Lisbon School of Economics & Management
Universidade de Lisboa

MASTER IN FINANCE

MASTER FINAL WORK

DISSERTATION

PORTFOLIO IMPLICATIONS OF MREL

GONÇALO DE JESUS ALVES BALSEMÃO PIRES

OCTOBER-2024

MASTER IN FINANCE

MASTER FINAL WORK

DISSERTATION

PORTFOLIO IMPLICATIONS OF MREL

GONÇALO DE JESUS ALVES BALSEMÃO PIRES

SUPERVISOR:

PROF. RAQUEL GASPAR

October-2024

Acknowledgements

I would like to express my deepest gratitude to my supervisor, Prof. Raquel Gaspar, for her invaluable guidance, support, and expertise throughout this research. A special mention to my colleagues and ISEG for their insights and support during this journey. I also extend my thanks to my family and friends for their constant encouragement which was essential in completing this dissertation.

Abstract

The global crisis of 2008 exposed vulnerabilities in the banking sector, leading to the establishment of regulatory measures aimed at strengthening financial institutions. One such regulation is the Minimum Requirement for Own Funds and Eligible Liabilities (MREL), designed to ensure that banks maintain an adequate buffer to absorb losses and avoid systemic risks. This dissertation explores the necessity of issuing debt to meet MREL requirements and investigates the feasibility of creating an investment portfolio to cover these issuances.

The growing importance of MREL in enhancing financial stability and preventing taxpayer-funded bailouts is clear. However, as banks navigate the complex regulatory landscape, understanding the implications of debt issuance to meet MREL becomes crucial. Furthermore, exploring the potential creation of investment portfolios to cover these debt costs presents an innovative perspective for managing regulatory compliance. This dissertation examines strategies like the Cash Flow Matching and Mean Variance Theory (MVT) to optimize potential banks' portfolios and manage liabilities issued due to MREL.

We focus on the application of a typical issuance from Portuguese banks and on bond portfolios. For this analysis, we examine a hypothetical MREL issuance and use financial market data from twenty-five bonds to determine the optimal portfolio.

Keywords: MREL; Investment portfolio; Cash Flow Matching; Mean Variance Theory.

JEL Codes: C61; G11; G21

Resumo

A crise mundial de 2008 expôs as vulnerabilidades do sector bancário, levando ao estabelecimento de medidas regulamentares destinadas a fortalecer as instituições financeiras. Um desses regulamentos é o *Minimum Requirements of Own Funds and Eligible Liabilities* (*MREL*), concebido para garantir que os bancos mantêm uma reserva adequada para absorver perdas e evitar riscos sistémicos. Esta dissertação explora a necessidade de emitir dívida para cumprir os requisitos do *MREL* e investiga a viabilidade de criar uma carteira de investimentos para cobrir essas emissões.

A importância crescente do *MREL* no reforço da estabilidade financeira e na prevenção de resgates financiados pelos contribuintes é clara, no entanto, à medida que os bancos navegam no complexo cenário regulamentar, torna-se essencial compreender as implicações da emissão de dívida para cumprir o *MREL*. Além disso, a exploração da potencial criação de carteiras de investimento para cobrir estes custos da dívida apresenta uma perspetiva inovadora para a gestão da conformidade regulamentar. Nesta dissertação examinamos estratégias como o *cash flow matching* e a Teoria da Variância Média (MVT) para otimizar as carteiras dos bancos e gerir os passivos.

Nós centramo-nos na aplicação de uma emissão típica de bancos portugueses e em possíveis carteiras de obrigações. Para esta análise, examinamos uma hipotética emissão de MREL e utilizamos dados financeiros de 25 obrigações para determinar a carteira ótima.

Palavras-Chave: *MREL*; Carteira de Investimentos; Correspondência de fluxos de caixa; Teoria Média-Variância.

JEL Codes: C61; G11; G21

Table of Contents

List of Figures

List of Tables

Abbreviations

α	Alpha
BCBS	Basel Committee on Banking Supervision
BCP	Banco Comercial Português
BPI	Banco Português de Investimento
BRRD	Bank Recovery and Resolutive Directive
CCoB	Capital Conservation Buffer
CCyB	Countercyclical Capital Buffer
CET1	Common Equity Tier 1
CGD	Caixa Geral de Depósitos
ECB	European Central Bank
EF	Efficient Frontier
EU	European Union
FSB	Financial Stability Board
G-SIBs	Globally Systemically Important Banks
G-SII	Globally Systemically Important Institutions
MREL	Minimum Requirements for Own Funds and Eligible Liabilities
MVT	Mean Variance Theory
NIM	Net Interest Margin
O-SII	Other Systemically Important Institutions
SRB	Single Resolution Board
SyRB	Systemic Risk Buffer
T1	Tier 1
T2	Tier 2
TLAC	Total Loss-Absorbing Capacity

1. Introduction

The financial stability and resilience of banking institutions have become paramount concerns for regulatory authorities worldwide, particularly in the dawn of the global crisis of 2008. One pivotal regulatory measure aimed at strengthening the banking sector within the European Union (EU) is the Minimum Requirement for own funds and Eligible Liabilities (MREL). MREL is designed to ensure that banks have sufficient capital and liabilities to absorb losses and facilitate recapitalization in times of financial distress, thereby safeguarding the broader financial system.

MREL plays a critical role in the effective implementation of the bail-in mechanism, a resolution tool that allows authorities to restructure a failing bank by imposing losses on its shareholders and creditors rather than relying on taxpayer-funded bailouts. This regulatory requirement is not one-size-fits-all; instead, it is tailored to the unique characteristics of each bank. Factors such as the institution's size, business model, funding structure, and risk profile are considered, along with the specific needs identified for executing the bank's resolution strategy. This individualized approach underscores the importance of each bank's operational and financial landscape.

In parallel, MREL aligns with international standards such as the Total Loss-Absorbing Capacity (TLAC) developed by the Financial Stability Board (FSB), which targets globally systemically important banks (G-SIBs). However, MREL's focus within the EU context brings unique challenges and implications, especially when considering the regulatory environment established by the Basel Committee on Banking Supervision (BCBS) and the EU Basel III framework. These prudential regulations set stringent capital requirements, including Common Equity Tier 1 (CET1), Tier 1 (T1), and the overall capital ratio, to ensure banks maintain a robust capital base to withstand financial shocks.

The introduction and enforcement of MREL have far-reaching consequences for banks. The requirement can lead to significant financial implications, including reduced income due to the impact on organic capital generation, pressures on net interest margins, and increased costs associated with issuing additional eligible liabilities.

This essay delves into the nature of MREL, exploring its regulatory foundations, the tailored application to individual banks, and the broader implications for the banking sector. By examining the intersection of regulatory compliance and financial strategy, the discussion aims to provide investment strategies, banks may have to apply the proceedings of MREL issuances.

One possibility for banks is the investment of the amount in a diversified portfolio with an expected return higher than the costs of the debt issuance. This is evaluated using cash flow matching and mean-variance theory.

We explore the cash flow matching between the liabilities that banks require to issue to comply with MREL and the cash flows that a bond portfolio can give in return.

Our study starts with the literature review about the MREL in Section 2, Section 3 deals with methodology, Section 4 presents and discusses the results. Finally, Section 5 concludes and points future research opportunities.

2. Literature Review (MREL)

Let us start by asking what Minimum Requirement for own funds and Eligible Liabilities (MREL) is. The Bank Recovery and Resolution Directive 2014/59/EU (BRRD) mandates that institutions operating within the European Union (EU) must fulfil a minimum requirement for their own funds and eligible liabilities, known as MREL, to guarantee the effective and credible implementation of the bail-in mechanism. Failing to meet MREL could adversely affect institutions' ability to absorb losses and recapitalize, undermining the overall efficacy of resolution efforts. This stipulation is one of the essential measures aimed at rendering institutions capable of being resolved (Single Resolution Board, 2023).

The MREL policy was implemented as a recommendation in 2016 by the Single Resolution Board (SRB) with national resolution authorities in the Banking Union. It only became mandatory to the banks in 2017 and only for major banking groups. Turned out universal in the beginning of 2019 (White & Case, 2019).

The BRRD specifies that MREL must be tailored to suit the unique characteristics of each bank, encompassing factors such as its size, business model, funding structure, and risk profile, as well as the requirements identified for executing the resolution strategy. MREL targets are established by EU resolution authorities, following consultations with prudential supervisors, and banks are expected to adhere to these targets by the conclusion of any transitional period which "must be bank-specific, because they depend on the MREL tailored to that bank and its resolution plan, and the bank's progress to date in raising MREL-eligible liabilities." (Single Resolution Board, 2023).

MREL serves the same regulatory purpose as the Total Loss-Absorbing Capacity (TLAC) standard developed by the Financial Stability Board (FSB), which is designed for globally systemically important banks (G-SIBs) on an international scale. However, TLAC differs in certain aspects of its formulation (Single Resolution Board, 2023), and we do not approach it in here.

The purpose of MREL is to mitigate the reliance of a bank's resolution on public financial assistance, thereby ensuring that shareholders and creditors bear a portion of the burden in absorbing losses and recapitalizing the institution.

MREL stands as a distinct minimum requirement mandated by resolution authorities, operating alongside a bank's prudential minimum capital requirements. The Basel Committee on Banking Supervision (BCBS) set standards for the prudential regulation of banks by creating the Basel Framework. On the European Union Basel III package, the Pillar I capital requirements are the following: Common Equity Tier 1 (CET1) equal or higher 4.5%; T1 (CET1 + Additional Tier 1) equal or higher 6%; Solvency Ratio (T1+T2) equal or higher 8% (all of Risk Weighted Assets). For the determination of Pillar 2, microprudential authorities shall assess the institution's specific risks and the corresponding control mechanisms implemented and based on this assessment, may decide to impose specific measures on the institution, including additional capital requirements. Pillar 2 requirement should be met with at least 75% of T1. Pillar 1 + Pillar 2 requirements must be met on an ongoing basis, including adverse scenarios (Banco de Portugal, 2020).

The combined capital buffer requirement (CBR) is composed by five buffers. The capital conservation buffer (CCoB) that must be equal to 2.5%; the Countercyclical Capital Buffer (CCyB) must be between 0 and 2.5%; the systemic risk buffer (SyRB) must be a multiple of 0.5% with no limit, though has not been applied in Portugal. The Global Systematically Important Institutions (G-SII) capital buffer has no limit and Other Systematically Important Institutions (O-SII) capital buffer must be equal or lower to 3%. The sum shall not exceed 5% of total risk-weighted exposure amount, unless authorised by the European Commission (Banco de Portugal, 2020).

