regulation and guidelines about the insurance industry. The IPS will adhere to all applicable legal and regulatory requirements governing the Company's investment activities, ensuring compliance, transparency, and accountability.

Lusitania allocates capital according to its investment policy guidelines, which goal is to guarantee the safety, quality, and liquidity of investments, as well as provide adequate returns in terms of risk management. It should also invest in assets that are by its respective liabilities and progressively align investment decisions with ESG principles.

The overall objective of the company is the preservation of capital while yielding sufficient returns considering an adequate level of risk. This means that the assets chosen should yield returns greater than the discount rate of the Eiopa curve.

However, arguably the most important point regarding Lusitania´s investment policy is related to Assets and Liabilities Management (ALM), more specifically cash flow matching and duration matching, which are key points when constructing the portfolio.

At this point, it is only important to briefly point out the main idea behind Cash Flow Matching, which consists in matching the yearly cash inflows from the portfolio of assets to cover the corresponding annual liabilities cash outflows. For example, if at the end of year 1, we are expected to pay liabilities of 0,5 million euros, our 10 million worth portfolios should theoretically yield at least 5% so there are no liquidity problems.

Regarding duration matching, the concept is quite similar in the sense that perfect portfolio immunization theoretically happens when the duration of assets is equal to the duration of liabilities (not yearly, but considering an average of 11 years, our time horizon). So, the matching principle also applies.

These were very simplistic explanations, but a "practical" twist is introduced, because in real-life applications, perfect portfolio immunization might be close to impossible to do. Especially when adding constraints regarding asset class weights, returns, and volatility, among others. Still, ALM is indispensable for successful interest rate and liquidity risk management, according to Choudhry (2011).

2.2. Governance

2.2.1   Principles of Operation

The management of investments at Lusitania follows the guidelines established for a prudent manager and is carried out according to the following principles:

a)   Investments should be made with an appropriate level of diversification and risk dispersion.

b)   The level of risk should be appropriate to the Company's risk appetite.

c)   The selection of investments should be careful and consider both intrinsic risk and market risk.

d)   Investments in assets funding technical provisions should be made in accordance with prudential criteria.

e)   Investments should only be made in assets with identifiable, measurable, and monitorable risks.

2.2.2   Responsibilities

The various units responsible for the execution and monitoring of procedures ensure the collection, analysis, processing, and production of high-level management information for strategic decision-making. The main responsibilities of the process are carried out by the following stakeholders:

- **Board of Directors**
- Approve the Investment Policy.
- Approve the Company's investment strategy and management, based on the Business Plan, Risk Appetite, and exposure limits.
- Monitor and decide on deviations from limits and risk tolerance levels, as well as approve active or reactive contingency measures in response to risk factors.

- **Investment Committee**
- Review the Investment Policy to be submitted to the Board of Directors.
- Assess the investment strategy and monitor its implementation.
- Monitor the performance of investments against benchmarks and portfolio exposure levels, considering limits on investment classes and established risk tolerance levels.
- Evaluate tactical investment options based on market expectations.

-       Monitor the performance of asset managers and compliance with management mandates (direct or indirect).

-       Analyze financial income trends against the Business Plan.

-       Analyze and propose mitigation measures and/or corrections for potential structural deviations from established limits and tolerance levels.

- **Financial Investment Office**
-       Develop and coordinate all necessary procedures to propose revisions to the Investment Policy.

-       Implement the approved investment strategy and, when deemed necessary, propose the use of specialized asset management companies. The management mandate contract must include the principles established in the Investment Policy and applicable regulations.

-       Optimize the investment portfolio profile by defining fund allocation and selecting securities under the guidelines outlined in the Company's Investment Policy and strategies defined for different portfolios (Annex I).

-       Manage the level of investment risk within the limits established in the Company's Risk Appetite Policy.

-       Propose methods and procedures for measuring profitability and risk.

-       Analyse and identify measures to mitigate and/or correct deviations from risk limits and tolerance levels.

-       Report to the Investment Committee and the Board of Directors on the development and expectations of financial markets, the updated status of the investment portfolio and its profitability, as well as any investment proposals.

-       Ensure the necessary liquidity management for the Company's investments.

-       Propose methods and take action to minimize administrative management costs related to the Investment Function.

-       Ensure the existence of technical expertise and experience necessary for compliance with the requirements outlined in this Policy, as well as any legal, regulatory, or administrative requirements in effect.

-       Ensure the ongoing development of existing competencies related to all investment operations topics, as well as products, market operations, and risks.

- **Risk Management Department**
-       Develop and coordinate all procedures to assess investment risks.

-       Propose methods and procedures for measuring risks and capital requirements.

-       Monitor capital requirements and report them to the Investment Committee, Risk Committee, and Board of Directors, when applicable.

-       Collaborate in the analysis and identification of measures to mitigate and/or correct deviations from risk limits and tolerance levels.

- **Finance Department**
-       Properly value financial assets.

-       Ensure the accounting of financial asset transactions.

-       Ensure external reporting of information related to the investment portfolio.

- **Internal Audit Department**
-       Ensure the existence of an adequate internal control environment, in accordance with the principles of the Internal Control System, to ensure that the investment management and decision-making process is sufficiently robust.

2.3. Investment, Return, and Risk Objectives

As briefly mentioned earlier, the main goal for the portfolio of assets is to cover the expected liabilities during the next 11 years. This means preservation of capital should be aimed for, and not necessarily return maximization.

However, returns cannot be neglected either. In fact, for a successful capital allocation, the returns should yield at least the discount rate of the liabilities from the EIOPA curve.

Otherwise, the risk would be taken for returns inferior to the ones "risk-free" asset, underperforming it. This would make covering future obligations a much more challenging task.

So, there is a clear trade-off: Too high of returns and too much risk would potentially jeopardize the ability to pay future liabilities, and the same would happen with a strategy that is not enough risk-seeking.

The institutional investor, Lusitania, provided a constraint in that sense, in which our portfolio should have at the very least an average expected annual return of 2,5% above the risk-free rate and no more than 7,5% average annual expected volatility.

This way it is possible to preserve capital by taking on a relatively low level of risk, while returns are not neglected.

2.3.1. Investor´s Risk Tolerance

Due to the nature of an insurance company´s business model, the risk appetite is generally quite low. Since there are expected liabilities that have to be paid at an exact point in the future. Although they are calculated using statistical methods, which makes the exact obligation amount unpredictable, it is certain that the obligation arises at that date.

So, there is this liquidity constraint that cannot be breached by any means, which implies more predictable securities should be picked. Because of that, the asset allocation primarily tends to fixed income securities, and real estate is also a suitable option. Other asset classes can and should be considered from a risk-seeking perspective, such as equities, but the majority of the assets should have predictable yields.

This is because equities would be too dependent on price movements, even from a dividend investing perspective, which implies unpredictability.

So, liquidity risk is arguably the most important risk to tackle, which means not having enough assets to cover future liabilities is the main concern. Fixed Income securities with lower volatilities but decent yields (or return potential, by buying at a discount, below par) should be a priority.

This type of securities is also auxiliary in tackling default risk. When investing in fixed- income securities, due diligence regarding the possibility of failed payments is a must. But by filtering fixed income by government and supranational bonds with ratings at the very least above AA, default

possibility diminishes exponentially. That is why only primely rate bonds were allocated.

The other key risk to face when investing mainly in fixed-income securities is interest rate risk. Interest rate risk can be separated into two risks: price and reinvestment. The first is relative to price movements, and the other is related to coupon yield movements.

For example, recently central banks increased rates at a tremendous pace, which means that bond prices dropped (higher price risk) but yields also increased (lower reinvestment risk). And vice versa. When the rates decrease, like during the last decade, the opposite scenario happens.

The main point is both risks are offset in a way, because if capital gains are sacrificed, the yield will increase, or the other way around.

All in all, the risk profile suggests a portfolio that aims for the preservation of capital and provides enough liquidity at a certain point in time, implying a more conservative approach based on a fixed income and real estate as key asset classes.

2.3.2. Portfolio Constraints

To sum it up, in order to optimally choose assets for the portfolio, the previously mentioned aspects/constraints had to be taken into account:

- Preservation of Capital is the main goal, aligning with low risk tolerance.

- To some degree, the portfolio Cash Flows should be predictable to do a proper CF Matching immunization strategy.

- Due to unexpected events and liquidity risk, a reasonable percentage of the total amount invested should stay allocated as Cash.

- Returns are constrained to at least 2,5% above the risk-free rate each year, on average.

- Not taking more risk than necessary, implying average annual volatility inferior to 7,5%, a cap value provided by Lusitania Seguros.

- The duration of the portfolio of assets should not deviate more than 2 years from the duration of liabilities. A great starting point to maximize the probability of this happening before using the numerical methods is to find assets with maturities and duration similar to the corresponding liabilities.

For example, the majority of the liabilities total CFs have to be paid within the first few years (especially during the first year), which means the majority of the portfolio´s assets should consist of short-term securities.

3. Investment Design

3.1. Investment Philosophy

As certain amounts of liabilities must be met at a specific future point in time, a conservative strategy with less volatile securities and predictable Cash Inflows is recommended.

For that, Fixed Income Securities and Real Estate would be arguably the most appropriate asset classes. Plus, a portfolio mainly composed of government and supranational bonds with at least an AA credit rating would add an extra layer of safety against credit risk, when compared with securities with lower ratings, and also when compared against corporate bonds, arguably.

In alignment with a conservative approach, and to tackle liquidity and interest rates risk, portfolio immunization is the most important strategic element.

1. The first step for the portfolio immunization strategy is Cash Flow Matching, which, as previously referred, means aligning cash flows that yield from a certain portfolio of assets to future liabilities. There are several advantages to engaging in this process:**Liability Management**- Liability Management relies on ensuring enough funds are available for future liabilities, which is especially relevant when working with long-term obligations.

2. **Risk Mitigation**- There is also a risk mitigation aspect in the sense that by buying a security that provides a "certain" Cash Flow in the future, interest rate and other market fluctuations effects can be diminished.

3. **Portfolio Construction**- Since very specific liabilities should be met at certain points in time, it imposes heavy constraints when building a portfolio. Because particular yields, maturities, and risk characteristics should be taken into account.

Table 1: Cash Flow Matching Results

CASH FLOWS	LIABILITIES	Δ
16 674 691,31 €	16 674 691,32 €	0,00 €
3 672 708,60 €	3 672 708,60 €	0,00 €
1 868 565,31 €	1 868 565,31 €	0,00 €
1 140 284,13 €	1 140 284,13 €	0,00 €
695 379,48 €	695 379,48 €	0,00 €
536 132,26 €	536 132,26 €	0,00 €
464 668,89 €	464 668,89 €	0,00 €
392 177,55 €	392 177,55 €	0,00 €
331 446,20 €	331 446,20 €	0,00 €
265 842,93 €	265 842,93 €	0,00 €
232 025,48 €	232 025,48 €	0,00 €
	Required Capital	
	24 559 759,76 €	

However, Cash Flow Matching is rarely the only portfolio immunization method used to manage risk. Although it is an efficient method to minimize liquidity shortfalls, in terms of interest rate risk and overall portfolio value, it is not sufficient.

As mentioned earlier in the IPS there is a method in which both interest rate risks (price and reinvestment risk) can be fully, or almost fully, offset. This method is duration matching and combined with Cash Flow Matching, they constitute an optimal way of risk management and immunization against uncertainty regarding the future economic environment.

Table 2: Duration Matching Results

Duration Assets	3,24579
Duration Liabilities	1,98602
Δ	1,25977

But it is relevant to note that in real life, it would be roughly impossible to do perfect portfolio immunization, due to all the discrepancy in constraints goals.

Conciliating equal duration between assets and liabilities, cash flows that perfectly cover each yearly liability, while achieving a return 2,5% above the risk-free rate and with a 7,5% volatility annual cap would be a very challenging task in practical terms. In addition, there are still constraints regarding weights for each asset class, for example.

For this reason, our duration constraint consists of an interval, and it is not an exact duration objective.

Table 3: Duration Computation of the Liabilities Portfolio

Maturity	Period (t)	Cash Outflows (Liabilities)	EIOPA curve Rates	Present Value	Duration Weights: PV/ NPV	Duration
31/12/2024	1	16 674 691,32 €	3,622%	16 091 844,70 €	0,656305602	0,656306
31/12/2025	2	3 672 708,60 €	3,684%	3 416 354,94 €	0,139335976	0,278672
31/12/2026	3	1 868 565,31 €	3,517%	1 684 508,67 €	0,068702656	0,206108
31/12/2027	4	1 140 284,13 €	3,370%	998 699,92 €	0,040731959	0,162928
31/12/2028	5	695 379,48 €	3,274%	591 925,27 €	0,024141662	0,120708
31/12/2029	6	536 132,26 €	3,210%	443 548,66 €	0,018090124	0,108541
31/12/2030	7	464 668,89 €	3,167%	373 557,95 €	0,015235555	0,106649
31/12/2031	8	392 177,55 €	3,144%	306 147,68 €	0,012486228	0,09989
31/12/2032	9	331 446,20 €	3,132%	251 114,67 €	0,010241707	0,092175
31/12/2033	10	265 842,93 €	3,125%	195 427,42 €	0,007970504	0,079705
31/12/2034	11	232 025,48 €	3,108%	165 698,93 €	0,006758028	0,074338

Macaulay Duration
1,9860

In this case, from the table above, we can observe the liabilities discounted according to the EIOPA curve rate for the Euro Zone lead to an average Macaulay Duration of 1,98602. Instead of having a portfolio of assets that mimics this value, our constraint is that it should not deviate more than 2 units from that number. A constraint that is complied with, as the average Macaulay Duration of the portfolio of assets is 3,24741 (a difference of only 1,26 years).

Although Macaulay duration is a more "simplistic" measure of sensitivity to interest rates (especially considering it assumes 2 small parallel shifts in the yield curve), there are a few reasons it was used instead of effective duration or modified duration:

1.   Macaulay Duration has a more "intuitive" interpretation as it represents the time in years it takes to recover the initial investment through the assets invested. This may be useful for an insurance company that requires specific cash flows to meet specific liabilities since gives a better understanding of the timing and magnitude of future cash flows.

2.   Modified Duration and especially Effective Duration, are more commonly used for portfolios that include bonds with embedded options. Since when a bond with an embedded option starts trading in the money it is assumed there is usually an incentive to be called, the issuer will reclaim it, thus duration will drastically drop. Because our portfolio does not include embedded options (as the Cash Flows would be more sensitive to interest rates) using these types of durations is unnecessary.

3.2. *Strategic Asset Allocation*

Regarding asset allocation, it has been mentioned that fixed income would compose the majority of the portfolio. Not only due to the nature of an insurer´s business and consequently its risk tolerance, but also due to Lusitania´s weight restrictions, that heavily favor a fixed income portfolio.

Before explaining the process of asset picking and how weights were computed, it is relevant to note that the construction of two separate portfolios took place: an Immunization Portfolio and an Optimization Portfolio.

This separation is mainly due to the computation of cash flow and duration matching, industry norms related to the style of portfolio management, and the introduction of mean- variance theory and the efficient frontier, which is introduced later in this document.

Firstly, the construction of the immunization portfolio is addressed. The importance of cash flow matching in terms of liabilities management, risk mitigation, and portfolio construction was already accentuated, and this process is not possible without individual bonds.

This is because cash flow matching implies we can accurately equal the future liabilities to our portfolio´s cash flows, which must be predictable. If we invest in individual bonds, it is possible to predict inflows at a certain period in time. The amount and date of fixed coupons payment are publicly available information, and the same applies to the maturity date and the par value at the maturity date. In other words, it is possible to know how much and when our fund inflows occur.

But this does not apply to an optimization portfolio. ETF´s capital gains and inflows are unpredictable, especially if we include equity indexes. For this reason, our immunization portfolio is 100% composed of individual fixed-income assets, to serve two purposes:

1. Accurately match Cash Inflows to future liabilities

2. Accurately estimate the immunization portfolio´s total cost

The first point can be seen by examining the figure below, in which each column corresponds to an individual Bond and each row corresponds to each year.

Table 4: Cash Inflows from Each Bond in the Immunization Portfolio

Sum of CF	COM AGB	BOA CB	LAN CB	3M CB	NW CB	NOR IB	EUR BB	LUX GB 2	FIN GB	AUS GB	GER GB	NTH GB	LUX GB
16 674 691	1,25	2,824	2,725	1,5	4,109	0,25	0,875	0,625	0,5	1,20	101,75	102,00	102,13
3 672 709	1,25	2,824	2,725	1,5	4,109	0,25	0,875	0,625	0,5	101,20			
1 868 565	1,25	2,824	2,725	1,5	4,109	0,25	0,875	0,625	100,50				
1 140 284	1,25	2,824	2,725	1,5	4,109	0,25	0,875	100,63					
695 379	1,25	2,824	2,725	1,5	4,109	0,25	100,88						
536 132	1,25	2,824	2,725	1,5	4,109	100,25							
464 669	1,25	2,824	2,725	1,5	104,11								
392 178	1,25	2,824	2,725	101,50									
331 446	1,25	2,824	102,73										
265 843	1,25	102,82											
232 025	101,25												

In year 1 the sum of CFs is 16.674.691 euros, in year 2 it is 3.672.702 euros, and so on. This Sum of CFs is referring to outflows, so it represents the liabilities. This means Cash Inflows should be at least equal to this number. By equaling liabilities and inflows, it is possible to minimize the total portfolio cost.

The total portfolio cost (required capital) and cash inflows compared with liabilities can be seen below. It can be concluded that Cash Flows perfectly match the liabilities (the difference between both in each year is 0), and the total portfolio cost is around 24,5 million euros.

CASH FLOWS	LIABILITIES	Δ
16 674 691,31 €	16 674 691,32 €	0,00 €
3 672 708,60 €	3 672 708,60 €	0,00 €
1 868 565,31 €	1 868 565,31 €	0,00 €
1 140 284,13 €	1 140 284,13 €	0,00 €
695 379,48 €	695 379,48 €	0,00 €
536 132,26 €	536 132,26 €	0,00 €
464 668,89 €	464 668,89 €	0,00 €
392 177,55 €	392 177,55 €	0,00 €
331 446,20 €	331 446,20 €	0,00 €
265 842,93 €	265 842,93 €	0,00 €
232 025,48 €	232 025,48 €	0,00 €

Required Capital
24 559 759,76 €

It is important to note that the only reason perfect cash flow matching was possible is because of the assumption that we can buy the exact number of bond units required, instead of buying by "blocks". That practical nuance is not included for model simplification reasons. Otherwise, perfect matching between inflows and outflows would not happen.

However, by being "theoretically" possible to acquire exact bond units, instead of blocks, combined with using numerical methods, it is possible to minimize the required capital. The following constraints were included:

- Minimize Capital Required.
- By changing the Weights of each Asset.

- Cash Flows from Assets each year are at least equal to the corresponding liability of the same year (CF1>= Liability1; CF2>=Liability2; (…); CF11>=Liability11, being t= 1, 2…,11, the year).
- No short selling→ Weights above 0%
- Germany Government Bonds and Luxembourg Government Bond from year 1 compose at least 20% of the portfolio. This is because the liability of year 1 represents a very considerable portion of the

overall liability's portfolio (almost 70%), which means it would not be reasonable to allocate only one bond to cover the first-year obligations. There would be a lot of risks associated with only one bond representing the vast majority of the immunization portfolio, and for this reason, three securities will cover the first-period liability.

However, due to the restrictions imposed, the weightings between the three bonds would tend almost entirely to the least costly bond (due to capital minimization restriction), the Netherlands Government Bond.

By imposing a weight of at least 20% in the other two securities, the three government bonds will cover the liability of 16 million euros (first year), almost equally, without having one asset overwhelming the others in terms of portfolio composition.

Plus, by multiplying the price of each asset by its weight, the total portfolio cost was calculated (Assuming Prices of the 3rd of March of 2023).

Lastly, regarding the immunization portfolio, it is relevant to point out that for simplification purposes it is assumed that Year 1 corresponds to 2024, and liabilities will have to be paid exactly at the end of the year. This means the fixed income securities that cover liabilities from year 1 must mature before 31 December of 2024, bonds from year 2 mature before 31 December of 2025, and so on, until the end of 2034 (11 years' time horizon).

As the immunization portfolio is entirely composed of fixed-income securities, it is possible to calculate each one´s duration. This is relevant for Duration Matching. As for now, The Optimization Portfolio is introduced.

This set of assets is composed of ETFs derived from a set of Indices from JPMorgan´s Long Term Market Capital Market Assumptions report since a matrix of correlations and volatilities of each index is provided. This data will be needed for mean-variance theory, which is addressed later.

Also, because the optimization portfolio will be composed of ETFs, it is possible to extract information regarding the product´s duration (but only for fixed-income ETFs). Still, this optimization set of assets will be composed of indexes from mixed asset classes.

Thus, duration matching will be done including every fixed-income asset, both from the immunization portfolio (individual bonds) and the optimization portfolio (Bond ETFs). Since the asset´s duration can be either calculated or extracted.

Appendice 1 shows that the 2023 JPMorgan Long Term Capital Market Assumptions Report has included a set of indices from different sub-asset classes. Each sub- asset class has its corresponding return and volatility of 2022 and expected values for 2023. It also includes correlations between each pair of indices. This is important because this set of data makes the calculation of the optimal portfolio and efficient frontier considerably easier.

From the chosen indices, the only task needed was to select a corresponding reliable ETF that tracked it with enough accuracy, liquidity, and at low fees. Another important criterion was how accessible was the information to investors, especially regarding average maturities, coupons, yields, and duration.

To perform duration matching, we used the reported duration in the ETF´s product specifications document.

Now, the Macaulay Duration for the individual bonds in the immunization portfolio is needed. But that calculation is also a straightforward step when using Excel, which requires information regarding the settlement date, maturity date, coupon rate, yield to maturity, and frequency of payments.

The settlement date was assumed to be T+1 for government bonds and T+2 for supranational and

corporate / covered bonds. The t date is assumed to be the 3rd of March of 2023 (Friday), which means T+1 corresponds to Monday (6th of March) and T+2 corresponds to Tuesday (7th of March).

The Excel function automatically calculates the Macaulay Duration, which, as previously mentioned, is the most suitable metric, compared with the Effective or Modified Duration (calculus displayed in Appendice 2).

What was calculated (Macaulay Duration times weight) corresponds to the Weighted Macaulay Duration for each asset in the immunization portfolio. For the complete calculation, the sum of the weighted Macaulay duration of each asset (in both portfolios), should be attained.

So, the second step for duration matching relies on finding the Weighted Macaulay Duration for each ETF. As already noted, this is information that can be consulted, and although ETFs reported the Effective Duration, to translate that figure to Macaulay, the only detail needed is to discount it by its yield (Appendice 3).

By summing the weighted duration of both portfolios, the Macaulay Duration is calculated as 3,24579 years. This means the amount paid for the portfolio (only including fixed-income securities) can be recovered in 3,24579 years since that is the Present Value of the Cash Flows of the mentioned securities.

Although Duration Matching only includes fixed-income securities, it is still a good benchmark regarding how much time it will take for the inflows to pay for the total portfolio cost, since the vast majority of the portfolio is composed of Bonds.

Duration Assets	3,24579
Duration Liabilities	1,98602
Δ	1,25977

In the figure shown above, it can be observed that the calculated duration of the liabilities is 1,98602. This means the difference between both durations is 1,25977 years, complying with the constrained range of 2 years.

As a final note regarding portfolio immunization, it is important to point out that the optimization portfolio represents 65% of the total set of assets, and consequently, the immunization portfolio represents 35%. This allocation is now going to be explained when discussing security selection and weight allocation.

3.3. Security Selection

Since we proposed two portfolios (immunization and optimization), two types of criteria for security selection are now covered.

Firstly, regarding the individual bonds of the immunization portfolio, the main criteria can be summarized in the following points:

- Lowest Default Risk possible (at the very least invest in an A-rating bond, but the majority are AAA-rated, prime securities). Government Securities are the priority and should constitute the majority of the Bond Portfolio.

- Each year will have at least one bond maturing in the same period to cover the corresponding yearly liability. For example, for the 2030 fiscal year liability, an individual bond that matures in the same year (but before the liability payment date) will be used to cover it.

- In other words, the portfolio will have at least one bond that matures each year until 2034. Only year 1, 2024, is an exception due to the liability amount relative to the overall obligations total. Three bonds were chosen due to the largely expected obligation (around 75% of the total liabilities portfolio)

- Invest in the lowest maturities possible, to mitigate interest rate risk (opposite of riding the yield curve strategy).

- Fixed coupon bonds, for stability in inflow amounts (even tough interest rate risk is higher, compared with floaters).

- Euro-denominated bonds, to completely mitigate currency risk.

- Safer bonds should cover the first few year´s obligations since they represent the vast majority of the overall liability's portfolio.

- Invest in corporate bonds and covered bonds from a return-seeking perspective (note that these should also have the best ratings possible, thus constituting prime securities).

In other words, the main criteria are safety, especially in terms of mitigation of default risk, mitigating reinvestment risk (to which fixed coupons are key), and mitigating interest rate risk (opposite of riding the yield curve strategy). Plus, by investing only in the Euro Zone, namely Euro- denominated Bonds, the currency risk is also addressed.

Putting it all together we have an immunization portfolio mainly composed of government and supranational bonds, AA, and AAA prime securities from the Euro Zone, in which the client is paid in fixed coupon amounts.

Plus, the portfolio includes at least one bond from each fiscal year until the maturity date (end of 2034), and in the first few year's government bonds will be covering the liabilities.

The Optimization Portfolio asset picking strategy is based on the JP Morgan´s Long Term Capital Market Assumptions report. Of the 40 reported sub-asset classes (from Fixed Income, Equities, and Alternative Investments) we consider only a few, linked to the IPS restrictions.