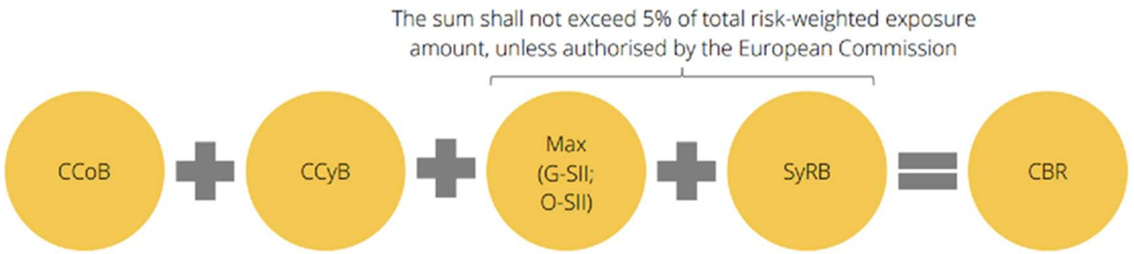

Figure 1: Composition of CBR.

Source: Banco de Portugal

Pillar 2 Guidance provides a “safety margin” for prudential requirements that is calculated considering the expected reduction in own funds in the event of a very adverse and very unlikely scenario (Banco de Portugal, 2020).

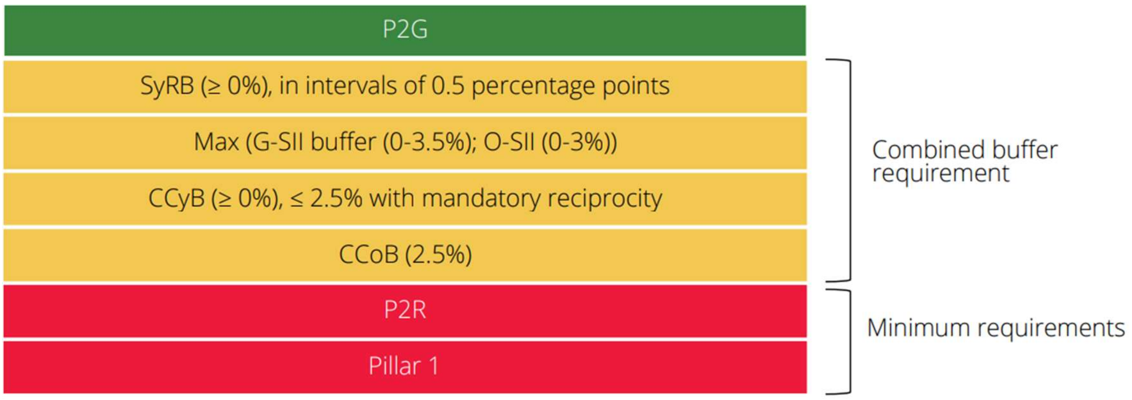

Figure 2: Basel Framework

Source: Banco de Portugal

A MREL shortfall occurs when a bank lacks sufficient own funds and eligible liabilities to fulfil its MREL target as determined by the resolution authority. This shortfall does not necessarily indicate a capital deficiency or imply that the bank is failing or likely to fail. Even well-capitalized banks that meet their prudential requirements may be instructed by resolution authorities, among other measures, to hold an additional amount of MREL liabilities, either in the form of own funds or eligible liabilities.

Under the MREL decisions of SRB and within the resolution framework, banks that fail to immediately meet their MREL target are typically granted a specific transitional period to comply with the requirement. During this period, banks may take actions such as issuing additional eligible debt instruments to enhance their resolvability.

Particularly for mid-size banks the introduction of MREL requirements may lead to lower income due to the impact on organic capital generation.

In Great Britain, the bank’s income can be lower 20% compared to the projected amount without the MREL, in absolute values. This means a reduction of GBP 42 billion in lending by the fifth year. Also, the net interest margins (NIM) could face pressure, contributing to a significant fall in projected lending. The cumulative lost profits due to MREL for the sector could lead to a reduction of GBP 240 million in tax payments in five years. Furthermore, the return on equity could fall from an average of 12.8% to 10.1% in the fifth year if MREL is introduced as drafted (Ernst & Young LLP, 2021).

In Spain, for example, banks issue debt when they would not need to comply with the MREL. "By our estimates, as of year-end 2016, the significant Spanish banks need to issue between 65 and 79 billion euros to meet the MREL requirement once it becomes binding, which will not be earlier than four years from when each entity is notified of its requirement" (Berges, Pelayo and Rojas, 2018).

Other consequence related to the need of complying with the MREL requirements is the costs of issuing debt. This can cause two key issues: a potential shortage of demand from investors and high expenses for banks. To lower the cost of issuing debt and interest payments, banks may issue more debt than necessary, which could lead to high carrying costs. This happens because there is a gap between the high interest banks pay on issued debt and the lower returns they earn from lending, investing in high-quality liquid assets, or keeping funds in overnight deposits with the central bank (Hills, 2021).

Being aware of these problems to banks, we study investment strategies banks may apply to the proceedings of MREL issuances.

3. Methodology

3.1 Cash Flow Matching

We explore the efficient allocation to a fixed income securities portfolio to cover MREL related liabilities while minimizing expenses. Key variables include the price (net present value) of asset i today (p_i), nominal value of the liability to be covered at time t in the future (y_t), nominal value of the cash flow from asset i at time t in the future ($x_{i,t}$) and the present expenditure (weight) on asset i in the portfolio (w_i). We want to cover a set of liabilities with interest payments from a fixed income securities portfolio at the minimum expense required to do so.

The minimization problem is formalized as a linear programming model aimed at finding optimal weights for assets in the portfolio, resulting in the equation:

$$Min_{\{w_1,w_2,\ldots,w_I\}} \sum_{i=1}^{I} p_i w_i \quad (1)$$

But it is a constrained minimisation. We have a couple of constraints:

- The first constraint is the cash flow in period t from the portfolio has to be greater than or equal to the value of the obligation that needs to be covered at time t, and this must be true for all time periods:

$$\sum_{i=1}^{I} \mathrm{x}_{i,t} w_i \geq y_t \text{ for all times } t = 1, 2, \ldots, T. \quad (2)$$

- The second constraint is a non-negativity constraint on every asset and what the non-negativity constraint does is that it rules out the possibility of short selling:

$$w_i \geq 0 \quad (3)$$

for all assets $i = 1, 2, \ldots, I$. (S. Levkoff, Ph.D. 2014)

For our cash flow matching problem, we use different bonds and for each bond we have the associated cash flows occurring. The criteria for selecting assets focus on fixed-rate bonds issued by corporations and governments across Eurozone (use of euro currency).

The aim is to capture active bonds with a maturity date set within 2028 that have already been issued before 2019. We also specified a bullet maturity type, the selection emphasizes straightforward repayment structures, which can appeal to investors seeking predictable cash flows. Overall, this selection prioritizes a balanced approach to risk and return within a defined geographical and temporal framework.

In every period, we receive the coupon payment and in the last period we receive the coupon payment plus the par/face value of the bond.

Our goal is to structure a bond portfolio to guarantee that we meet all MREL liabilities with its coupons and principal.

If the proceedings of MREL exceeds the cost of the portfolio, then we can freely invest the remaining. In the next section we discuss how to invest this difference.

3.2 Mean Variance Theory (MVT)

This section follows closely Elton, Gruber, Brown, Goetzmann (2014) in terms of MVT.

We assume investors focus only on the mean and variance of future returns, when making investment decisions. Investors prefer higher means (expected returns) over lower means, and lower variances (lower risk) over higher variances.

To apply MVT, one needs to estimate its inputs: expected returns of all assets under consideration, $\overline{R}$, and their covariance-variance matrix, V.

$$\overline{R} = \begin{pmatrix} \overline{R}_1 \\ \overline{R}_2 \\ \vdots \\ \overline{R}_n \end{pmatrix} \tag{4}$$

and

$$V = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \cdots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \dots & \sigma_n^2 \end{pmatrix} \tag{5}$$

Many investors are concerned about downside risk and focus on protecting against some adverse outcomes, which involves caring about the left tail of return distributions. Even if investors worry about more than expected returns and variance, worrying for instance about downsize risk, it is possible to use the MVT. With some additional assumptions about the distribution of returns.

For Gaussian distribution of returns we can use safety criteria to control downsize risk.

Within the investment opportunity set, the efficient frontier represents the subset that comprises efficient combinations. These combinations achieve the optimal balance between risk and return.

MVT considers the existence of a riskless asset, F. An asset whose return in advance is said to be risk-free. An asset is risk-free if and only if is assumed its variance is zero. We chose the risk-free interest rate, R_f, to be the yield of a "AAA-rated" euro area central government bonds, i.e. debt securities with the most favourable credit risk assessment (ECB, 2024).

In our analysis the focus on the following MVT efficient portfolios: tangent and the minimum variance portfolio.

3.2.1 Tangent Portfolio

If W is a vector of portfolio weights, $\overline{R}$ is the vector of the assets' expected returns and V is the variance-covariance matrix, we have for all risky portfolios P:

$$\overline{R}_p = W'\overline{R} \tag{6}$$

and

$$\sigma_p = (W'VW)^{\frac{1}{2}} \tag{7}$$

So, when we max the Sharpe ratio we have:

$$\max \theta(W) = \frac{W'R - R_f}{(W'VW)^{\frac{1}{2}}} \tag{8}$$

subject to:

$$\sum w_i = W'\mathbf{1} = 1 \tag{9}$$

and $w_i \geq 0$ for all $i = 1,2, \dots, n$.

Additional n inequality restrictions, such that we must rely on numerical solutions.

3.2.2 Minimum Variance Portfolio

The minimum variance portfolio is given by:

$$\min_{W} \sigma_p^2 = W'VW \tag{10}$$

$s.t\ W'\mathbf{1} = 1$ and $w_i \geq 0$.

3.2.3 Efficient Frontier (EF)

The EF is the subset of the Investment Opportunity Set (IOS) which is efficient. The IOS is the set of all pairs of standard deviations and returns attainable from investing in a collection of assets. It is important to realize that efficiency is only defined relative to a set of investment opportunities. If we change the set of assets which the investor can put his money into then the set of efficient portfolios changes too. In general, if we allow an extra asset then portfolios that were previously efficient are no longer efficient. Similarly, if we throw away an asset both from the set of investment opportunities and from an efficient portfolio, then the portfolio containing the remaining assets may not be efficient.

To build our Efficient Frontier, we will use Solver to maximise the expected return for various levels of standard deviations.

The efficient frontier is starting from the Minimum-variance portfolio (MVP).