The idea is to diversify between the three available asset classes, but not so much where diminishing "advantages" in terms of diversification to reduce volatility takes place. In other words, it would be counterproductive to reach a point where adding an extra ETF would have an almost non-existing influence on the overall portfolio volatility.
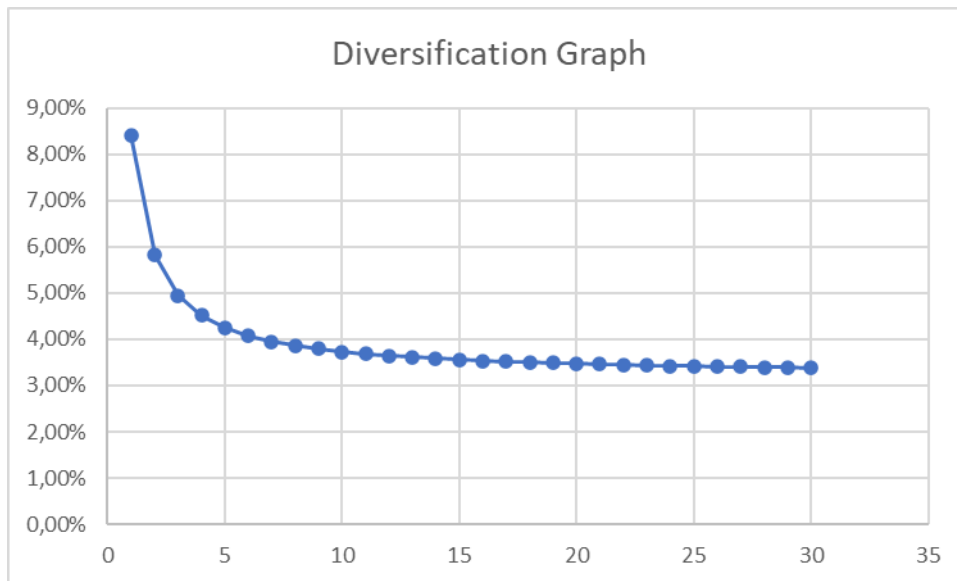
Source: Author´s Computations

According to the computed diversification graph, around 10-15 indices would be nearly enough to minimize volatility.

The fixed-income sub-asset classes chosen are:

- Euro Inflation
- Euro Cash
- US Aggregate Bonds Hedged
- Euro Aggregated Bonds
- US Investment Grade Corporate Bonds Hedged
- Euro Investment Grade Corporate Bonds
- US High Yield Bonds Hedged
- Euro High Yield Bonds
- U.S. Leveraged Loans Hedged
- Euro Government Bonds
- Euro Government-Inflation Linked Bonds
- World Government Bonds
- Emerging Market Corporate Bond

By choosing these sub-asset classes to work with, the idea is to diversify within the fixed- income asset class by incorporating US and Euro Bonds of all risk types (Government and Investment Grade). It is also pertinent to diversify globally and have some exposure to emerging markets, from a risk-seeking perspective.

However, the majority is allocated to Euro and US, arguably more developed regions since a conservative approach is undertaken.

Lastly, there is also exposure to Cash, and Inflation, to minimize risks regarding liquidity and the current inflationary environment.

Lastly, according to Grundl et al (2016), on average, pension funds in Europe are mildly exposed to the Loan sector, a practice replicated in this optimization portfolio. So, this portfolio also has some light exposure.

Regarding equities, the portfolio is invested in the following sub-asset classes:

- European Large Cap Equities
- US Large Cap Equities
- Euro Area Large Cap Equities
- UK Large Cap Equities
- Emerging Markets Equity
- AC World Equity

It is noticeable that the focus is on large cap securities, because equities are already a volatile asset class that produces high returns on average, thus mid-cap or small-cap securities would mean a considerably aggressive strategy.

The portfolio would likely incur more volatility than the constraint permits, if the equity exposure were to increase.

Among large-cap equities the focal point is on developed markets (Europe and US), however, some indices related to emerging markets and a more global set of securities were included.

Lastly, alternative investments only include real estate:

- US Core Real Estate
- European Core Real Estate
- Asia Pacific Core Real Estate

It can be observed in Appendice 1 that there were plenty of options regarding choosing a sub- asset class in JPMorgan´s report.

For example, for the alternative investments' asset class, only real estate indices were selected among all the options. This is because it is an asset class that suits Lusitania´s investment objectives, providing high yields and more predictable Cash Flows at a reasonable level of volatility.

This contrasts with commodities and private equity or venture capital, which is why these sub-asset classes were not chosen among the alternative investment indices.

There is a level of volatility that must be respected due to the constraints.

In Appendice 4, the indices chosen to replicate each sub-asset class can be examined. For Fixed Income precedence was given to Bloomberg Barclays Indexes, and regarding Equities and Real Estate, most Indices are from MSCI.

The reason for these specific asset class tracking companies is that Lusitania itself uses mainly indices from Bloomberg-Barclays and MSCI as Benchmarks.

3.4. Portfolio Composition

In terms of portfolio composition, Appendice 4 displays the optimization portfolio, while the following graph shows the individual bonds chosen for the immunization portfolio.

Figure 1: Immunization Portfolio Composition
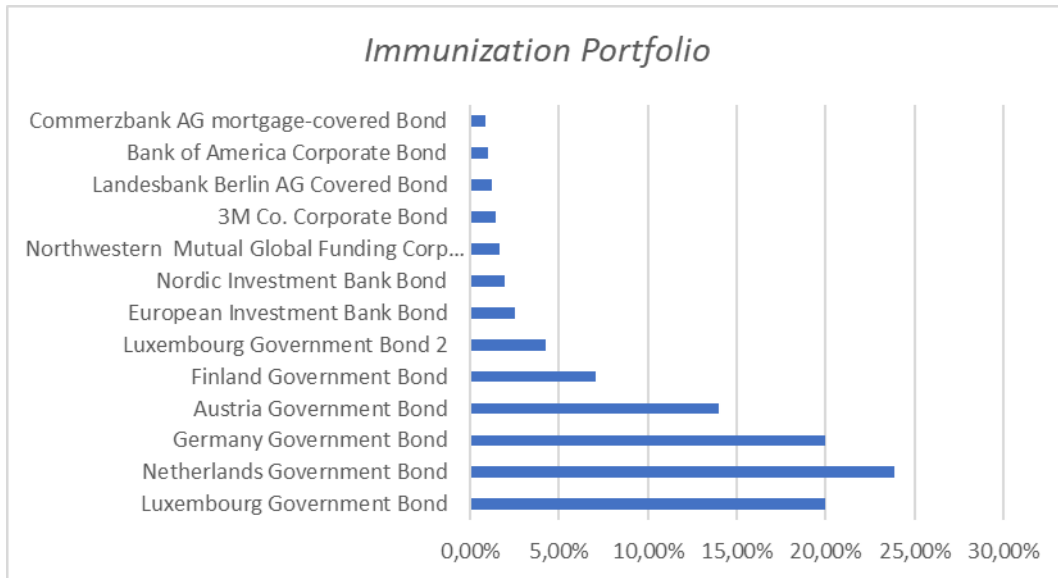
Source: Author´s Computations

Also, the graph below shows the dominance of the weightings of government and supranational bonds (in the immunization portfolio).

Figure 2: Immunization Portfolio Allocation by Type of Security
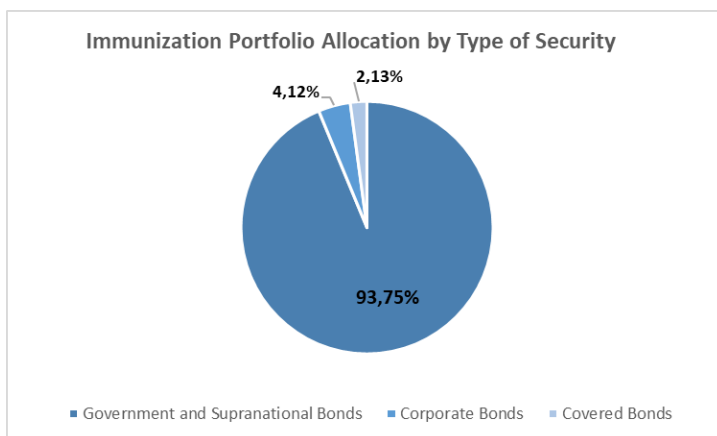
Source: Author´s Computations

The weighting process for the optimization portfolio is now going to be addressed, since the numerical methods constraints to achieve the weights of the immunization portfolio have been explained.

The main goal in terms of immunization was to minimize the total cost of the portfolio, by changing the asset weights and including other constraints. And at the end of this process, the weights were automatically computed, using numerical methods. All the constraints were previously mentioned, but the following can be highlighted:

- Government bonds and supranational bonds are paying the first few period´s liabilities, which weigh the most.

- Plus, no short-selling is allowed, and three prime-rated government bonds will cover the first year´s liability due to it composing roughly 70% of the total amount of liabilities. Each one of these three bonds is then constrained to weights of at least 20%, otherwise, one of the bonds would have a disproportionately high weight in the overall portfolio composition.

For the optimization portfolio, the same numerical methods were utilized, but with a different purpose and criteria. This time, the main goal was not the reduction of total portfolio cost, from a CF Matching context, but maximization of the Sharpe Ratio.

The JP Morgan´s Long-Term Capital Market Assumptions report provides the expected return and volatility of every indice, which computes a certain portfolio return and volatility (depending on the weight allocated to each indice).

Then, to calculate and maximize the Sharpe Ratio, the only variable needed is the risk-free rate. That risk-free rate is assumed to be 3,109%, which is the EIOPA Curve rate for the Euro Area, assuming no shocks or volatility adjustments.

With this setup, the only step needed was to use Solver to compute the maximum Sharpe Ratio by automatically changing the corresponding asset´s weights.

There should also be a risk-seeking component, as required by Lusitania´s constraint regarding the return. Besides, the following constraints were provided by Lusitania:

- Expected Annual Return of at least 2,5% above the risk-free rate (5%-5,5%)

- Expected Volatility cap of 7,5%.

- Fixed Income securities weights may range from 45%-100%

- Equities securities weights may range from 0%-35%

- Real Estate weights may range from 0%-7,5%

- Cash weights may range from 0%-10%

- The sum of total weights must equal 100%

- The duration between the optimization portfolio of assets and the portfolio of liabilities should not exceed 2 years.

Table 5: Optimization Portfolio Composition

#	Sub-Asset Class	Index	ETF Ticker	Returns(JPM)	Volatility (JPM)	St Dev (JPM)	Weights	Weights (%)
1	Euro Inflation	Bloomberg Barclays Eurozone Inflation Linked Bond Index	IBCI	1,80%	0,0106	10,30%	0,397092	0,79%
2	Euro Cash	ECB Deposit Facility Rate	ERNE	1,30%	0,0061	7,81%	0,397092	5,00%
3	US Aggregate Bonds hedged	Bloomberg Barclays US Aggregate Bond Index	AGG	3,90%	0,0412	20,30%	0,794185	30,00%
4	US High Yield Bonds hedged	Bloomberg Barclays US Corporate High Yield Bond Index	HYG	5,90%	0,0865	29,41%	0,794185	25,00%
5	Emerging Markets Corporate Bonds	J.P. Morgan CEMBI Broad Diversified Index	EMCP	5,80%	0,0922	30,36%	3,176738	26,71%
6	Euro Area Large Cap Equities	EURO STOXX 50 Index	FEZ	8,40%	0,1698	41,21%	0,079418	2,50%
7	Emerging Markets Equity	MSCI Emerging Markets Index	EIMI	8,00%	0,1658	40,72%	0,397092	2,50%
8	European Core Real Estate	MSCI Europe Real Estate Index	IPRP	4,70%	0,1015	31,86%	0,794185	7,50%

With these constraints respected the weights displayed in Appendice 4 were reached. As can be observed, from the original 14 indices chosen, only 8 can be included in the optimization portfolio, in order to comply with the imposed constraints.

Also, because weights were computed for two separate portfolios, a total portfolio allocation must be calculated. This implies defining a weight for the immunization portfolio and for the optimization portfolio.

Lusitania´s guidance is that optimization assets should cover around 70% of the total portfolio, and subsequently, the immunization portfolio should compose 30% of the total weighing. However, the total portfolio we present, has a 65/35 split, instead of 70/30.

The reason for this 500bps difference relies on the duration matching constraint. If a 70/30 split was assumed, the optimization problem would not find a reasonable solution as the difference between the duration of the portfolio of assets and liabilities would be higher than 2. That would not comply with the given constraint.

Having this in mind, the total portfolio composition is displayed in Appendice 5, by multiplying the individual weight of each asset (from each portfolio) by either 35% or 65%.

3.5. Expected Performance

The procedures to reach expected performance were indirectly specified when explaining the process to compute the optimization portfolio weights.

Because the main criterion is to maximize the sharpe ratio of the portfolio, with certain constraints, by changing the weights of each asset. So, calculating the weights was an automatic procedure. And subsequently, calculate the expected performance, as the expected returns and volatility are available from the JP Morgan report.

Expected performance must be compared in relative terms, and not just absolute. The portfolio has an expected return of 5,04% (roughly 2% above the risk-free rate), and an expected volatility of 7,5%, corresponding to its constrained cap value.

Portfolio Expected Return	**5,04%**
Portfolio Expected Volatility	**7,50%**
Risk Free Rate	**3,10%**
Sharpe Ratio	**0,2581**

For comparison purposes, a benchmark should be selected. Since the portfolio includes four different asset classes, it is better to pick a benchmark for each, and then perform a weighted average to compute its expected return and volatility.

It can be observed that the following benchmarks were selected, for the subsequent asset classes:

Table 6: Selected Benchmarks and average past returns

Asset Class	Portfolio Benchmark Index	Historical 10y yearly avg Ret.
Fixed Income	Bloomberg Barclays Global Aggregate Bond Index	0,72%
Real Estate	MSCI World Real Estate Index	4,21%
Equities	MSCI ACWI Index	9,12%
Cash	ECB Deposit Facility Rate	0,07%
	Weighted Average	1,37%

The characteristic in common of these benchmarks is that they represent the overall market of the corresponding asset class. They focus on global markets geographically and on different types of securities.

For example, Fixed Income includes government bonds, corporate bonds, and high-yield bonds from different regions, and equities include large and mid-cap securities from several industries and continents.

By assuming the future expected returns and volatility based on the historical 10-year average (as displayed in the figure), it is possible to do a portfolio-weighted average and reach the benchmark´s expected performance.

Table 7: Benchmark Returns and Volatilities Compared with the Portfolio

	Benchmark	Portfolio
Average Yearly Return	1,37%	5,04%
Average Standard Deviation	2,40%	7,50%
Yearly Return/ Volatility	0,570	0,671

Table 8: Portfolio Value Compared with the Benchmark 10 Years Later

	Benchmark	Portfolio
Initial Portfolio Value	24 559 759,76 €	24 559 759,76 €
Portfolio Value 10 Years Later	28 128 813,32 €	40 141 716,35 €
Total Return (Absolute)	3569053,554	15581956,58
Total Return (as a %)	14,53%	63,45%

As the risk-free rate would be superior to the average returns, the Sharpe Ratio of the benchmark was not computed. Instead, the measure used for comparison was simply the expected returns divided by the expected volatility.

The tables displayed above show the difference in average yearly returns of the recommended portfolio, and the benchmark, as well as the returns/volatility ratio.

The recommended portfolio takes on more volatility, however, yields a considerably higher return, which is evident when comparing the expected portfolio value after 10 years.

3.5.1. *Expected Returns using a Monte Carlo Simulation Model*

Besides computing an expected future portfolio value of roughly 40 million euros, through JPMorgan´s report data, we also performed a Monte Carlo Simulation.

By using data regarding required capital, expected return and volatility, time horizon, and assuming no annual investment besides the initial one, it is possible to compute return scenarios.

In this case, ten thousand iterations were simulated. The process was as follows, step by step:

- Compute a random return for each of the 11 years, based on a normal distribution and the average

annual expected returns and volatility computed previously (4,87% and 7,5% respectively).

- Thus, by assuming random yearly returns for the portfolio´s time horizon (11 years), it is possible to calculate an ending portfolio value, as observed below.

Table 9: Portfolio Ending Value for the Main Simulation

Year	Return	Ending Value
1	6,29%	26 103 840,70 €
2	-4,18%	25 011 949,29 €
3	15,95%	29 000 662,90 €
4	10,02%	31 907 936,79 €
5	-1,22%	31 518 247,07 €
6	13,76%	35 853 995,73 €
7	8,80%	39 009 121,01 €
8	-5,53%	36 850 947,09 €
9	5,19%	38 764 028,24 €
10	1,25%	39 249 352,99 €
11	-4,27%	37 572 954,09 €

- 10,000 different simulations for the ending portfolio value were ran and then computed its average.

- This is important because even though the ending value of the portfolio deviates a lot for each scenario, the average value computed by the 10,000 iterations is stable.

Table 10: Portfolio Mean Ending Value of the 10,000 Simulations

Current Investment	24 559 759,76 €	Mean	42141217,7
Average Return	5,04%	Median	41714772,65
Standard Deviation	7,50%	St. Dev.	9594099,18
Time Horizon (years)	11	**Percentiles**	
Amount Invested Annually	0	5,00%	28 254 854,15 €
		25,00%	34 786 427,90 €

Following the Monte Carlo Method, the average ending portfolio value based on a thousand simulations is around 41 million euros, which is very close to the 40 million euros computed based on the expected values by JPMorgan´s report when using the Excel Solver to maximize the Sharpe Ratio.

It can also be concluded there is a 95% chance that the ending portfolio value will be at least around 28,2 million euros.

3.5.2. Mean-Variance Theory

Lusitania´s portfolio is restricted by a fair number of constraints regarding asset class weights and portfolio immunization, as well as expected performance.

For this reason, the mean-variance theory is an interesting tool to evaluate and compare different portfolios in terms of their expected returns and risk, namely the mean-variance and the tangent portfolio, according to Markowitz (1952).

Due to the heavy load of restrictions imposed, it would be utopic to assume Lusitania´s portfolio could have equal volatility compared with the optimal portfolio. The idea is to assess how far off the recommended portfolio is compared to the tangent portfolio.

In order to compute the tangent and optimal portfolios, as well as the efficient frontier, the variance-covariance matrix is required.

To compute this matrix the only data needed is related to the standard deviations of each asset and the correlations between the indexes. As formerly referred, JP Morgan´s Long-Term Market Expectations document not only reports the expected volatility of each sub-asset class, but the correlations among them. Thus, the variance-covariance matrix can be computed.

Both the correlations matrix and the variance-covariance matrix are displayed in Appendices 6 and 7 respectively.

According to Markowitz (1952), the envelop hyperbola is given by:

$$(1) \qquad \sigma_p^2 = \frac{A\bar{R}_p^2 - 2B\bar{R}_p + C}{AC - B^2}$$

Where $A = 1'V^{-1}1$, $B = 1'V^{-1}\bar{R}$ and $C = \bar{R}'V^{-1}\bar{R}$ $\qquad (2)$

The second relevant formula is that of the weights of the minimum variance portfolio:

$$(3) \qquad Xmv = \frac{1}{A}V^{-1}1$$

The minimum-variance portfolio weights can then be observed in Appendice 8.

The tangent portfolio was also computed, since it is the portfolio that provides the maximum sharpe ratio. It can be seen in Appendice 9 that to compute the portfolio weights for each index, a "z value" must be known since each weight relies on it. The weight of the "Z-value" for each index represents its portfolio weights.

To compute that variable, the inverse of the covariance matrix should be multiplied by the difference between the Expected Return and Risk-free rate, for each index.

Thus, we have the Z-Value for each index, that divided by its sum, will lead to the tangent portfolio weights.

As the two portfolios are now computed, in order to compare them with Lusitania´s portfolio, an investment opportunity set graph must be plotted.

The investment opportunity set was plotted using the hyperbola and data from both the lowest variance portfolio and tangent portfolio, as observed in Appendice 10.

For each random expected return, volatility for both the tangent line and the hyperbole (efficient frontier) can be calculated, leading to the following graph:

Figure 3: Recommended Portfolio Compared with Tangent and Minimum Variance Portfolios (Assuming Restrictions)
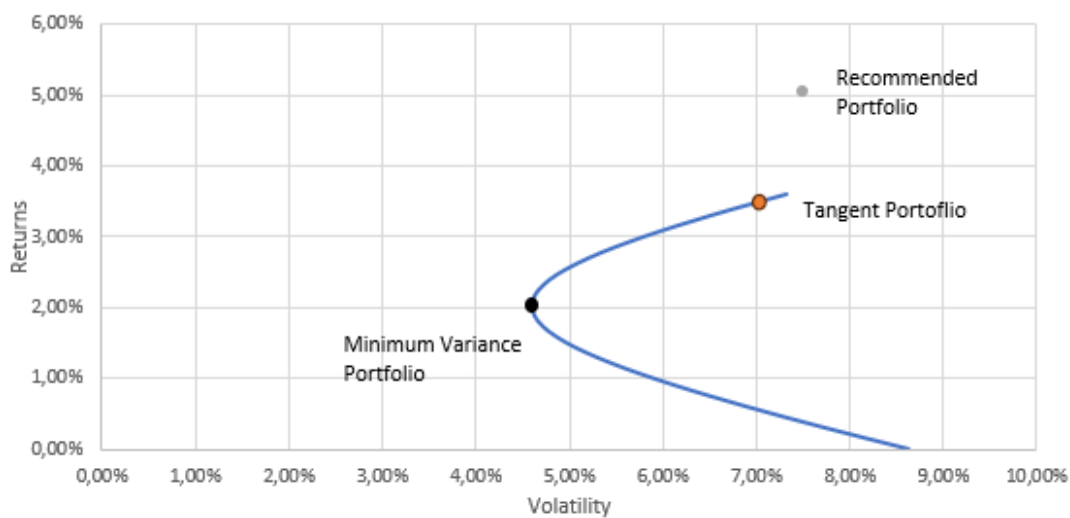
Source: Author´s Computations

It can be concluded that Lusitania´s portfolio have a considerably higher return compared with both the mean variance portfolio and the optimal portfolio, while taking on more risk too. If we include all the mentioned constraints for the portfolio, the graph shows that the recommended portfolio is not in the efficient frontier. However, if we take the same portfolio without restrictions, it can be observed it lies in the efficient frontier, as shown below:

Figure 4: Recommended Portfolio Compared with Minimum Variance Portfolio (Without Restrictions)
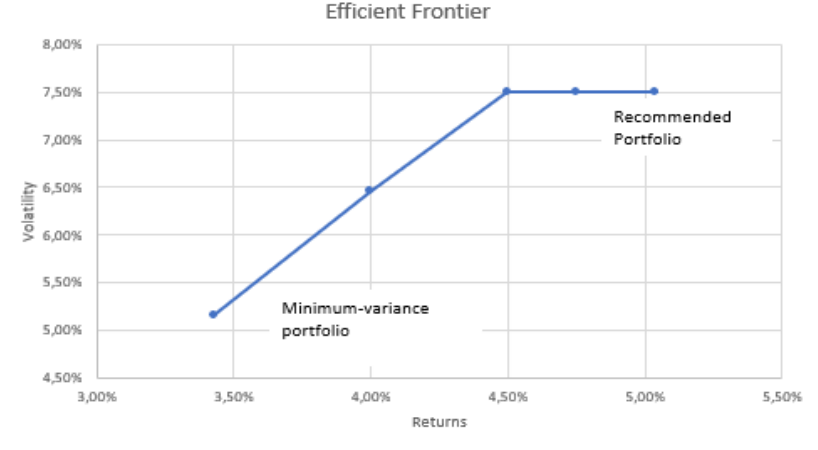
3.6. Risk Analysis

In terms of risk analysis, attention should go to two main metrics:

- **Value at Risk (VaR)**

- **Conditional Value at Risk (Expected Shortfall)**

With both ratios, two questions can be answered: "How bad can things get?", and "If things do get bad, how big of an impact will it have in terms of Expected Loss?".

Firstly, the Value at Risk was computed through the Historical Method and the Monte Carlo Simulation Method.

3.6.1. Historical Method Value at Risk

To compute the Value at Risk using the Historical Method, the data needed consists of the Variance-Covariance Matrix, the Initial Investment, plus the Mean Annual Returns and Standard Deviation.

Investment	24 559 759,76 €
Mean Return	5,04%
Standard Deviation	7,50%

To calculate the Absolute Value at Risk for a certain significance level, the first step relies on subtracting the Initial Portfolio Investment from the Cutoff Value.

The Cutoff can be calculated through an Excel function that relies on the inverse of the normal distribution, being the Cutoff given by NORMINV (Mean Investment; Standard Deviation; Significance Level).

With the Cutoff computed for a 99% confidence level, and for a 99,9% confidence level, it is possible to calculate the VaR for the respective confidence levels.

Since, as mentioned earlier, the absolute loss VaR can be computed by subtracting the Cutoff Level from the Initial Portfolio Investment.

The Absolute Value at Risk is roughly 3,089 million euros and 5 million euros, for 1% and 0,1% significance levels. By dividing these numbers by the initial investment, the VaR in relative terms is computed.

The Value at Risk for a 1% significance level is 12,58%, which in other words means there is a 1% probability that the maximum potential loss will not exceed 12,58% of the total portfolio for 1 year. Or a 99% confidence that the portfolio will not lose more than 12,58%, or 3,089 million euros.

The same applies to the 0,1% Value at Risk. There is a 99,9% confidence level that the maximum portfolio loss will not exceed 18,31% of the total portfolio or almost 5 million euros.

Table 11: VaR Computed for a 1% and 0,1% Significance Level

Cutoff 1% level	21 511 439,45 €
Cumulative PDF	1%
Z-Score	2,236
1 year VaR at 1% level	3 048 320,31 €
1 year VaR at 1% level (in %)	12,41%

Cutoff 0,1% level	20 104 378,09 €
Cumulative PDF	0,1%
Z-Score	3,09
1 year VaR at 0,1% level	4 455 381,67 €
1 year VaR at 0,1% level (in %)	18,14%

Source: Author´s Computations

Lastly, the Expected Shortfall, or Conditional Value at Risk, can also be computed through the following formula, for a certain significance level:

$$Cvar = Portfolio\ Investment * (VaR + (Z\ Score * Standard\ Deviation)) \quad (4)$$

It can be noticed that the only variable missing in this equation is the Z-Score. However, this variable will be 2,326 and 3,09 for a 1% and 0,1% significance level, respectively, from standard normal tables.