3.3 Safety-First Criteria

Besides the classical MVT portfolios previously mentioned we also investigate downside risk and the so-called safety-first criteria. We consider three portfolios that are efficient under the assumption of Gaussian returns.

1. The portfolio that minimize the likelihood of returns falling below a certain threshold R_L (Roy portfolio).

2. The portfolio with the lowest value-at-risk given a α% (Kataoka portfolio).

3. The portfolio that given a restriction of type $Pr(R_p \leq R_L) \leq \alpha\%$, maximize expected return (Telser portfolio).

Many times, criteria of some sort of portfolio protection are imposed by managers and/or investors. The notion of "safety" may differ between them.

For a portfolio p, with ϕ(.) the distribution function of the portfolio returns Rp, we have:

$$\Pr(R_p < R_L) = \Pr\left(\frac{R_p - \bar{R}_p}{\sigma_p} < \frac{R_L - \bar{R}_p}{\sigma_p}\right) = \Pr\left(z < \frac{R_L - \bar{R}_p}{\sigma_p}\right) = \phi\left(\frac{R_L - \bar{R}_p}{\sigma_p}\right) \tag{11}$$

3.3.1 Roy Criteria

According to this criterion the best portfolio is the one that solves: $\min_p Pr(R_p < R_L)$.

The threshold is pre-determined, it can take all sort of values. No matter the distribution of portfolio returns:

$$\min_p Pr(R_p < R_L) \Leftrightarrow \min_p \phi\left(\frac{R_L - \bar{R}_p}{\sigma_p}\right) \Leftrightarrow \min_p \left(\frac{R_L - \bar{R}_p}{\sigma_p}\right) \Leftrightarrow \max_p \frac{\bar{R}_p - R_L}{\sigma_p} \tag{12}$$

Finding the safest portfolio according to Roy is, thus finding p solves:

$$\max_p \frac{\bar{R}_p - R_L}{\sigma_p} \tag{13}$$

3.3.2 Kataoka Criteria

Alternatively, one can define bad outcomes in terms of the likelihood of their occurrence. One may be worried about what happens in the α% worst scenarios:

$$\max_{p} R_L$$

$$s.t. Pr\left(R_p < R_L\right) \leq \alpha\% \tag{14}$$

The focus this time is on what, unlikely bad scenarios, may mean. Note that the higher the R_L of a given portfolio the safer it is, in the sense's losses are not as severe as in portfolios with a lower R_L.

For any portfolio returns with distribution function ϕ, we get:

$$Pr\left(R_p < R_L\right) \leq \alpha\% \Leftrightarrow \phi\left(\frac{R_L - \bar{R}_p}{\sigma_p}\right) \leq \alpha\% \Leftrightarrow \frac{R_L - \bar{R}_p}{\sigma_p} \leq \phi^{-1}(\alpha\%)$$
$$\Leftrightarrow R_L \leq \phi^{-1}(\alpha\%)\sigma_p + \bar{R}_p \Leftrightarrow \bar{R}_p \geq R_L - \phi^{-1}(\alpha\%)\sigma_p \tag{15}$$

I.e., for each portfolio p the best we can do is to choose: $R_p = R_L - \phi^{-1}(\alpha\%)\sigma_p$.

3.3.3 Telser Criteria

If safety is defined *a la* Telser than one pre-defines both:

- what are bad outcomes, fixing $R_L$and,
- what is highest likelihood acceptable for those bad outcomes α%.

For given R_L and α%, acceptable portfolios are only those that verify: $Pr\left(R_p \leq R_L\right) \leq \alpha\%$. From all portfolios that satisfy the above condition and since risk has already been considered, Telser recommends choosing the one with the highest expected return. Telser criterion is thus:

$$\max_{p} \bar{R}_p$$
$$s.t. Pr\left(R_p \leq R_L\right) \leq \alpha\% \tag{16}$$

For Gaussian returns, we already know $Pr\left(R_p \leq R_L\right) \leq \alpha\% \Leftrightarrow R_L \leq \phi^{-1}(\alpha\%)\sigma_p + \bar{R}_p \Leftrightarrow \bar{R}_p \geq R_L - \phi^{-1}(\alpha\%)\sigma_p$.

$R_L - \phi^{-1}(\alpha\%)\sigma_p$ is a straight-line equation. Telser safe portfolios are those above a pre-determined straight-line since we fix both y. Either we get a set of acceptable portfolios or no.

The restriction considered for the mean-variance portfolios – namely, no shortselling – also applies to the safety-first portfolios.

This leads to the need to evaluate numerically all portfolios under consideration.

4. Results

4.1 Cash Flow Matching Portfolio

First, we have extracted specifically the Portuguese banks' debt issuances to comply with Minimum Requirements of Own Funds and Eligible Liabilities (MREL), from the bank's respective websites. The banks considered are: "Montepio", "Banco Comercial Português" (BCP), "Caixa Geral de Depósitos" (CGD), "Novo Banco" and "Banco Português de Investimento" (BPI). For all, we consider issuances for MREL's purpose from 2019 to 2023. Since the concept of MREL is recent, the sample is not that large. The characteristics of the debt issuances are detailed in Table 1.

Table 1: Debt Issuances' Characteristics

Bank	Issuance Date	Amount (million €)	Emission price	Coupon	Maturity (years)	Maturity Date
CGD	18/09/2019	500	100.00%	1.250%	5	18/09/2024
BPI	27/02/2020	450	100.00%	0.875%	5	27/02/2025
BCP	12/02/2021	500	99.879%	1.125%	5	12/02/2026
CGD	14/09/2021	500	100.00%	0.375%	5	14/09/2026
BPI	24/09/2021	700	100.00%	0.427%	5	24/09/2026
BCP	06/10/2021	500	99.527%	1.750%	5.5	06/04/2027
BPI	28/02/2022	425	100.00%	2.807%	5	28/02/2027
CGD	07/06/2022	300	100.00%	2.875%	3	07/06/2025
BCP	25/10/2022	350	100.00%	8.500%	2	25/10/2024
CGD	24/10/2022	500	100.00%	5.750%	5	24/10/2027
Novo Banco	24/05/2023	500	100.00%	9.875%	5	24/05/2028
BCP	02/10/2023	500	99.825%	5.625%	2	02/10/2025
Montepio	30/10/2023	200	100.00%	10.000%	2	30/10/2026

Nonetheless, with the information collected we have calculated the mean, median and some descriptive statistics of the issue dates, amounts issued (in millions), emission prices, yearly coupon rates, number of years and maturity dates to see the number of periods to have a reference of how costly is going to be an issuance, as stated in Table 2.

Table 2: Issuances' Descriptive Statistics

	Issuance Date	Amount (million €)	Emission price	Coupon	Maturity (years)	Maturity Date
Mean	08/02/2022	456	99.94%	3.941%	4	17/05/2026
Median	28/02/2022	500	100.00%	2.807%	5	14/09/2026
Mode	-	500	100.00%	-	5	-
Range	-	500	0.4730%	9.625%	3.5	-
Minimum	18/09/2019	200	99.53%	0.375%	2	18/09/2024
Maximum	30/10/2023	700	100.00%	10.000%	5.5	24/05/2028
Sum	-	5925	1299.23%	51.234%	54.5	-
Count	13	13	13	13	13	13

Since the median results are rounder, in the following we consider a typical issuance with the median values. Concretely, we consider an issuance of five hundred million euros, with 5 years to maturity and a coupon of 2.807%. The issuance date is 28/02/2022.

Table 3 presents the cash flows (in millions), multiplying for each period the amount issued, five hundred million euros, with the coupon rate, 2.807%. In the last period we also added the face value. The results are the following:

Table 3: Cash Flows of Median Issuance (in million)

Year	Median CFs
1	14.035
2	14.035
3	14.035
4	14.035
5	514.035

The cash flows in Table 3 are the liabilities that we need to cover with the cash flow matching approach.

We consider the investment date to be 28/02/2022, same as the issuance date. To cover the coupons and the principal, we built a portfolio via Bloomberg of European bonds with fixed coupon, maturity between 01/01/2028 to 12/31/2028, bullet maturity with euro currency and positive daily average annualized return. These criteria offered a selection of twenty-five securities which includes seventeen corporate bonds, and eight government bonds as detailed in Table 4.

Table 4: Bond Portfolio

Issuer Name	Sector	Country	ISIN	Price	Coupon	Abbreviation
P&V Verzekeringen SC	Corporate	Belgium	BE0002603810	110.738	5.500%	CORP.BE.10_5.5%.28
Deutsche Bank AG	Corporate	Germany	DE000DL19T26	98.725	1.750%	CORP.DE.26_1.7%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB0PC1	104.895	2.125%	CORP.DE.C1_2.1%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB0PD9	105.705	2.250%	CORP.DE.D9_2.2%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB0QD7	104.944	2.125%	CORP.DE.D7_2.1%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB0QE5	104.983	2.125%	CORP.DE.E5_2.1%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB2567	101.089	1.500%	CORP.DE.67_1.5%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB2JQ0	98.327	1.000%	CORP.DE.Q0_1.0%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB2PW5	105.591	2.250%	CORP.DE.W5_2.2%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB8CQ2	107.141	2.500%	CORP.DE.Q2_2.5%.28
Norddeutsche Landesbank-Girozentrale	Corporate	Germany	DE000NLB8D50	103.474	1.875%	CORP.DE.50_1.8%.28
Caisse Nationale de Reassurance Mutuelle Agricole Groupama	Corporate	France	FR0013365640	104.706	3.375%	CORP.FR.40_3.3%.28
Hellenic Republic Government Bond	Sovereign	Greece	GR0124034688	112.285	3.750%	SOVE.GR.88_3.7%.28
Banca Nuova SpA	Corporate	Italy	IT0004929839	99.879	6.060%	CORP.IT.39_6.0%.28
Italy Buoni Poliennali Del Tesoro	Sovereign	Italy	IT0005246134	114.147	1.300%	SOVE.IT.34_1.3%.28
Italy Buoni Poliennali Del Tesoro	Sovereign	Italy	IT0005323032	105.477	2.000%	SOVE.IT.32_2.0%.28
Serbia Treasury Bonds	Sovereign	Serbia	RSMFRSD20605	108.23	3.500%	SOVE.RS.05_3.5%.28
Hellenic Republic Government International Bond	Sovereign	Greece	XS0110307930	123.107	6.140%	SOVE.GR.30_6.1%.28
Republic of Italy Government International Bond	Sovereign	Italy	XS1121804279	115.955	1.510%	SOVE.IT.79_1.5%.28
Republic of Italy Government International Bond	Sovereign	Italy	XS1180157544	102.281	1.862%	SOVE.IT.44_1.8%.28
Republic of Italy Government International Bond	Sovereign	Italy	XS1227831382	101.212	1.666%	SOVE.IT.82_1.6%.28
Teva Pharmaceutical Finance Netherlands II BV	Corporate	Netherlands	XS1439749364	82.256	1.625%	CORP.NL.64_1.6%.28
Banco Santander SA	Corporate	Spain	XS1767931121	99.619	2.125%	CORP.ES.21_2.1%.28
UnipolSai Assicurazioni SpA	Corporate	Italy	XS1784311703	101.044	3.875%	CORP.IT.03_3.8%.28
Vittoria Assicurazioni SpA	Corporate	Italy	XS1855456288	112.267	5.750%	CORP.IT.88_5.7%.28

To an easier recognition of each bond, we use the “Abbreviation” column. This abbreviation consists of the combination of the sector, the 2-letter country code, the last two characters of the ISIN, the coupon, and the maturity date of each bond that in our case is 2028 for all bonds.