So, it is possible to calculate the absolute level of expected shortfall, and therefore, its loss in percentage of the total portfolio investment.

The Expected Shortfall for a 99% confidence interval in terms of relative loss in relation of total portfolio is 29,18%. The conditional value at risk is a measure of the average magnitude of losses beyond VaR, which in this case can be interpreted as a 1% probability that the investment loss will be worse than the value at risk. And if this occurs, the magnitude of losses will be, on average, 29,18%.

Table 12: Conditional Value at Risk Computation for a 1% Significance Level

Conditional Value at Risk (1% level)	7 166 992,03 €
CVaR (1% level in %)	29,18%

Simultaneously, assuming a 0,1% probability that the magnitude of losses will have a more negative impact than the value at risk, the average loss computed would be 41,32%.

Conditional Value at Risk (0,1% level)	10 147 106,01 €
CVaR (0,1% level in %)	41,32%

3.6.2.   *Monte Carlo Simulation Method Value at Risk*

Similarly, to the expected returns forecast, the Value at Risk was also computed through a Monte Carlo Simulation. With an initial portfolio investment value and a mean standard deviation as "benchmarks" for a seed value, the goal was also to produce 10000 different scenarios for the portfolio value for a certain time horizon.

However, the "base value" for the 10000 iterations, or what is called the seed value, was computed differently, though it was also based on random variables from a normal distribution.

This time the seed value was calculated based on the Black Scholes Merton Model, ,and the formula utilized was the following, according to Chen(2021):

$$Seed\ Value = e^{\text{Rf-}0,5*SD^2+SD*NORMINV\ (RAND\ (\quad))} \qquad (5)$$

(Note: SD=Standard Deviation)

Thus, by using this formula we reach a base scenario value (seed iteration) of 0,9611, which symbolizes roughly a 4% loss. However, a thousand other scenarios regarding 1 year gain/loss were computed. By multiplying each simulation for the initial portfolio value, multiple scenarios regarding its expected value after 1 year are displayed.

By utilizing a 1% significance level, the Value at Risk of the 10000 simulations would consist of the 100th worst loss (by multiplying 1% by 10000). And for a 0,1% significance level, the Value at Risk

corresponds to the 10th worst loss simulation (0,1% multiplied by 10000). We use the SMALL (range; 10) function in Excel, for both these calculations.

VaR for each significance level is then 17,02%, and 21,94%, respectively. Also, because Expected Shortfall can be interpreted as the average potential losses above a certain probability level (Value at Risk), by using the AVERAGEIF (range;">VAR"; range) function the conditional VaR can be computed.

The average loss impact, if above Value at Risk, is then, on average, 19,96% and 24,91%.

Table 14: Value at Risk and Expected Shortfall Computations for 0,1% and 1% Significance Level (Using Monte Carlo)

Significance Level	VaR in %	Expected Shortfall	CVaR Absolute Loss
0,10%	20,43%	27,46%	6 744 611,28 €
1,00%	16,82%	20,69%	5 081 111,37 €

As can be observed, these Value at Risk figures are considerably lower when compared to using historical data. That is due to one of Monte Carlo´s Method's biggest disadvantages which relies on its underestimation of the probability of extreme bear events. This is because this model relies on a normal distribution, which is bell-shaped. In other words, most of the data lies close to the mean and its tails are short, which suggests a very low probability of observing extreme events.

The graphic results for VaR using this method can be observed below:

Figure 5: Monte Carlo Method VaR Results
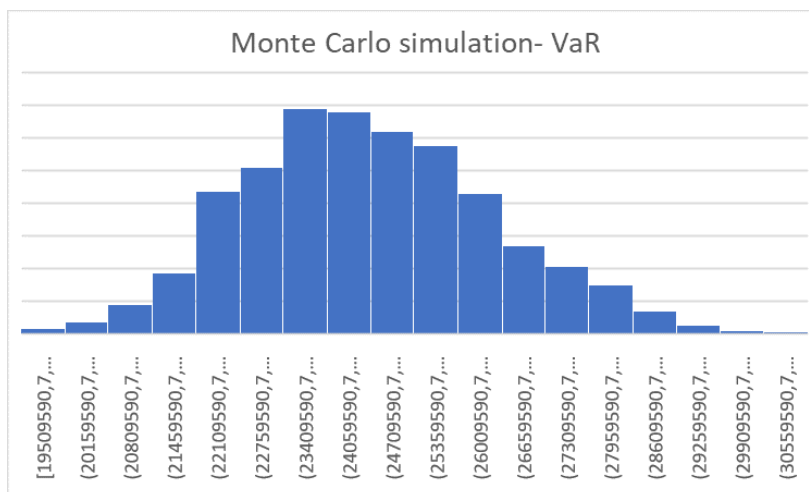
3.6.3. *Portfolio Rebalancing*

Continuous monitoring of the portfolio and its weights plus expected performance, as well as defining thresholds, is the key to a rebalancing policy.

For this reason, a periodic report outlining the rebalancing activities, portfolio changes, and their impact on the overall portfolio composition and risk profile should be generated quarterly.

The rebalancing thresholds will be based on the desired level of deviation, and once those limits are breached, a rebalancing trigger takes place. Triggers may be based on either an absolute percentage or a relative deviation from the target allocation.

The rebalancing methodology is established on the previous constraints regarding asset class weightings and portfolio immunization. The portfolio should be urgently rebalanced when the following weightings are either not respected, or when are rapidly deviating from the benchmark constraints:

- Fixed Income Asset Class Weights from 35% to 100%.
- Equities Asset Class Weights from 0% to 35%.
- Real Estate Asset Class Weights from 0% to 7,5%.
- Cash & Equivalents Asset Class Weights from 0% to 10%.
- The duration between the portfolio of assets and liabilities should not have a difference that exceeds 2 years.
- Expected Annual Return of at least 2,5%, and ideally, above EIOPA curve Euro Zone rates.
- Expected Annual Standard Deviation should not exceed 7,5%.
- At any point in time, the Present Value from Cash inflows should be superior to the Present Value of the Liabilities.

It is also important to delineate a follow-up strategy, by conducting periodic reviews of the rebalancing process to assess its effectiveness and make any necessary adjustments or enhancements. This review will consider factors such as the accuracy of triggers, efficiency of execution, and overall impact on portfolio performance and risk management. It will be conducted annually or as needed, based on evolving market conditions and regulatory requirements.

4.Conclusion

This Investment Policy Statement aims to govern a portfolio of assets that can cover future expected liabilities. To accomplish this, portfolio immunization is one of the key aspects as well as achieving returns superior to the Eiopa risk free rates.

To perform this double approach, two portfolios were created: An immunization portfolio and an optimization portfolio.

The immunization portfolio serves to match the portfolio of assets and the corresponding liabilities in terms of cash flows and duration. The closer these parameters are, the better the immunization portfolio is protected against liquidity and interest rates risks.

In order to accurately implement cash flow matching and duration matching, the immunization portfolio is composed of fixed income securities, being the majority government and supranational bonds (roughly 93%). In addition, the majority of the bonds also have a prime credit rating (AAA), and no less than A, in order to tackle credit risk, which was achieve by selecting government bonds of countries with consistent real GDP growth and a controlled debt/GDP ratio, as well as being historically more "recession-proof".

The immunization portfolio accomplished its goals by making possible a perfect cash flow matching scenarios (future cash inflows cover the expected liabilities, while minimizing the portfolio cost), and achieving a Macaulay Duration of roughly 3,25 years. Since the duration of the portfolio of liabilities is roughly 1,99, as the difference between both is less than 2, the immunization constraints were respected.

Besides the process of portfolio immunization, the other key goal is to achieve sufficient returns in terms of having the ability to cover the future expected liabilities. If the portfolio can´t provide enough returns, it is not viable in the long term, as the ability to pay its liabilities would be at risk.

This issue can be translated into a constraint where the portfolio should yield returns roughly 2%-2,5% superior to the Eiopa curve euro risk free rates, which means, total returns of around 5%-5,5%, while having an annual liquidity cap of 7,5%.

To comply with both constraints, an optimization portfolio is created, to maximize the Sharpe Ratio, and

thus, achieve the mentioned objectives in terms of returns and volatility. The institutional investor also set a restriction in which ETFs had to be included in this portfolio, plus a constraint regarding each asset class weight. And lastly, it mentioned 70% of the total weightings should be allocated to the optimization portfolio, and 30% of the weightings to the immunization portfolio.

The result is a portfolio with 5,01% annual expected return, and 7,5% volatility, complying with the proposed restrictions. The composition of the portfolio of assets can be observed in the figure below.

Figure 6: Total Portfolio Weights
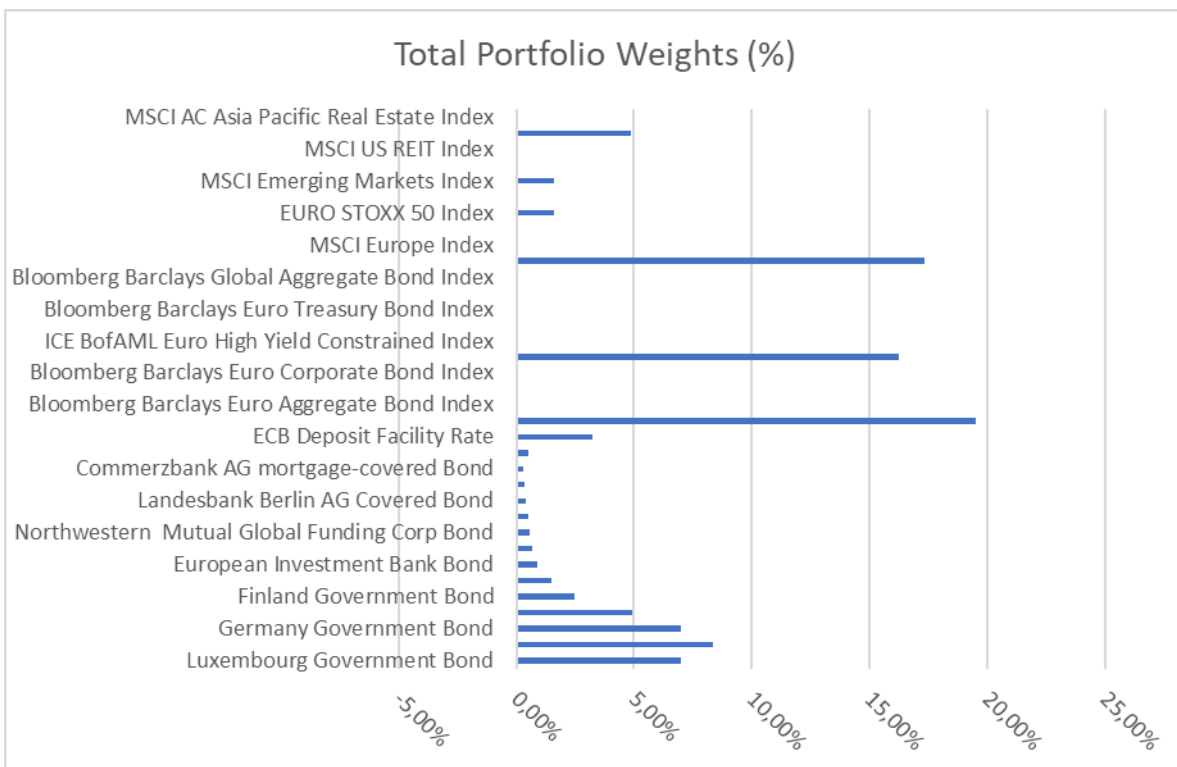
Appendices

Appendice 1. JPMorgan´s Long Term Capital Market Expectations Report Sub-Asset Classes and Data

	Compound Return 2022 (%)	Annualized Volatility (%)	Arithmetic Return 2023 (%)	Compound Return 2023 (%)	Euro Inflation	Euro Cash	U.S. Aggregate Bonds hedged	Euro Aggregate Bonds	U.S. Inv Grade Corporate Bonds hedged	Euro Inv Grade Corp Bonds	U.S. High Yield Bonds hedged	Euro High Yield Bonds	U.S. Leveraged Loans hedged	Euro Government Bonds	Euro Govt Inflation-Linked Bonds	World Government Bonds hedged	World Government Bonds	World ex-Euro Government Bonds hedged	World ex-Euro Government Bonds	Global Multiverse Bonds hedged	Emerging Markets Sovereign Debt hedged	Emerging Markets Local Currency Debt	Emerging Markets Corporate Bonds hedged	European Large Cap
Fixed income																								
Euro Inflation	1.80	1.81	1.06	1.50	1.00																			
Euro Cash	1.30	1.30	0.61	0.10	-0.17	1.00																		
U.S. Aggregate Bonds hedged	3.50	3.58	4.12	1.40	-0.41	0.31	1.00																	
Euro Aggregate Bonds	3.00	3.10	4.48	1.20	-0.46	0.30	0.75	1.00																
U.S. Inv Grade Corporate Bonds hedged	4.30	4.55	7.19	1.50	-0.35	0.15	0.83	0.67	1.00															
Euro Inv Grade Corp Bonds	3.60	3.73	5.10	1.50	-0.38	0.12	0.62	0.78	0.83	1.00														
U.S. High Yield Bonds hedged	5.70	6.05	8.65	2.70	-0.11	0.02	0.35	0.27	0.63	0.64	1.00													
Euro High Yield Bonds	5.70	6.14	9.70	2.90	-0.14	-0.01	0.25	0.32	0.54	0.69	0.87	1.00												
U.S. Leveraged Loans hedged	5.10	5.40	7.99	3.50	-0.02	-0.07	0.05	0.10	0.35	0.48	0.78	0.86	1.00											
Euro Government Bonds	2.80	2.92	4.88	1.10	-0.42	0.30	0.98	0.98	0.59	0.66	0.14	0.19	-0.03	1.00										
Euro Govt Inflation-Linked Bonds	2.60	2.74	5.32	0.80	-0.18	0.14	0.43	0.67	0.50	0.64	0.39	0.40	0.25	0.65	1.00									
World Government Bonds hedged	2.60	2.67	3.70	0.80	-0.45	0.33	0.86	0.86	0.60	0.53	0.07	0.02	-0.18	0.89	0.48	1.00								
World Government Bonds	2.30	2.53	6.85	1.00	-0.23	0.20	0.39	0.52	0.23	0.23	-0.19	-0.14	-0.18	0.55	0.19	0.60	1.00							
World ex-Euro Government Bonds hedged	2.50	2.57	3.72	0.70	-0.38	0.24	0.86	0.67	0.57	0.38	0.01	-0.12	-0.28	0.70	0.31	0.94	0.55	1.00						
World ex-Euro Government Bonds	2.10	2.52	9.26	1.00	-0.18	0.15	0.26	0.33	0.08	0.07	-0.29	-0.23	-0.23	0.36	0.03	0.45	0.96	0.44	1.00					
Global Multiverse Bonds hedged	3.10	3.16	3.55	1.20	-0.47	0.32	0.95	0.89	0.83	0.75	0.40	0.34	0.13	0.84	0.58	0.90	0.45	0.82	0.28	1.00				
Emerging Markets Sovereign Debt hedged	6.00	6.50	10.31	4.00	-0.24	0.07	0.59	0.52	0.78	0.73	0.75	0.61	0.44	0.41	0.50	0.38	-0.05	0.33	-0.20	0.64	1.00			
Emerging Markets Local Currency Debt	5.00	5.39	9.14	4.60	-0.10	0.14	0.32	0.40	0.43	0.52	0.45	0.46	0.38	0.34	0.39	0.25	0.27	0.13	0.17	0.42	0.56	1.00		
Emerging Markets Corporate Bonds hedged	5.80	6.20	9.22	3.60	-0.23	0.04	0.53	0.46	0.77	0.75	0.76	0.68	0.57	0.33	0.43	0.28	-0.05	0.22	-0.19	0.57	0.90	0.56	1.00	
Equities																								
European Large Cap	7.70	8.69	14.76	5.10	-0.08	-0.15	0.10	0.16	0.37	0.50	0.70	0.76	0.65	0.06	0.35	-0.10	-0.22	-0.20	-0.29	0.18	0.52	0.48	0.55	1.00
European Small Cap	9.20	10.62	17.88	6.50	-0.14	-0.13	0.14	0.19	0.43	0.55	0.74	0.80	0.69	0.06	0.33	-0.07	-0.21	-0.16	-0.29	0.22	0.54	0.41	0.59	0.92
U.S. Large Cap	5.80	6.80	14.73	2.80	-0.03	-0.17	0.04	0.17	0.27	0.44	0.56	0.61	0.57	0.09	0.28	-0.06	0.06	-0.17	-0.01	0.14	0.38	0.49	0.39	0.81
U.S. Large Cap hedged	6.80	8.00	16.26	2.80	-0.03	-0.15	0.18	0.17	0.44	0.52	0.73	0.66	0.56	0.08	0.33	-0.02	-0.33	-0.09	-0.44	0.23	0.62	0.37	0.59	0.83
Euro Area Large Cap	8.40	9.69	16.98	5.80	-0.11	-0.12	0.14	0.19	0.39	0.50	0.70	0.73	0.60	0.09	0.35	-0.06	-0.29	-0.16	-0.37	0.22	0.56	0.45	0.58	0.97
Euro Area Small Cap	9.30	10.77	18.23	6.20	-0.13	-0.11	0.15	0.19	0.41	0.51	0.73	0.78	0.65	0.08	0.36	-0.06	-0.28	-0.16	-0.36	0.23	0.54	0.40	0.57	0.92
UK Large Cap	7.00	7.98	14.66	3.70	0.05	-0.20	-0.06	0.03	0.24	0.39	0.60	0.70	0.66	-0.07	0.23	-0.25	-0.16	-0.34	-0.20	0.02	0.36	0.47	0.44	0.91
UK Large Cap hedged	6.40	7.22	13.31	2.60	-0.05	-0.10	0.08	0.09	0.32	0.38	0.59	0.59	0.52	0.01	0.32	-0.11	-0.33	-0.19	-0.40	0.15	0.47	0.41	0.48	0.86
Japanese Equity	8.30	9.20	14.14	5.40	-0.12	-0.12	0.07	0.17	0.31	0.41	0.49	0.53	0.48	0.09	0.24	-0.05	0.11	-0.15	0.07	0.14	0.31	0.49	0.36	0.67
Japanese Equity hedged	8.70	10.06	17.46	5.00	0.01	-0.17	-0.10	-0.03	0.17	0.28	0.51	0.53	0.49	-0.10	0.20	-0.27	-0.46	-0.35	-0.52	-0.04	0.33	0.29	0.38	0.73
Chinese Domestic Equity	9.70	13.10	28.37	6.90	-0.07	0.00	0.03	0.07	0.16	0.18	0.22	0.26	0.24	0.05	0.01	-0.05	-0.02	-0.11	-0.05	0.05	0.15	0.22	0.24	0.27
Emerging Markets Equity	8.00	9.24	16.58	5.60	-0.07	-0.06	0.12	0.15	0.40	0.49	0.68	0.70	0.64	0.05	0.31	-0.09	-0.18	-0.18	-0.26	0.19	0.53	0.63	0.60	0.77
AC Asia ex-Japan Equity	7.90	9.14	16.60	5.70	-0.11	-0.07	0.14	0.17	0.40	0.49	0.63	0.66	0.59	0.07	0.29	-0.05	-0.12	-0.15	-0.19	0.20	0.48	0.59	0.57	0.73
AC World Equity	6.40	7.29	13.93	3.70	-0.06	-0.15	0.09	0.18	0.37	0.52	0.67	0.73	0.66	0.08	0.34	-0.08	-0.05	-0.19	-0.13	0.18	0.48	0.55	0.51	0.92
AC World ex-EMU Equity	6.30	7.19	13.87	3.50	-0.06	-0.15	0.08	0.18	0.36	0.51	0.66	0.71	0.66	0.08	0.33	-0.08	-0.02	-0.19	-0.09	0.17	0.46	0.56	0.49	0.89
Developed World Equity	6.30	7.22	14.13	3.50	-0.06	-0.16	0.08	0.18	0.35	0.50	0.65	0.71	0.64	0.08	0.33	-0.08	-0.04	-0.18	-0.11	0.17	0.46	0.52	0.48	0.91
Global Convertible Bonds hedged	8.00	8.64	11.88	4.30	-0.24	-0.03	0.30	0.30	0.61	0.65	0.80	0.76	0.67	0.19	0.42	0.06	-0.26	-0.03	-0.39	0.36	0.69	0.38	0.71	0.78
Global Credit Sensitive Convertible hedged	6.10	6.40	8.04	3.40	-0.17	-0.10	0.24	0.36	0.42	0.54	0.45	0.51	0.42	0.27	0.27	0.18	-0.01	0.10	-0.13	0.33	0.42	0.22	0.44	0.49
Alternatives																								
Private Equity	7.80	9.36	18.69	6.80	0.11	-0.17	-0.21	-0.12	0.18	0.31	0.58	0.58	0.64	-0.23	0.16	-0.39	-0.19	-0.46	-0.21	-0.12	0.38	0.45	0.46	0.72
Venture Capital	6.40	8.60	22.18	-	0.03	-0.22	-0.25	-0.16	0.01	0.13	0.36	0.33	0.44	-0.22	0.03	-0.34	-0.11	-0.38	-0.11	-0.18	0.22	0.31	0.27	0.50
U.S. Core Real Estate	3.60	4.34	12.48	4.50	0.31	-0.38	-0.19	-0.20	-0.03	0.07	0.34	0.35	0.44	-0.25	0.00	-0.28	0.00	-0.26	0.05	-0.19	0.10	0.29	0.22	0.38
European Core Real Estate	4.70	5.19	10.15	4.80	0.16	-0.31	-0.31	-0.28	-0.02	0.05	0.34	0.33	0.45	-0.33	-0.04	-0.43	-0.13	-0.42	-0.11	-0.28	0.18	0.23	0.24	0.47
European Value-Added Real Estate	6.70	7.98	16.75	6.80	0.18	-0.30	-0.36	-0.35	-0.05	0.02	0.35	0.33	0.46	-0.40	-0.09	-0.50	-0.19	-0.49	-0.17	-0.34	0.15	0.20	0.23	0.48
Asia Pacific Core Real Estate	6.00	6.87	13.70	6.20	0.16	-0.32	-0.05	-0.07	0.24	0.31	0.55	0.55	0.62	-0.17	0.12	-0.26	-0.03	-0.27	-0.03	-0.02	0.35	0.43	0.45	0.61
Global REITs	4.90	5.74	13.43	4.60	-0.08	-0.15	0.20	0.26	0.41	0.51	0.62	0.64	0.57	0.19	0.46	0.06	-0.02	-0.02	-0.22	0.29	0.47	0.57	0.46	0.78
Global Core Infrastructure	4.20	4.98	12.91	4.80	0.22	-0.20	-0.12	-0.08	0.06	0.13	0.38	0.39	0.53	-0.12	0.13	-0.21	0.07	-0.25	0.06	-0.08	0.25	0.37	0.31	0.31
Global Core Transport	5.40	6.32	14.09	6.10	0.20	-0.11	-0.11	-0.11	-0.36	-0.33	-0.29	-0.26	-0.16	-0.03	-0.15	0.05	0.42	0.08	0.49	-0.13	-0.33	0.12	-0.31	-0.10
Global Timberland	4.60	5.35	12.66	-	0.08	0.05	-0.06	0.03	-0.10	-0.04	-0.11	-0.09	-0.06	0.04	0.03	0.04	0.45	0.01	0.48	0.00	-0.09	0.36	-0.10	0.12
Diversified Hedge Funds hedged	3.80	4.02	6.77	2.40	-0.06	-0.12	0.06	0.08	0.37	0.44	0.65	0.68	0.68	-0.03	0.27	-0.16	-0.31	-0.22	-0.39	0.11	0.48	0.28	0.52	0.73
Event Driven Hedge Funds hedged	4.20	4.56	8.75	2.00	-0.03	-0.09	0.11	0.11	0.39	0.50	0.80	0.79	0.76	-0.01	0.30	-0.14	-0.36	-0.22	-0.46	0.17	0.56	0.36	0.60	0.80
Long Bias Hedge Funds hedged	3.80	4.38	11.07	2.10	-0.10	-0.08	0.16	0.12	0.46	0.51	0.78	0.74	0.67	0.01	0.30	-0.10	-0.40	-0.17	-0.50	0.20	0.60	0.35	0.63	0.80
Relative Value Hedge Funds hedged	3.70	3.89	6.33	2.60	0.01	-0.01	0.13	0.14	0.42	0.53	0.84	0.85	0.87	0.01	0.34	-0.14	-0.30	-0.23	-0.38	0.19	0.57	0.44	0.64	0.75
Macro Hedge Funds hedged	2.90	3.22	8.16	1.50	-0.01	0.09	-0.04	0.00	0.08	0.09	0.08	0.12	0.09	-0.04	0.30	-0.08	-0.13	-0.10	-0.15	0.00	0.06	0.05	0.02	0.23
Direct Lending	5.70	6.77	15.21	5.60	0.10	-0.10	-0.13	-0.02	-0.08	0.02	0.12	0.13	0.25	-0.04	0.01	-0.11	0.43	-0.16	0.47	-0.07	-0.02	0.41	0.04	0.22
Commodities	1.00	2.28	16.36	1.30	0.31	-0.21	-0.32	-0.30	-0.11	-0.04	0.23	0.23	0.35	-0.36	0.12	-0.45	-0.18	-0.45	-0.14	-0.30	0.04	0.18	0.09	0.29
Gold	1.40	2.65	16.15	1.70	0.03	0.08	0.18	0.10	0.11	0.05	-0.07	-0.10	-0.07	0.10	0.14	0.18	0.36	0.21	0.36	0.16	0.02	0.21	0.04	-0.17