As we can see the characteristics of these bonds, we have coupon rates ranging from 1.00% and 6.14%, a mean coupon of 2.78% and a median coupon of 2.25%.

With these bonds, using Solver, we minimize the cost of the portfolio with the constraints that the portfolio cash flows must match the liabilities amounts for each period and without shortselling as detailed in Chapter 3.1.

The cost of the cash flow matching portfolio is 435 million euros which is lower than the amount issued which leaves us with sixty-five million euros unused. We need only two bonds to cover all liabilities. Figure 3 gives the portfolio composition.

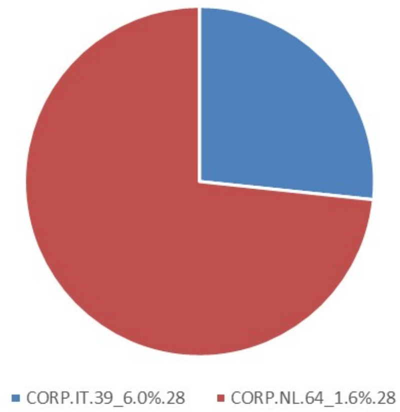

Figure 3: Weights of Cash Flow Matching Portfolio

The bond CORP.NL.64_1.6%.28 constitutes 73.35% of the portfolio and the bond CORP.IT.39_6.0%.28, 26.65%, as is detailed in Figure 3. Despite the coupon of the bond CORP.NL.64_1.6%.28 not be one of the highest and its lower than the average, its price is the lowest of all bonds. The CORP.IT.39_6.0%.28 bond has a price lower than the average and the coupon is the second highest coupon of the portfolio.

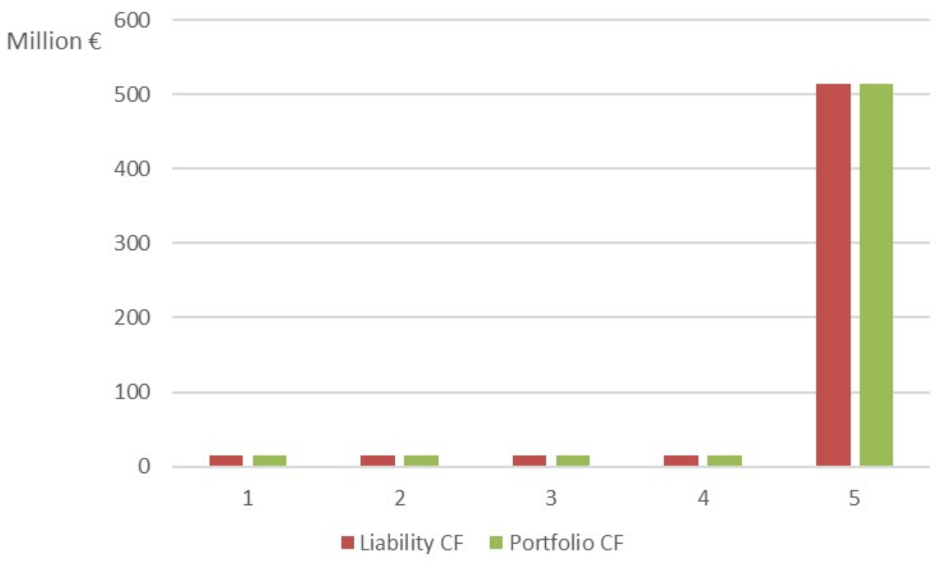

Figure 4: Liability and Portfolio Cash Flows

Figure 4 shows the portfolio cash flows indeed cover the liability cash flows in all periods.

In the following sections we present applications for that amount using MVT and Safety-first criteria.

Since we use only 435 million euros of the MREL issuance, there is sixty-five million euros left to invest freely.

4.2 MVT Results

Under the Mean Variance Theory (MVT), we work on a hypothetical optimal portfolio that would catalyse our unused sixty-five million euros. To go further in the MVT, we have extracted from Bloomberg the last 5 years before MREL issuance, daily adjusted close prices, adjusted for splits and dividend and/or capital gain distributions of our portfolio of twenty-five bonds. The number of observations (n) is equal to 1269.

Then, we calculated the annualized daily average returns and standard deviation of each instrument, plus all covariances.

To compute the expected returns, we first derived the relative daily price variation of each bond and averaged these variations over the five-year period. This average was multiplied by 252 (the number of trading days in a year) to annualize the return.

For the standard deviation, we utilized Excel's "STDEV.S" function on the sample of daily returns, and similarly, multiplied the result by the square root of 252 to obtain the annualized standard deviation. For the variances, we squared the standard deviations for each bond.

The Table 5 summarizes the annualized average returns and standard deviations for the assets in our portfolio.

Table 5: Annualized Average Returns, Standard Deviations and Variances

Bond ISIN	Annualized Average Returns	Standard Deviation	Variance
CORP.BE.10_5.5%.28	5.6519%	4.836%	0.00234
CORP.DE.26_1.7%.28	1.9575%	7.099%	0.00504
CORP.DE.C1_2.1%.28	2.5417%	13.876%	0.01925
CORP.DE.D9_2.2%.28	2.6176%	14.744%	0.02174
CORP.DE.D7_2.1%.28	2.4754%	14.548%	0.02117
CORP.DE.E5_2.1%.28	2.4950%	15.036%	0.02261
CORP.DE.67_1.5%.28	2.3060%	15.324%	0.02348
CORP.DE.Q0_1.0%.28	3.1194%	14.796%	0.02189
CORP.DE.W5_2.2%.28	1.1523%	13.613%	0.01853
CORP.DE.Q2_2.5%.28	2.4591%	14.448%	0.02088
CORP.DE.50_1.8%.28	3.2566%	15.516%	0.02407
CORP.FR.40_3.3%.28	5.0677%	7.092%	0.00503
SOVE.GR.88_3.7%.28	5.9597%	8.322%	0.00693
CORP.IT.39_6.0%.28	6.1548%	17.482%	0.03056
SOVE.IT.34_1.3%.28	2.5090%	8.702%	0.00757
SOVE.IT.32_2.0%.28	2.4127%	7.605%	0.00578
SOVE.RS.05_3.5%.28	4.2236%	4.904%	0.00241
SOVE.GR.30_6.1%.28	6.7495%	9.286%	0.00862
SOVE.IT.79_1.5%.28	4.3116%	21.165%	0.04480
SOVE.IT.44_1.8%.28	2.6504%	6.099%	0.00372
SOVE.IT.82_1.6%.28	2.4261%	6.199%	0.00384
CORP.NL.64_1.6%.28	5.5333%	14.916%	0.02225
CORP.ES.21_2.1%.28	2.9995%	7.189%	0.00517
CORP.IT.03_3.8%.28	8.0362%	6.169%	0.00381
CORP.IT.88_5.7%.28	6.1964%	5.261%	0.00277

For a better analysis of the expected returns and standard deviations, we go further with descriptive statistics, in Table 6.

Table 6: Expected Returns and Standard Deviations' Descriptive Statistics

	Expected Returns	Standard deviation
Mean	3.81%	10.97%
Median	3.00%	9.29%
Range	6.88%	16.33%
Minimum	1.15%	4.84%
Maximum	8.04%	21.17%
Sum	95.26%	274.22%
Count	25	25

Next, we derived the Correlation matrix and the Variance Covariance matrix for the portfolio. Using Excel's data analysis tools, we computed the correlation and covariance of the daily price returns between the bonds.

Table 7 shows the correlation matrix.