Source: JPMorgan´s 2023 Long Term Capital Market Assumptions Report

Appendice 2: Macaulay Duration Computation for the Immunization Portfolio

#	Asset	Settlement	Maturity	Coupon Rate	Yield	Frequency	Macaulay Duration	Weights	Weighted Duration
1	Luxembourg Government Bond	06/03/2023	10/07/2023	2,125%	2,86%	1	0,334867241	20,00%	0,02344
2	Netherlands Government Bond	06/03/2023	15/07/2024	2,000%	2,58%	1	1,304975622	23,89%	0,10911
3	Germany Government Bond	06/03/2023	15/02/2024	1,750%	2,51%	1	0,918631074	20,00%	0,06430
4	Austria Government Bond	06/03/2023	20/10/2025	1,200%	2,38%	1	2,526018388	14,02%	0,12395
5	Finland Government Bond	06/03/2023	15/04/2026	0,500%	0,53%	1	3,062346202	7,09%	0,07604
6	Luxembourg Government Bond 2	06/03/2023	01/02/2027	0,625%	0,74%	1	3,837172075	4,27%	0,05730
7	European Investment Bank Bond	07/03/2023	14/01/2028	0,875%	3,29%	1	4,608975305	2,54%	0,04103
8	Nordic Investment Bank Bond	07/03/2023	09/03/2029	0,250%	3,38%	1	5,751597631	1,94%	0,03905
9	Northwestern Mutual Global Funding Corp Bond	07/03/2023	15/03/2030	4,109%	4,01%	1	5,772948507	1,66%	0,03362
10	3M Co. Corporate Bond	07/03/2023	02/06/2031	1,500%	3,76%	1	7,381404535	1,45%	0,03739
11	Landesbank Berlin AG Covered Bond	07/03/2023	25/06/2032	2,725%	2,26%	4	8,182162075	1,23%	0,03522
12	Bank of America Corporate Bond	07/03/2023	27/04/2033	2,824%	4,35%	1	8,26359398	1,01%	0,02908
13	Commerzbank AG mortgage-covered Bond	07/03/2023	09/01/2034	1,250%	3,48%	1	9,746736889	0,90%	0,03074

Source: Author´s Computations

Appendice 3: Macaulay Duration Computation for the Optimization Portfolio

		ETF	Coupon Rate	Yield	Eff Duration	Macaulay Duration	Weights	Weighted Duration
14	Euro Inflation	IBCI	1%	3,24%	7,94	7,691	0,91%	0,04533
15	Euro Cash	ERNE	1,74%	3,64%	0,37	0,357	5,71%	0,01326
16	US Aggregate Bonds hedged	AGG	2,83%	4,41%	6,27	6,005	34,29%	1,33829
17	Euro Aggregate Bonds	IEAG	1,54%	3,41%	6,39	6,179	0,00%	0,00000
18	US Inv Grade Corp Bonds hedged	LQD	3,89%	5,12%	13,08	12,443	0,00%	0,00000
19	Euro Inv Grade Corp Bonds	IBCX	1,69%	4,01%	4,89	4,701	0,00%	0,00000
20	US High Yield Bonds hedged	HYG	5,65%	8,11%	3,7	3,422	28,57%	0,63560
21	Euro High Yield Bonds	IHYG	3,93%	7,54%	2,73	2,539	0,00%	0,00000
22	U.S Leveraged Loans Hedged	BKLN	7,99%	9,08%	0,17	0,156	0,00%	0,00000
23	Euro Government Bonds	IBGS	0.92%	3,20%	1,6	1,550	0,00%	0,00000
24	Euro Govt Inflation-Linked Bonds	XGIU.MI	0,43%	2,40%	9,07	8,857	0,00%	0,00000
25	World Goverment Bonds	AGGU	2,20%	3,58%	6,68	6,449	0,00%	0,00000
26	Emerging Markets Corporate Bonds	EMCP	4,54%	7,19%	4,62	4,310	30,52%	0,85509

Source: Author´s Computations

Appendice 4: Optimization Portfolio Composition and Weights

#	Sub-Asset Class	Index	ETF Ticker	Returns(JPM)	Volatility (JPM)	St Dev (JPM)	Weights	Weights (%)
1	Euro Inflation	Bloomberg Barclays Eurozone Inflation Linked Bond Index	IBCI	1,80%	0,0106	10,30%	0,397092	0,79%
2	Euro Cash	ECB Deposit Facility Rate	ERNE	1,30%	0,0061	7,81%	0,397092	5,00%
3	US Aggregate Bonds hedged	Bloomberg Barclays US Aggregate Bond Index	AGG	3,90%	0,0412	20,30%	0,794185	30,00%
4	US High Yield Bonds hedged	Bloomberg Barclays US Corporate High Yield Bond Index	HYG	5,90%	0,0865	29,41%	0,794185	25,00%
5	Emerging Markets Corporate Bonds	J.P. Morgan CEMBI Broad Diversified Index	EMCP	5,80%	0,0922	30,36%	3,176738	26,71%
6	Euro Area Large Cap Equities	EURO STOXX 50 Index	FEZ	8,40%	0,1698	41,21%	0,079418	2,50%
7	Emerging Markets Equity	MSCI Emerging Markets Index	EIMI	8,00%	0,1658	40,72%	0,397092	2,50%
8	European Core Real Estate	MSCI Europe Real Estate Index	IPRP	4,70%	0,1015	31,86%	0,794185	7,50%

Appendice 5: Total Portfolio Composition
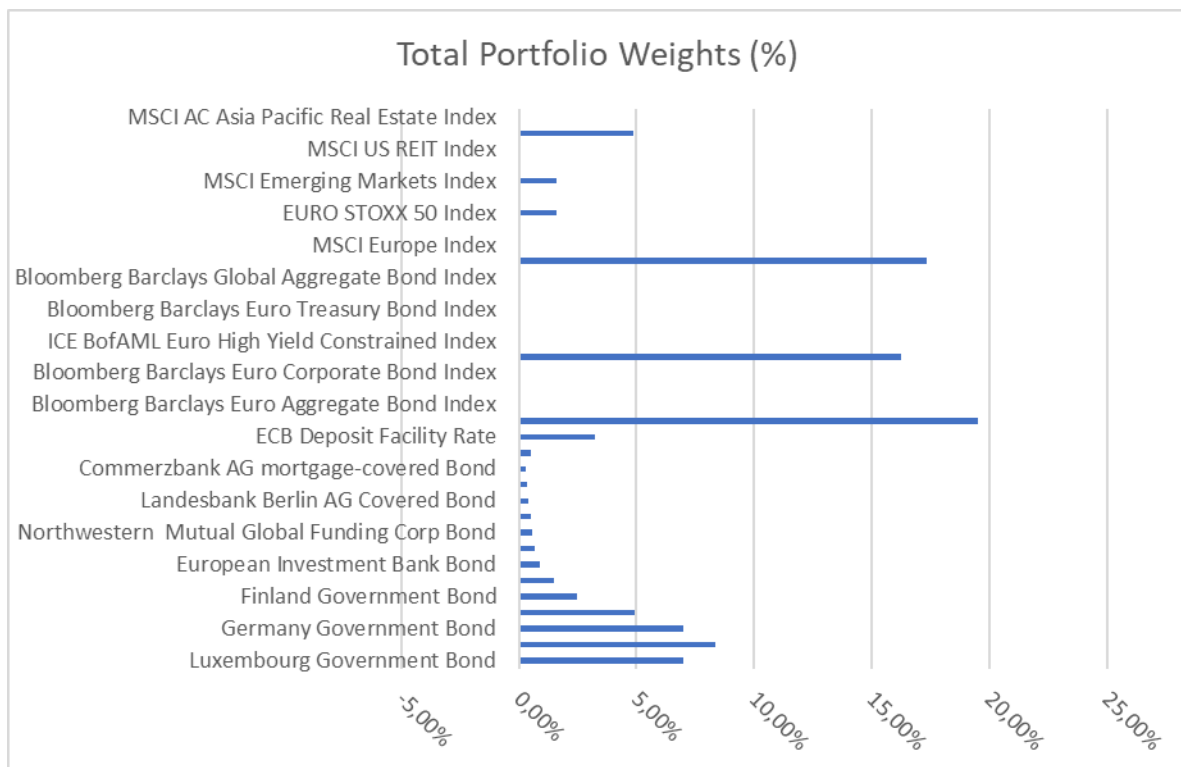
Appendice 6: Correlation Matrix

Correlation Matrix	Euro inf	Euro Cash	USAgg	Euro Agg	US Inv Gr	Euro Inv Gr	US HY	Euro HY	US Lev. L	Euro Gov	Euro Gov Inf-Link	Wrld Gov B	EM Corp B	Europe LC E	US LC E	EA LC E	UK LC E	EM E	AC W E	US RE	Euro RE	Asia P RE
Euro Inflation	1	-0,17	-0,41	-0,46	-0,35	-0,38	-0,11	-0,14	-0,02	-0,42	-0,18	-0,23	-0,23	-0,08	-0,03	-0,11	0,05	-0,07	-0,06	0,31	0,16	0,16
Euro Cash	-0,17	1	0,31	0,3	0,15	0,12	0,02	-0,01	-0,07	0,3	0,14	0,2	0,04	-0,15	-0,17	-0,12	-0,2	-0,06	-0,15	-0,38	-0,31	-0,32
US Aggregate Bonds hedged	-0,41	0,31	1	0,75	0,83	0,62	0,35	0,25	0,05	0,7	0,43	0,39	0,53	0,1	0,05	0,14	-0,06	0,12	0,09	-0,19	-0,31	-0,05
Euro Aggregate Bonds	-0,46	0,3	0,75	1	0,67	0,78	0,27	0,32	0,1	0,98	0,67	0,52	0,47	0,16	0,17	0,19	0,03	0,15	0,09	-0,2	-0,28	-0,07
US Inv Grade Corp Bonds hedged	-0,35	0,15	0,83	0,67	1	0,83	0,63	0,54	0,35	0,57	0,5	0,23	0,77	0,37	0,27	0,39	0,24	0,4	0,37	-0,03	-0,02	0,24
Euro Inv Grade Corp Bonds	-0,38	0,12	0,62	0,78	0,83	1	0,64	0,69	0,48	0,66	0,64	0,23	0,75	0,5	0,44	0,5	0,39	0,49	0,52	0,07	0,05	0,31
US High Yield Bonds hedged	-0,11	0,02	0,35	0,27	0,63	0,64	1	0,87	0,78	0,14	0,39	-0,19	0,76	0,7	0,56	0,7	0,6	0,68	0,67	0,34	0,34	0,55
Euro High Yield Bonds	-0,14	-0,01	0,25	0,32	0,54	0,69	0,87	1	0,86	0,19	0,4	-0,14	0,68	0,76	0,61	0,73	0,7	0,7	0,73	0,35	0,33	0,56
U.S Leveraged Loans Hedged	-0,02	-0,07	0,05	0,1	0,35	0,48	0,78	0,86	1	-0,03	0,25	-0,18	0,57	0,65	0,57	0,6	0,66	0,64	0,66	0,44	0,45	0,62
Euro Government Bonds	-0,42	0,3	0,7	0,98	0,57	0,66	0,14	0,19	-0,03	1	0,55	0,55	0,33	0,06	0,09	0,09	-0,07	0,05	0,08	-0,25	-0,33	-0,17
Euro Govt Inflation-Linked Bonds	-0,18	0,14	0,43	0,67	0,5	0,64	0,39	0,4	0,25	0,55	1	0,19	0,43	0,35	0,28	0,35	0,23	0,31	0,34	0	-0,04	0,12
World Goverment Bonds	-0,23	0,2	0,39	0,52	0,23	0,23	-0,19	-0,14	-0,18	0,55	0,19	1	-0,05	-0,22	0,07	-0,29	-0,16	-0,18	-0,05	0	-0,13	-0,03
Emerging Markets Corporate Bonds	-0,23	0,04	0,53	0,47	0,77	0,75	0,76	0,68	0,57	0,33	0,43	-0,05	1	0,55	0,39	0,58	0,44	0,6	0,51	0,22	0,24	0,45
European Large Cap Equities	-0,08	-0,15	0,1	0,16	0,37	0,5	0,7	0,76	0,65	0,06	0,35	-0,22	0,55	1	0,81	0,97	0,91	0,77	0,92	0,38	0,47	0,61
U.S Large Cap Equities	-0,03	-0,17	0,04	0,17	0,27	0,44	0,56	0,61	0,57	0,09	0,28	0,07	0,39	0,81	1	0,75	0,77	0,64	0,96	0,48	0,54	0,6
Euro Area Large Cap Equities	-0,11	-0,12	0,14	0,19	0,39	0,5	0,7	0,73	0,6	0,09	0,35	-0,29	0,58	0,97	0,75	1	0,82	0,73	0,86	0,29	0,38	0,52
UK Large Cap Equities	0,05	-0,20	-0,06	0,03	0,24	0,39	0,6	0,7	0,66	-0,07	0,23	-0,16	0,44	0,91	0,77	0,82	1	0,73	0,86	0,45	0,65	0,65
Emerging Markets Equity	-0,07	-0,06	0,12	0,15	0,4	0,49	0,68	0,7	0,64	0,05	0,31	-0,18	0,6	0,77	0,64	0,73	0,73	1	0,8	0,33	0,44	0,62
AC World Equity	-0,06	-0,15	0,09	0,09	0,37	0,52	0,67	0,73	0,66	0,08	0,34	-0,05	0,51	0,92	0,96	0,86	0,86	0,8	1	0,45	0,54	0,65
U.S Core Real Estate	0,31	-0,38	-0,19	-0,2	-0,03	0,07	0,34	0,35	0,44	-0,25	0	0	0,22	0,38	0,48	0,29	0,45	0,33	0,45	1	0,49	0,75
European Core Real Estate	0,16	-0,31	-0,31	-0,28	-0,02	0,05	0,34	0,33	0,45	-0,33	-0,04	-0,13	0,24	0,47	0,54	0,38	0,55	0,44	0,54	0,49	1	0,57
Asia Pacific Core Real Estate	0,16	-0,32	-0,05	-0,07	0,24	0,31	0,55	0,56	0,62	-0,17	0,12	-0,03	0,45	0,61	0,6	0,52	0,65	0,62	0,65	0,75	0,57	1