Table 7: Correlation Matrix

	CORP.IT.88_5.7%.28	SOVE.IT.34_1.3%.28	SOVE.IT.32_2.0%.28	SOVE.GR.30_6.1%.28	CORP.ES.21_2.1%.28	CORP.IT.03_3.8%.28	CORP.FR.40_3.3%.28	CORP.BE.10_5.5%.28	CORP.DE.26_1.7%.28	SOVE.IT.44_1.8%.28	CORP.IT.39_6.0%.28	SOVE.IT.82_1.6%.28	SOVE.GR.88_3.7%.28	SOVE.RS.05_3.5%.28	CORP.DE.50_1.8%.28	SOVE.IT.79_1.5%.28	CORP.DE.Q2_2.5%.28	CORP.DE.W5_2.2%.28	CORP.DE.D9_2.2%.28	CORP.DE.C1_2.1%.28	CORP.DE.D7_2.1%.28	CORP.DE.E5_2.1%.28	CORP.DE.67_1.5%.28	CORP.DE.Q0_1.0%.28	CORP.NL.64_1.6%.28
CORP.IT.88_5.7%.28	1	0.30869	0.26833	0.27194	0.37913	0.52733	0.46288	0.2332	0.32159	0.2056	-0.00001	0.19106	0.32334	0.05401	0.0315	0.14603	0.03408	0.03731	0.03448	0.03628	0.03461	0.03311	0.03304	0.0347	0.38935
SOVE.IT.34_1.3%.28	0.30869	1	0.90654	0.60188	0.50919	0.4656	0.51462	0.27984	0.432	0.58329	0.01417	0.53237	0.69387	0.20743	0.1034	0.34622	0.10753	0.11196	0.1068	0.11122	0.10807	0.10582	0.10603	0.10811	0.31941
SOVE.IT.32_2.0%.28	0.26833	0.90654	1	0.60495	0.51244	0.37432	0.5208	0.30125	0.43788	0.64904	0.01958	0.6076	0.71067	0.24927	0.13242	0.29516	0.13698	0.14149	0.13617	0.14072	0.13771	0.13538	0.13512	0.13764	0.25087
SOVE.GR.30_6.1%.28	0.27194	0.60188	0.60495	1	0.43137	0.41752	0.40063	0.23162	0.3544	0.38983	0.03384	0.39148	0.80529	0.17025	0.04785	0.17026	0.05148	0.05518	0.05079	0.05496	0.05177	0.04994	0.04947	0.05359	0.23805
CORP.ES.21_2.1%.28	0.37913	0.50919	0.51244	0.43137	1	0.67933	0.89448	0.33734	0.88343	0.54908	0.05105	0.51007	0.46239	0.22709	0.1962	0.2043	0.20147	0.20683	0.20056	0.20539	0.20176	0.19876	0.19843	0.2022	0.42091
CORP.IT.03_3.8%.28	0.52733	0.4656	0.37432	0.41752	0.67933	1	0.69106	0.26547	0.60451	0.3924	0.02002	0.33369	0.50247	0.0815	0.05507	0.17403	0.05797	0.06155	0.05733	0.06036	0.05812	0.05574	0.05634	0.05911	0.51578
CORP.FR.40_3.3%.28	0.46288	0.51462	0.5208	0.40063	0.89448	0.69106	1	0.33162	0.8337	0.55823	0.06421	0.52606	0.46064	0.23528	0.18346	0.22097	0.18934	0.19596	0.18823	0.19425	0.18994	0.18646	0.18604	0.19067	0.41499
CORP.BE.10_5.5%.28	0.2332	0.27984	0.30125	0.23162	0.33734	0.26547	0.33162	1	0.3143	0.20273	0.0303	0.23144	0.24772	0.13934	0.07945	0.1471	0.08151	0.08382	0.08137	0.08226	0.08198	0.08127	0.07932	0.0805	0.17102
CORP.DE.26_1.7%.28	0.32159	0.432	0.43788	0.3544	0.88343	0.60451	0.8337	0.3143	1	0.46772	0.05165	0.42593	0.37804	0.19659	0.1863	0.17769	0.19133	0.19656	0.19049	0.19522	0.1918	0.18891	0.18798	0.19133	0.31658
SOVE.IT.44_1.8%.28	0.2056	0.58329	0.64904	0.38983	0.54908	0.3924	0.55823	0.20273	0.46772	1	0.03317	0.87911	0.46127	0.21503	0.14861	0.23197	0.15342	0.15665	0.15224	0.15553	0.15334	0.15118	0.15097	0.15352	0.22325
CORP.IT.39_6.0%.28	-0.00001	0.01417	0.01958	0.03384	0.05105	0.02002	0.06421	0.0303	0.05165	0.03317	1	0.04029	0.03599	0.02084	0.00088	0.01008	0.00143	-0.00007	0.00139	0.00133	-0.00069	-0.00012	-0.00745	0.00111	0.02551
SOVE.IT.82_1.6%.28	0.19106	0.53237	0.6076	0.39148	0.51007	0.33369	0.52606	0.23144	0.42593	0.87911	0.04029	1	0.44253	0.20756	0.15675	0.20377	0.16037	0.16393	0.15954	0.16301	0.16061	0.15865	0.15875	0.16112	0.17106
SOVE.GR.88_3.7%.28	0.32334	0.69387	0.71067	0.80529	0.46239	0.50247	0.46064	0.24772	0.37804	0.46127	0.03599	0.44253	1	0.18	0.07212	0.18555	0.07594	0.07875	0.07505	0.07869	0.07564	0.07424	0.07333	0.07745	0.26828
SOVE.RS.05_3.5%.28	0.05401	0.20743	0.24927	0.17025	0.22709	0.0815	0.23528	0.13934	0.19659	0.21503	0.02084	0.20756	0.18	1	0.07487	0.10077	0.07582	0.07713	0.0751	0.07745	0.07605	0.07462	0.07263	0.0766	0.09756
CORP.DE.50_1.8%.28	0.0315	0.1034	0.13242	0.04785	0.1962	0.05507	0.18346	0.07945	0.1863	0.14861	0.00088	0.15675	0.07212	0.07487	1	0.02692	0.99868	0.99586	0.99912	0.99673	0.99868	0.99928	0.99875	0.99805	0.08353
SOVE.IT.79_1.5%.28	0.14603	0.34622	0.29516	0.17026	0.2043	0.17403	0.22097	0.1471	0.17769	0.23197	0.01008	0.20377	0.18555	0.10077	0.02692	1	0.02861	0.02881	0.02733	0.02911	0.02816	0.02686	0.02664	0.02835	0.10469
CORP.DE.Q2_2.5%.28	0.03408	0.10753	0.13698	0.05148	0.20147	0.05797	0.18934	0.08151	0.19133	0.15342	0.00143	0.16037	0.07594	0.07582	0.99868	0.02861	1	0.99858	0.99971	0.99899	0.99973	0.99949	0.99876	0.99914	0.08384
CORP.DE.W5_2.2%.28	0.03731	0.11196	0.14149	0.05518	0.20683	0.06155	0.19596	0.08382	0.19656	0.15665	-0.00007	0.16393	0.07875	0.07713	0.99586	0.02881	0.99858	1	0.99813	0.99957	0.99877	0.99752	0.99698	0.99869	0.08498
CORP.DE.D9_2.2%.28	0.03448	0.1068	0.13617	0.05079	0.20056	0.05733	0.18823	0.08137	0.19049	0.15224	0.00139	0.15954	0.07505	0.0751	0.99912	0.02733	0.99971	0.99813	1	0.9987	0.99975	0.99975	0.99907	0.99915	0.08458
CORP.DE.C1_2.1%.28	0.03628	0.11122	0.14072	0.05496	0.20539	0.06036	0.19425	0.08226	0.19522	0.15553	0.00133	0.16301	0.07869	0.07745	0.99673	0.02911	0.99899	0.99957	0.9987	1	0.99911	0.99809	0.99741	0.99911	0.08561
CORP.DE.D7_2.1%.28	0.03461	0.10807	0.13771	0.05177	0.20176	0.05812	0.18994	0.08198	0.1918	0.15334	-0.00069	0.16061	0.07564	0.07605	0.99868	0.02816	0.99973	0.99877	0.99975	0.99911	1	0.99957	0.99906	0.99931	0.08446
CORP.DE.E5_2.1%.28	0.03311	0.10582	0.13538	0.04994	0.19876	0.05574	0.18646	0.08127	0.18891	0.15118	-0.00012	0.15865	0.07424	0.07462	0.99928	0.02686	0.99949	0.99752	0.99975	0.99809	0.99957	1	0.99935	0.99883	0.08342
CORP.DE.67_1.5%.28	0.03304	0.10603	0.13512	0.04947	0.19843	0.05634	0.18604	0.07932	0.18798	0.15097	-0.00745	0.15875	0.07333	0.07263	0.99875	0.02664	0.99876	0.99698	0.99907	0.99741	0.99906	0.99935	1	0.99844	0.08327
CORP.DE.Q0_1.0%.28	0.0347	0.10811	0.13764	0.05359	0.2022	0.05911	0.19067	0.0805	0.19133	0.15352	0.00111	0.16112	0.07745	0.0766	0.99805	0.02835	0.99914	0.99869	0.99915	0.99911	0.99931	0.99883	0.99844	1	0.08547
CORP.NL.64_1.6%.28	0.38935	0.31941	0.25087	0.23805	0.42091	0.51578	0.41499	0.17102	0.31658	0.22325	0.02551	0.17106	0.26828	0.09756	0.08353	0.10469	0.08384	0.08498	0.08458	0.08561	0.08446	0.08342	0.08327	0.08547	1

Notice that a correlation matrix is perfectly symmetrical. For example, the top right cell shows the exact same value as the bottom left cell. This is because both cells are measuring the correlation between the same bonds. Also notice that the correlation coefficients along the diagonal of the table are all equal to 1 because each variable is perfectly correlated with itself. These cells are not useful for interpretation. The correlation matrix above shows the correlation coefficients between several variables.

A relevant example is the high and positive correlation of the bonds issued by the *Norddeutsche Landesbank-Girozentrale*:

- CORP.DE.50_1.8%.28
- CORP.DE.Q2_2.5%.28
- CORP.DE.W5_2.2%.28
- CORP.DE.D9_2.2%.28
- CORP.DE.C1_2.1%.28
- CORP.DE.D7_2.1%.28
- CORP.DE.E5_2.1%.28
- CORP.DE.67_1.5%.28

- CORP.DE.Q0_1.0%.28

No bond is strongly or even weakly negatively correlated, and we can notice that the bond CORP.IT.39_6.0%.28 has extraordinarily little association with any other bond which indicates that they are not correlated.

To make the covariance results comparable on an annual basis, we multiplied each element of the matrix by 252 and by n/(n-1), where n is the number of observations, yielding a scaling factor of 1.0008. To validate the accuracy of the covariance matrix, we verified that the diagonal elements, representing the variances of each asset, matched the calculated variances from the individual asset's data.

Table 8 shows the Variance Covariance Matrix.

Table 8: Variance Covariance Matrix

	CORP.IT.88_5.7%.28	SOVE.IT.34_1.3%.28	SOVE.IT.32_2.0%.28	SOVE.GR.30_6.1%.28	CORP.ES.21_2.1%.28	CORP.IT.03_3.8%.28	CORP.FR.40_3.3%.28	CORP.BE.10_5.5%.28	CORP.DE.26_1.7%.28	SOVE.IT.44_1.8%.28	CORP.IT.39_6.0%.28	SOVE.IT.82_1.6%.28	SOVE.GR.88_3.7%.28	SOVE.RS.05_3.5%.28	CORP.DE.50_1.8%.28	SOVE.IT.79_1.5%.28	CORP.DE.Q2_2.5%.28	CORP.DE.W5_2.2%.28	CORP.DE.D9_2.2%.28	CORP.DE.C1_2.1%.28	CORP.DE.D7_2.1%.28	CORP.DE.E5_2.1%.28	CORP.DE.67_1.5%.28	CORP.DE.Q0_1.0%.28	CORP.NL.64_1.6%.28
CORP.IT.88_5.7%.28	0.0027678	0.0014132	0.0010736	0.0013285	0.001434	0.0017114	0.001727	0.0005933	0.001201	0.0006597	-0.0000001	0.0006231	0.0014157	0.0001394	0.0002572	0.001626	0.000259	0.0002672	0.0002674	0.0002648	0.0002649	0.0002619	0.0002664	0.0002701	0.0030552
SOVE.IT.34_1.3%.28	0.0014132	0.0075718	0.0059988	0.0048634	0.0031855	0.0024992	0.0031757	0.0011776	0.0026685	0.0030954	0.0002156	0.0028716	0.0050248	0.0008852	0.001396	0.0063763	0.0013519	0.0013262	0.0013702	0.0013428	0.0013681	0.0013845	0.0014138	0.0013919	0.0041456
SOVE.IT.32_2.0%.28	0.0010736	0.0059988	0.0057831	0.0042719	0.0028017	0.001756	0.0028087	0.0011079	0.0023638	0.0030101	0.0002604	0.0028643	0.0044977	0.0009296	0.0015624	0.0047506	0.0015051	0.0014646	0.0015268	0.0014849	0.0015236	0.0015479	0.0015745	0.0015487	0.0028456
SOVE.GR.30_6.1%.28	0.0013285	0.0048634	0.0042719	0.0086229	0.0028798	0.0023917	0.0026383	0.0010402	0.0023362	0.0022077	0.0005494	0.0022535	0.0062233	0.0007753	0.0006894	0.0033462	0.0006907	0.0006975	0.0006954	0.0007082	0.0006994	0.0006972	0.0007039	0.0007363	0.0032971
CORP.ES.21_2.1%.28	0.001434	0.0031855	0.0028017	0.0028798	0.0051688	0.0030128	0.0045605	0.0011729	0.0045087	0.0024075	0.0006417	0.0022732	0.0027666	0.0008007	0.0021886	0.0031088	0.0020928	0.0020242	0.0021261	0.002049	0.0021103	0.0021485	0.0021862	0.0021508	0.0045137
CORP.IT.03_3.8%.28	0.0017114	0.0024992	0.001756	0.0023917	0.0030128	0.0038053	0.0030232	0.000792	0.0026472	0.0014763	0.0002159	0.001276	0.0025796	0.0002466	0.0005271	0.0022722	0.0005167	0.0005169	0.0005214	0.0005166	0.0005216	0.000517	0.0005326	0.0005395	0.0047458
CORP.FR.40_3.3%.28	0.001727	0.0031757	0.0028087	0.0026383	0.0045605	0.0030232	0.0050292	0.0011373	0.004197	0.0024143	0.000796	0.0023126	0.0027186	0.0008183	0.0020187	0.0033166	0.0019401	0.0018917	0.0019681	0.0019114	0.0019597	0.0019882	0.0020217	0.0020006	0.0043896
CORP.BE.10_5.5%.28	0.0005933	0.0011776	0.0011079	0.0010402	0.0011729	0.000792	0.0011373	0.0023389	0.001079	0.0005979	0.0002562	0.0006939	0.000997	0.0003305	0.0005962	0.0015057	0.0005696	0.0005518	0.0005802	0.000552	0.0005768	0.0005909	0.0005879	0.000576	0.0012337
CORP.DE.26_1.7%.28	0.001201	0.0026685	0.0023638	0.0023362	0.0045087	0.0026472	0.004197	0.001079	0.0050392	0.0020249	0.000641	0.0018743	0.0022334	0.0006844	0.0020519	0.0026697	0.0019624	0.0018994	0.0019937	0.0019229	0.0019808	0.0020163	0.0020448	0.0020095	0.0033521
SOVE.IT.44_1.8%.28	0.0006597	0.0030954	0.0030101	0.0022077	0.0024075	0.0014763	0.0024143	0.0005979	0.0020249	0.0037194	0.0003537	0.0033235	0.0023412	0.0006431	0.0014062	0.0029943	0.0013519	0.0013005	0.001369	0.0013161	0.0013605	0.0013863	0.0014109	0.0013852	0.0020308
CORP.IT.39_6.0%.28	-0.0000001	0.0002156	0.0002604	0.0005494	0.0006417	0.0002159	0.000796	0.0002562	0.000641	0.0003537	0.0305631	0.0004366	0.0005236	0.0001787	0.000024	0.0003731	0.0000362	-0.0000017	0.000036	0.0000322	-0.0000175	-0.0000033	-0.0001996	0.0000287	0.0006653
SOVE.IT.82_1.6%.28	0.0006231	0.0028716	0.0028643	0.0022535	0.0022732	0.001276	0.0023126	0.0006939	0.0018743	0.0033235	0.0004366	0.0038427	0.002283	0.000631	0.0015076	0.0026735	0.0014363	0.0013833	0.0014582	0.0014021	0.0014484	0.0014787	0.001508	0.0014777	0.0015817
SOVE.GR.88_3.7%.28	0.0014157	0.0050248	0.0044977	0.0062233	0.0027666	0.0025796	0.0027186	0.000997	0.0022334	0.0023412	0.0005236	0.002283	0.006926	0.0007347	0.0009312	0.0032683	0.0009131	0.0008921	0.0009209	0.0009087	0.0009158	0.000929	0.0009352	0.0009537	0.0033302
SOVE.RS.05_3.5%.28	0.0001394	0.0008852	0.0009296	0.0007753	0.0008007	0.0002466	0.0008183	0.0003305	0.0006844	0.0006431	0.0001787	0.000631	0.0007347	0.0024052	0.0005697	0.001046	0.0005373	0.0005149	0.0005431	0.000527	0.0005426	0.0005502	0.0005458	0.0005558	0.0007136
CORP.DE.50_1.8%.28	0.0002572	0.001396	0.0015624	0.0006894	0.0021886	0.0005271	0.0020187	0.0005962	0.0020519	0.0014062	0.000024	0.0015076	0.0009312	0.0005697	0.0240733	0.000884	0.0223879	0.0210331	0.0228565	0.0214583	0.0225428	0.0233117	0.0237461	0.0229114	0.001933
SOVE.IT.79_1.5%.28	0.001626	0.0063763	0.0047506	0.0033462	0.0031088	0.0022722	0.0033166	0.0015057	0.0026697	0.0029943	0.0003731	0.0026735	0.0032683	0.001046	0.000884	0.0447959	0.0008749	0.0008301	0.0008528	0.000855	0.000867	0.0008549	0.000864	0.0008878	0.0033048
CORP.DE.Q2_2.5%.28	0.000259	0.0013519	0.0015051	0.0006907	0.0020928	0.0005167	0.0019401	0.0005696	0.0019624	0.0013519	0.0000362	0.0014363	0.0009131	0.0005373	0.0223879	0.0008749	0.0208755	0.01964	0.0212968	0.0200276	0.0210143	0.0217129	0.0221131	0.0213587	0.0018067
CORP.DE.W5_2.2%.28	0.0002672	0.0013262	0.0014646	0.0006975	0.0020242	0.0005169	0.0018917	0.0005518	0.0018994	0.0013005	-0.0000017	0.0013833	0.0008921	0.0005149	0.0210331	0.0008301	0.01964	0.0185301	0.0200331	0.01888	0.0197796	0.0204165	0.0207967	0.0201142	0.0017254
CORP.DE.D9_2.2%.28	0.0002674	0.0013702	0.0015268	0.0006954	0.0021261	0.0005214	0.0019681	0.0005802	0.0019937	0.001369	0.000036	0.0014582	0.0009209	0.0005431	0.0228565	0.0008528	0.0212968	0.0200331	0.0217393	0.0204318	0.021445	0.0221632	0.0225729	0.0217965	0.00186
CORP.DE.C1_2.1%.28	0.0002648	0.0013428	0.0014849	0.0007082	0.002049	0.0005166	0.0019114	0.000552	0.0019229	0.0013161	0.0000322	0.0014021	0.0009087	0.000527	0.0214583	0.000855	0.0200276	0.01888	0.0204318	0.019253	0.0201685	0.0208229	0.0212076	0.0205115	0.0017718
CORP.DE.D7_2.1%.28	0.0002649	0.0013681	0.0015236	0.0006994	0.0021103	0.0005216	0.0019597	0.0005768	0.0019808	0.0013605	-0.0000175	0.0014484	0.0009158	0.0005426	0.0225428	0.000867	0.0210143	0.0197796	0.021445	0.0201685	0.0211654	0.0218648	0.0222728	0.0215102	0.0018327
CORP.DE.E5_2.1%.28	0.0002619	0.0013845	0.0015479	0.0006972	0.0021485	0.000517	0.0019882	0.0005909	0.0020163	0.0013863	-0.0000033	0.0014787	0.000929	0.0005502	0.0233117	0.0008549	0.0217129	0.0204165	0.0221632	0.0208229	0.0218648	0.0226068	0.0230253	0.0222199	0.0018709
CORP.DE.67_1.5%.28	0.0002664	0.0014138	0.0015745	0.0007039	0.0021862	0.0005326	0.0020217	0.0005879	0.0020448	0.0014109	-0.0001996	0.001508	0.0009352	0.0005458	0.0237461	0.000864	0.0221131	0.0207967	0.0225729	0.0212076	0.0222728	0.0230253	0.0234823	0.0226373	0.0019032
CORP.DE.Q0_1.0%.28	0.0002701	0.0013919	0.0015487	0.0007363	0.0021508	0.0005395	0.0020006	0.000576	0.0020095	0.0013852	0.0000287	0.0014777	0.0009537	0.0005558	0.0229114	0.0008878	0.0213587	0.0201142	0.0217965	0.0205115	0.0215102	0.0222199	0.0226373	0.0218909	0.0018862
CORP.NL.64_1.6%.28	0.0030552	0.0041456	0.0028456	0.0032971	0.0045137	0.0047458	0.0043896	0.0012337	0.0033521	0.0020308	0.0006653	0.0015817	0.0033302	0.0007136	0.001933	0.0033048	0.0018067	0.0017254	0.00186	0.0017718	0.0018327	0.0018709	0.0019032	0.0018862	0.0222477

4.2.1 Tangent Portfolio Results

Following the equations 6-9 of the chapter 3.2.1, we consider a risk-free asset exists which is represented by the Euro area daily yield for 5-year maturities, limited to AAA-rated bonds, as of 28 February 2022: our issuance date. The yield for the 5-year AAA-rated bonds on this date was -0.112991%. This specific yield was chosen because it provides the most accurate reflection of the risk-free rate available at the time the MREL-compliant debt was issued, ensuring consistency with the market conditions faced by the bank at that time.

To compute the Tangent portfolio, we want the maximum Sharpe Ratio (SR) possible. So, we used Solver in Excel to maximise SR, by changing the weight cells making them non-negative, while the sum of the weights is equal to 1. The expected return and standard deviation of our Tangent portfolio is 5.933% and 3.324%, respectively. The portfolio's SR is 1.819. Comparing this portfolio with the statistics in Table 6, we can see that the expected return is higher than the mean and the standard deviation is lower than the minimum value of an individual bond.

The composition of the tangent portfolio is in Figure 5.