Source: JPMorgan´s 2023 Long Term Capital Markets Assumptions Report

Appendice 7: Variance-Covariance Matrix

Var-Cov Matrix	Euro inf	Euro Cash	USAgg	Euro Agg	US Inv Gr	Euro Inv Gr	US HY	Euro HY	US Lev. L	Euro Gov	Gov Inf-L	Wrld Gov	EM Corp B	Europe LC E	US LC E	EA LC E	UK LC E	EM E	AC W E	US RE	Euro RE	Asia P RE
Euro Inflation	0,0106	-0,00137	-0,00857	-0,01002	-0,00966	-0,00884	-0,00333	-0,00449	-0,00058	-0,00955	-0,00427	-0,0062	-0,00719	-0,00316	-0,00119	-0,00467	0,001971	-0,00293	-0,00231	0,011275	0,005248	0,006097239
Euro Cash	-0,00137	0,0061	0,004914	0,004959	0,003141	0,002117	0,000459	-0,00024	-0,00155	0,005176	0,002522	0,004088	0,000949	-0,0045	-0,0051	-0,00386	-0,00598	-0,00191	-0,00477	-0,01048	-0,00771	-0,00925071
US Aggregate Bonds hedged	-0,00857	0,004914	0,0412	0,032222	0,045174	0,02842	0,020894	0,015804	0,002869	0,031387	0,020131	0,020719	0,032666	0,007798	0,003895	0,01171	-0,00466	0,009918	0,007438	-0,01362	-0,02005	-0,00375646
Euro Aggregate Bonds	-0,01002	0,004959	0,032222	0,0448	0,038026	0,037284	0,016808	0,021095	0,005983	0,045822	0,032709	0,028806	0,030207	0,013011	0,01381	0,016571	0,002431	0,012928	0,007757	-0,01495	-0,01888	-0,005484
US Inv Grade Corp Bonds hedged	-0,00966	0,003141	0,045174	0,038026	0,0719	0,050261	0,049684	0,045097	0,026528	0,033764	0,030924	0,016141	0,062693	0,038116	0,027786	0,043092	0,02464	0,043673	0,040398	-0,00284	-0,00171	0,023819683
Euro Inv Grade Corp Bonds	-0,00884	0,002117	0,02842	0,037284	0,050261	0,051	0,042508	0,048531	0,030641	0,032926	0,033337	0,013594	0,051429	0,043381	0,038136	0,046529	0,033722	0,045058	0,047817	0,005585	0,003597	0,025912366
US High Yield Bonds hedged	-0,00333	0,000459	0,020894	0,016808	0,049684	0,042508	0,0865	0,079692	0,064845	0,009096	0,026456	-0,01463	0,067871	0,079095	0,063212	0,084835	0,067566	0,081435	0,080237	0,035326	0,031858	0,059873001
Euro High Yield Bonds	-0,00449	-0,00024	0,015804	0,021095	0,045097	0,048531	0,079692	0,097	0,075711	0,013072	0,028734	-0,01141	0,064307	0,090937	0,072915	0,093687	0,083474	0,088772	0,092577	0,038509	0,032744	0,064555638
U.S Leveraged Loans Hedged	-0,00058	-0,00155	0,002869	0,005983	0,026528	0,030641	0,064845	0,075711	0,0799	-0,00187	0,016299	-0,01332	0,048923	0,070588	0,061837	0,069887	0,071431	0,073662	0,075964	0,043937	0,040525	0,064867231
Euro Government Bonds	-0,00955	0,005176	0,031387	0,045822	0,033764	0,032926	0,009096	0,013072	-0,00187	0,0488	0,028024	0,031799	0,022135	0,005092	0,007631	0,008193	-0,00592	0,004498	0,007196	-0,01951	-0,02323	-0,01390014
Euro Govt Inflation-Linked Bonds	-0,00427	0,002522	0,020131	0,032709	0,030924	0,033337	0,026456	0,028734	0,016299	0,028024	0,0532	0,01147	0,030115	0,031015	0,024787	0,033265	0,020312	0,029115	0,031932	0	-0,00294	0,010244655
World Goverment Bonds	-0,0062	0,004088	0,020719	0,028806	0,016141	0,013594	-0,01463	-0,01141	-0,01332	0,031799	0,01147	0,0685	-0,00397	-0,02212	0,007031	-0,03128	-0,01603	-0,01918	-0,00533	0	-0,01084	-0,00290621
Emerging Markets Corporate Bonds	-0,00719	0,000949	0,032666	0,030207	0,062693	0,051429	0,067871	0,064307	0,048923	0,022135	0,030115	-0,00397	0,0922	0,064161	0,04545	0,072571	0,051155	0,074184	0,063056	0,023599	0,023217	0,050575276
European Large Cap Equities	-0,00316	-0,0045	0,007798	0,013011	0,038116	0,043381	0,079095	0,090937	0,070588	0,005092	0,031015	-0,02212	0,064161	0,1476	0,119434	0,153562	0,13386	0,120455	0,143921	0,051574	0,057527	0,086742772
U.S Large Cap Equities	-0,00119	-0,0051	0,003116	0,01381	0,027786	0,038136	0,063212	0,072915	0,061837	0,024787	0,007031	0,04545	0,119434	0,1473	0,118613	0,113151	0,100017	0,150025	0,06508	0,066028	0,085234007
Euro Area Large Cap Equities	-0,00467	-0,00386	0,01171	0,016571	0,043092	0,046529	0,084835	0,093687	0,069887	0,008193	0,033265	-0,03128	0,072571	0,153562	0,118613	0,1698	0,129375	0,122485	0,144298	0,042216	0,049887	0,079310825
UK Large Cap Equities	0,001971	-0,00598	-0,00466	0,002431	0,02464	0,033722	0,067566	0,083474	0,071431	-0,00592	0,020312	-0,01603	0,051155	0,13386	0,113151	0,129375	0,1466	0,11381	0,134078	0,060868	0,067091	0,092117178
Emerging Markets Equity	-0,00293	-0,00191	0,009918	0,012928	0,043673	0,045058	0,081435	0,088772	0,073662	0,004498	0,029115	-0,01918	0,074184	0,120455	0,100017	0,122485	0,11381	0,1658	0,13264	0,047469	0,057079	0,093442454
AC World Equity	-0,00231	-0,00437	0,006818	0,00711	0,037029	0,043829	0,073546	0,084856	0,069629	0,006596	0,029269	-0,00488	0,057798	0,131919	0,137514	0,132264	0,122897	0,121579	0,151973	0,059333	0,06421	0,089794389
U.S Core Real Estate	0,011275	-0,01048	-0,01362	-0,01495	-0,00284	0,005585	0,035326	0,038509	0,043937	-0,01951	0	0	0,023599	0,051574	0,06508	0,042216	0,060868	0,047469	0,064731	0,1248	0,055149	0,098068344
European Core Real Estate	0,005248	-0,00771	-0,02005	-0,01888	-0,00171	0,003597	0,031858	0,032744	0,040525	-0,02323	-0,00294	-0,01084	0,023217	0,057527	0,066028	0,049887	0,067091	0,057079	0,070052	0,055149	0,1015	0,067215303
Asia Pacific Core Real Estate	0,006097	-0,00925	-0,00376	-0,00548	0,02382	0,025912	0,059873	0,064556	0,064867	-0,0139	0,010245	-0,00291	0,050575	0,086743	0,085234	0,079311	0,092117	0,093442	0,097964	0,098068	0,067215	0,137

Source: Author´s Computations

Appendice 8: Minimum-Variance Portfolio Weights

Mean Variance Portfolio	Weights
Bloomberg Barclays Eurozone Inflation Linked Bond Index	34,49%
ECB Deposit Facility Rate	46,22%
Bloomberg Barclays US Aggregate Bond Index	5,06%
Bloomberg Barclays Euro Aggregate Bond Index	0,01%
Bloomberg Barclays US Corporate Bond Index	0,00%
Bloomberg Barclays Euro Corporate Bond Index	1,37%
Bloomberg Barclays US Corporate High Yield Bond Index	0,00%
ICE BofAML Euro High Yield Constrained Index	0,00%
S&P/LSTA U.S. Leveraged Loan 100 Index	0,00%
Bloomberg Barclays Euro Treasury Bond Index	4,59%
Bloomberg Barclays Euro Government Inflation-Linked Bond Index	0,00%
Bloomberg Barclays Global Aggregate Bond Index	1,04%
J.P. Morgan CEMBI Broad Diversified Index	0,00%
MSCI Europe Index	0,00%
S&P 500 Index	0,00%
EURO STOXX 50 Index	0,81%
FTSE 100 Index	0,00%
MSCI Emerging Markets Index	0,00%
MSCI ACWI Index	0,00%
MSCI US REIT Index	1,37%
MSCI Europe Real Estate Index	5,04%
MSCI AC Asia Pacific Real Estate Index	0,00%

Source: Author´s Computations

Appendice 9: Tangent Portfolio Weights and Methodology

Tangent Portfolio			
EIOPA Euro Zone Risk Free Rate	0,95%		
	Rbar-Rf	z	Weights
Bloomberg Barclays Eurozone Inflation Linked Bond Index	0,85%	2,180258585	43,03%
ECB Deposit Facility Rate	0,35%	0,044374204	0,88%
Bloomberg Barclays US Aggregate Bond Index	2,95%	2,436957552	48,09%
Bloomberg Barclays Euro Aggregate Bond Index	2,05%	0,374164987	7,38%
Bloomberg Barclays US Corporate Bond Index	3,35%	-1,665335403	-32,87%
Bloomberg Barclays Euro Corporate Bond Index	2,65%	0,649854697	12,82%
Bloomberg Barclays US Corporate High Yield Bond Index	4,95%	0,228002287	4,50%
ICE BofAML Euro High Yield Constrained Index	4,75%	-0,255246608	-5,04%
S&P/LSTA U.S. Leveraged Loan 100 Index	4,15%	0,403577932	7,96%
Bloomberg Barclays Euro Treasury Bond Index	1,85%	-0,375412163	-7,41%
Bloomberg Barclays Euro Government Inflation-Linked Bond Index	1,65%	-0,35905786	-7,09%
Bloomberg Barclays Global Aggregate Bond Index	1,35%	0,706194912	13,94%
J.P. Morgan CEMBI Broad Diversified Index	4,85%	-0,139578283	-2,75%
MSCI Europe Index	6,75%	-1,018016918	-20,09%
S&P 500 Index	4,95%	-0,63082758	-12,45%
EURO STOXX 50 Index	7,45%	1,485589025	29,32%
FTSE 100 Index	6,05%	0,18201374	3,59%
MSCI Emerging Markets Index	7,05%	0,245806517	4,85%
MSCI ACWI Index	5,45%	0,080618022	1,59%
MSCI US REIT Index	2,65%	-0,218736905	-4,32%
MSCI Europe Real Estate Index	3,75%	0,62475483	12,33%
MSCI AC Asia Pacific Real Estate Index	5,05%	0,087198385	1,72%
	Sum	5,067153956	100,00%

Source: Author´s Computations

Appendice 10: Hyperbole and Capital Allocation Line Computation

Expected Returns	Hyperbole Volatility
0,00%	8,62%
0,30%	7,73%
0,60%	6,89%
0,90%	6,13%
1,20%	5,47%
1,50%	4,97%
1,80%	4,67%
2,10%	4,61%
2,40%	4,80%
2,70%	5,21%
3,00%	5,80%
3,30%	6,51%
3,60%	7,32%
3,90%	8,19%
4,20%	9,11%
4,50%	10,06%
4,80%	11,03%
5,10%	12,02%
5,40%	13,03%
5,70%	14,05%
6,00%	15,07%
6,30%	16,11%
6,60%	17,15%
6,90%	18,19%
7,20%	19,24%
7,50%	20,30%
7,80%	21,35%
8,10%	22,41%
8,40%	23,47%
8,70%	24,53%
9,00%	25,60%

Source: Author´s Computations

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Abbreviations

ACW-All Countries World Index CF-Cash Flow Statement

EIOPA-European Insurance and Occupational Pensions Authority IPS- Investment Policy Statement

VaR-Value at Risk

ESG-Environmental, Social, and Governance

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