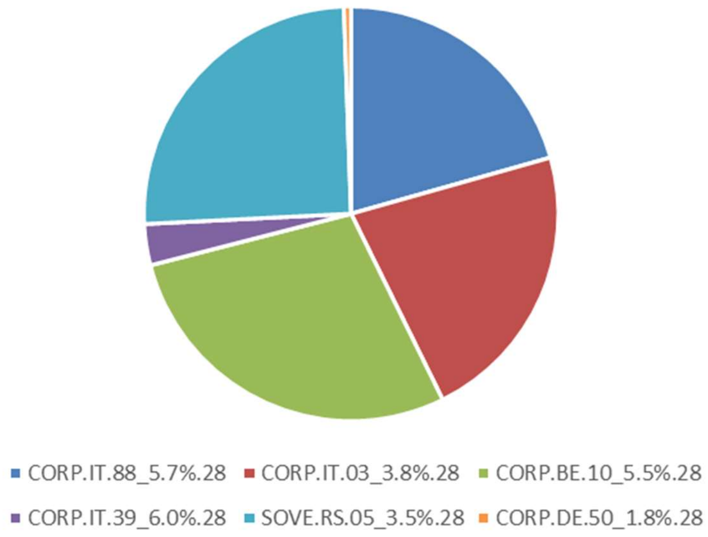

Figure 5: Weights of Tangent Portfolio

This portfolio is constituted by six bonds of which:

- CORP.BE.10_5.5%.28 with 28.29%
- CORP.DE.50_1.8%.28 with 0.55%
- CORP.IT.39_6.0%.28 with 3.21%
- SOVE.RS.05_3.5%.28 with 25.24%
- CORP.IT.03_3.8%.28 with 22.09%
- CORP.IT.88_5.7%.28 with 20.62%.

Analysing Table 5 and 6, we can state that all bonds have expected returns higher than 3%, the median value.

4.2.2 Minimum Variance Portfolio

The only difference in our steps to discover the Tangent portfolio and the MVP is that instead of maximising the Sharpe Ratio, we minimise the standard deviation, all else equal. The MVP expected return is equal to 4.993% and the standard deviation is 3.119%.

The composition of the MVP portfolio is in Figure 6.

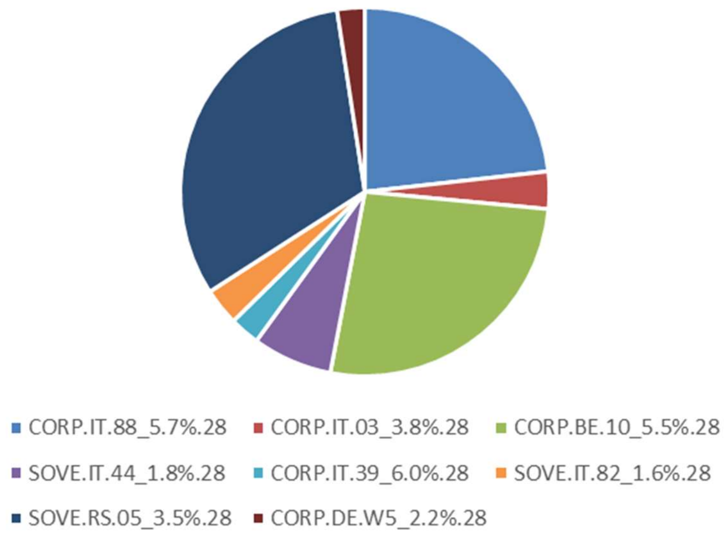

Figure 6: Weights of Minimum Variance Portfolio

The MVP portfolio is constituted by eight bonds of which:

- CORP.BE.10_5.5%.28 at 26.51%
- CORP.DE.W5_2.2%.28 at 2.42%
- CORP.IT.39_6.0%.28 at 2.63%
- SOVE.RS.05_3.5%.28 at 31.69%
- SOVE.IT.44_1.8%.28 at 7.00%
- SOVE.IT.82_1.6%.28 at 3.25%
- CORP.IT.03_3.8%.28 at 3.27%
- CORP.IT.88_5.7%.28 at 23.23%.

Being more diversified reduces the standard deviation, but the expected return also decreases. The SR is 1.637 which is, as expected, lower than the tangent portfolio.

4.2.3 Efficient Frontier

Since our EF starts in the MVP, we will set the standard deviation to values higher than 3.119% ending with the volatility of the highest expected return bond.

For the range of volatilities considered, Table 9 reports the efficient portfolios composition.

Table 9: Weights of Portfolios across Efficient Frontier

Bond	$\sigma = \sigma^{MVP}$	$\sigma = \sigma^{T}$	σ = 3.5%	σ = 4%	σ = 4.5%	σ = 5%	σ = 6%	σ = 6.17%
CORP.BE.10_5.5%.28	26.51%	28.28%	27.88%	26.57%	26.61%	18.38%	0.00%	0.00%
CORP.DE.50_1.8%.28	0.00%	0.55%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CORP.DE.67_1.5%.28	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
CORP.DE.W5_2.2%.28	2.42%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
CORP.IT.03_3.8%.28	3.27%	22.09%	29.77%	45.06%	53.29%	72.47%	96.59%	100.00%
CORP.IT.39_6.0%.28	2.63%	3.21%	3.41%	3.82%	4.21%	4.08%	3.41%	0.00%
CORP.IT.88_5.7%.28	23.23%	20.62%	18.88%	15.34%	13.57%	5.04%	0.00%	0.00%
CORP.NL.64_1.6%.28	0.00%	0.00%	0.00%	0.00%	1.80%	0.01%	0.00%	0.00%
SOVE.GR.30_6.1%.28	0.00%	0.00%	0.00%	0.10%	0.46%	0.00%	0.00%	0.00%
SOVE.IT.44_1.8%.28	7.00%	0.00%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%
SOVE.IT.79_1.5%.28	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
SOVE.IT.82_1.6%.28	3.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SOVE.RS.05_3.5%.28	31.69%	25.24%	20.06%	9.06%	0.06%	0.00%	0.00%	0.00%

The minimum variance portfolio is the most diversified holding more stable or less risky assets. As we move towards higher SD, the composition shifts toward bonds with higher expected returns but greater risk. The efficient frontier stops with 100% investment in the bond with the highest expected return.

In Figure 7 we have the mean-variance representation of all the basic assets, as well as the MVT portfolios and the Efficient Frontier. Naturally, all the assets are inside the efficient frontier, except the highest expected return asset, so investing in only one asset would clearly not be efficient. We also notice there are two bond clusters and only bonds on lower volatilities cluster belong to the efficient frontier.

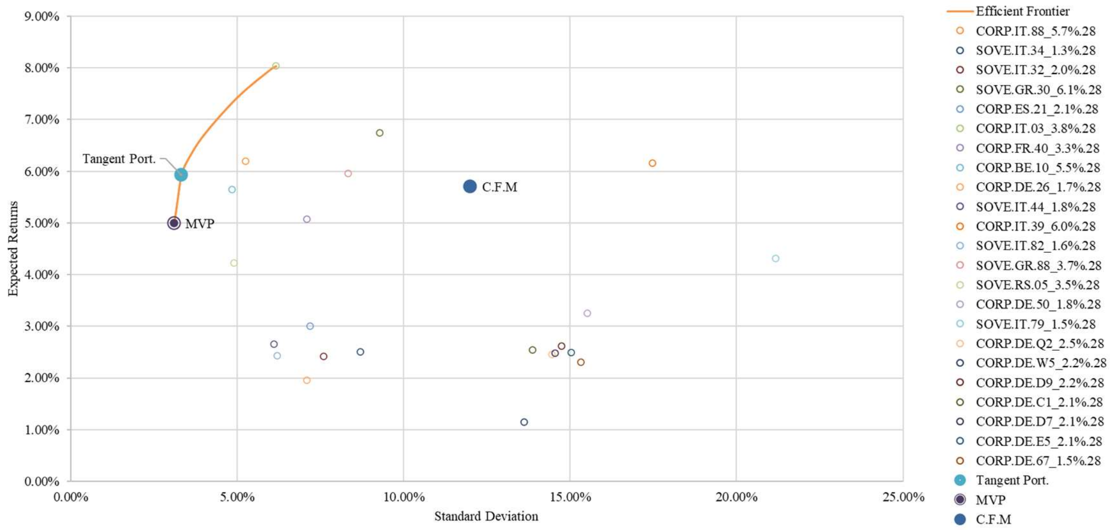

Figure 7: Efficient Frontier with selected Bonds and Tangent and MV portfolio

4.2.4 Safety Criteria

Following the equation 12 and 13 of the chapter 3.3.1 to find the Roy portfolio we assumed R_L= 0%. For that threshold, our Roy portfolio has an expected return of 5.94%, a standard deviation of 3.33%. Almost equal to the Tangent portfolio. The Sharpe Ratio is equal to 1.818.

The composition of the Roy portfolio is in Figure 8.

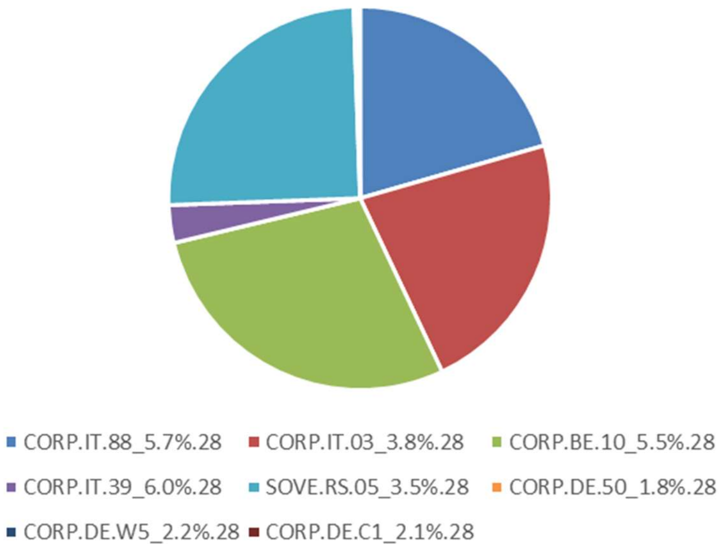

Figure 8: Weights of Roy Portfolio

The Roy portfolio is constituted by eight bonds of which:

- CORP.DE.C1_2.1%.28 with 0.07%
- CORP.BE.10_5.5%.28 with 28.27%
- CORP.DE.W5_2.2%.28 with 0.15%
- CORP.DE.50_1.8%.28 with 0.33%
- CORP.IT.39_6.0%.28 with 3.18%
- SOVE.RS.05_3.5%.28 with 25.03%
- CORP.IT.03_3.8%.28 with 22.41%
- CORP.IT.88_5.7%.28 with 20.56%.

The slope of our Roy equation is going to be the maximised value of: $\frac{\bar{R}_p - R_L}{\sigma_p}$.

The Roy Equation, in this case, is $\bar{R}_p = 1.784 \cdot \sigma_p$

Going to the Kataoka criteria, we follow equations 14 and 15 and we assume that α = -10% which, consequently, $z(\alpha$= -10%) = -1.28. For that level of alpha, the equation of the Kataoka portfolio is $\bar{R} = R_L + 1.28 \cdot \sigma_p$.

We found the efficient portfolio under the Kataoka criteria by maximising R_L. The results of the Kataoka portfolio were that R_L is equal to 1.71%, the expected return is 6.184% and the standard deviation is 3.492%. Then, the Kataoka equation is $\bar{R}_p = 1.71\% + 1.28 \cdot \sigma_p$. The Sharpe ratio is 1.803.

The composition of the Kataoka portfolio is in Figure 9. This is also the portfolio with the lowest value-at-risk when we consider a confidence level of 90% (1-α).

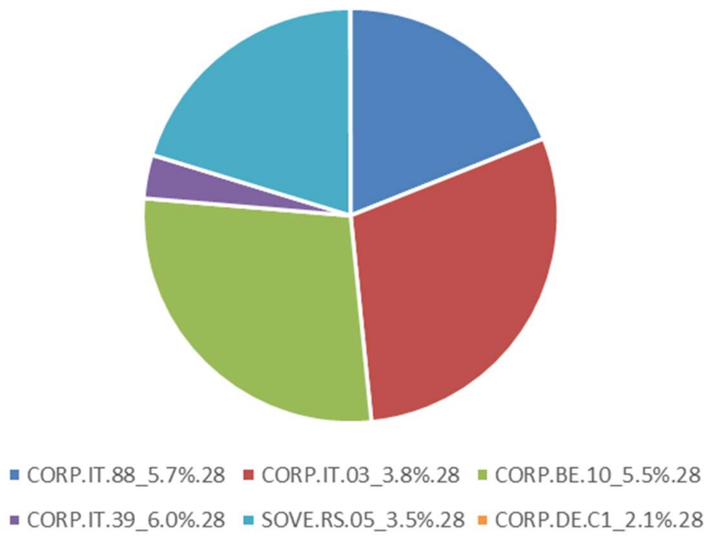

Figure 9: Weights of Kataoka Portfolio

The Kataoka portfolio is constituted by six bonds of which:

- CORP.BE.10_5.5%.28 with 27.93%
- CORP.DE.C1_2.1%.28 with 0.10%
- CORP.IT.39_6.0%.28 with 3.40%
- SOVE.RS.05_3.5%.28 with 20.24%
- CORP.IT.03_3.8%.28 with 29.38%
- CORP.IT.88_5.7%.28 with 18.95%.

Finally, under the Telser criteria, we follow equation 16 and we assume that our equation line is $\bar{R}_p = 1.28 \cdot \sigma$.

The Telser portfolio has expected return of 8.036% and standard deviation of 6.17%. The SR is 1.321.

The composition of the Telser portfolio is in Figure 10.

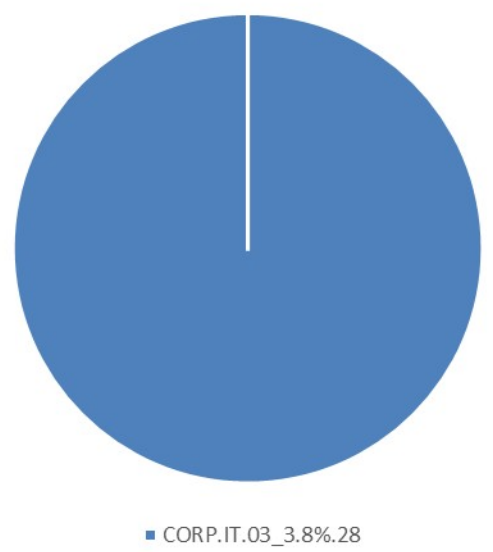

Figure 10: Weights of Telser Portfolio

The Telser portfolio is constituted by one bond which is CORP.IT.03_3.8%.28. This is the highest level of risk of our efficient frontier.

We can state that Kataoka portfolio has the same assets as Roy's Portfolio except for two additional bonds that Roy's has and only have slightly differences in the weights of them. Kataoka portfolio is riskier than Roy portfolio. Telser portfolio is riskier than both portfolios, using only one bond.

In Figure 11, we can see a graphical representation of the results of all MVT reported.

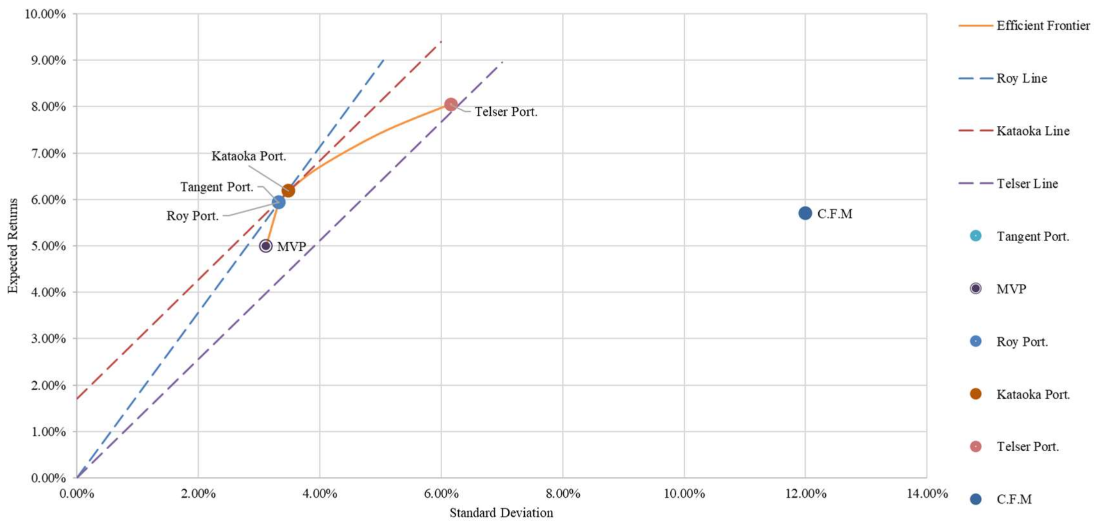

Figure 11: Mean-Variance Space with Safety-First Criteria

Analysing Figure 11 and all the results obtained, we can say that all the portfolios above the Telser line are safe under these criteria, and our tangent portfolio is also safe under Roy and Kataoka criteria. The cash flow matching portfolio clearly does not comply with any safety criteria. We can also observe that the Roy and the Tangent portfolio are so similar in terms of results that in the figure they are merged. They only have slight differences in the expected return, standard deviation, and different weight's assets as we can see above.

Analysing all MVT portfolios compositions we can note that some bonds are common to some portfolios. The bond CORP.IT.03_3.8%.28 is common to all portfolios. The CORP.IT.88_5.7%.28, CORP.IT.39_6.0%.28, CORP.BE.10_5.5%.28 and the SOVE.RS.05_3.5%.28 are common to all portfolios except the Telser portfolio.

4.3 The Proposed Portfolio

Going back to the beginning of this chapter, we said that we would spend 435 million euros with the cash flow matching portfolio, which leaves us with sixty-five million euros to invest. Table 10 summarizes the statistics on the obtained portfolios.

Table 10: Portfolios' Results

	$\bar{R}$	σ	Sharpe Ratio
Cash Flow M. Portfolio	5.699%	12.000%	0.484
M. V. Portfolio	4.933%	3.119%	1.637
Tangent Portfolio	5.933%	3.324%	1.819
Roy Portfolio	5.940%	3.330%	1.818
Kataoka Portfolio	6.184%	3.492%	1.803
Telser Portfolio	8.036%	6.169%	1.321

Regarding the sixty-five million we would advise to invest in the portfolio with highest Sharpe Ratio, i.e. the Tangent Portfolio.

We could expect a return of 5.933%. If we were to invest for the period of five years like our issuance and in the end of this period out of the sixty-five million invested assuming we would reinvest in the next period (t+1) the final amount of period t, we would have 87 million euros having a profit of 22 million euros in the end of the fifth year.

The final portfolio is thus a combination of the CF matching portfolio with the tangent portfolio.

Figure 12 shows the final portfolio composition.

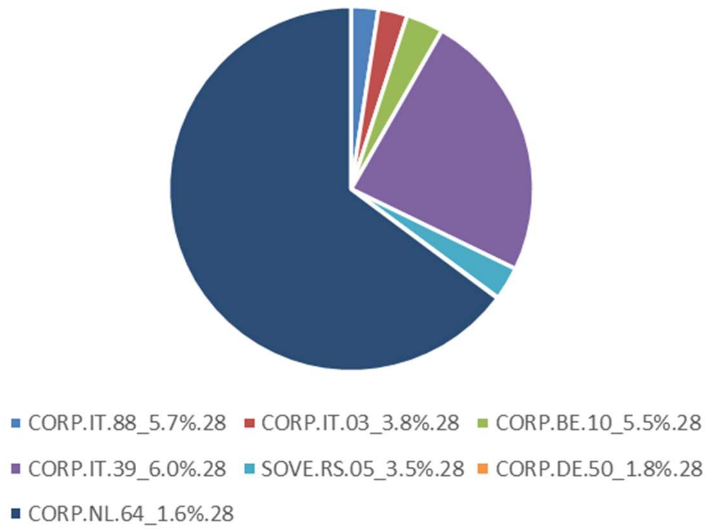

Figure 12: Weights of Final Portfolio

The portfolio is constituted by seven bonds of which:

- CORP.BE.10_5.5%.28 with 3.04%
- CORP.DE.50_1.8%.28 with 0.06%
- CORP.IT.39_6.0%.28 with 24.13%
- SOVE.RS.05_3.5%.28 with 2.71%
- CORP.NL.64_1.6%.28 with 65.46%
- CORP.IT.03_3.8%.28 with 2.38%
- CORP.IT.88_5.7%.28 with 2.22%.

This portfolio has an expected return of 5.723%, a volatility of 10.959% and a Sharpe Ratio of 0.533.

Given an investment date of 28.02.2022. Figure 13 presents the evolution of the daily realised returns of the proposed portfolio until the end of 2023.

From the graph we can see that the daily realised returns vary between -2.38% and 3.00%. The expected return (annualized) has been 4.40% with a volatility of 9.04%.

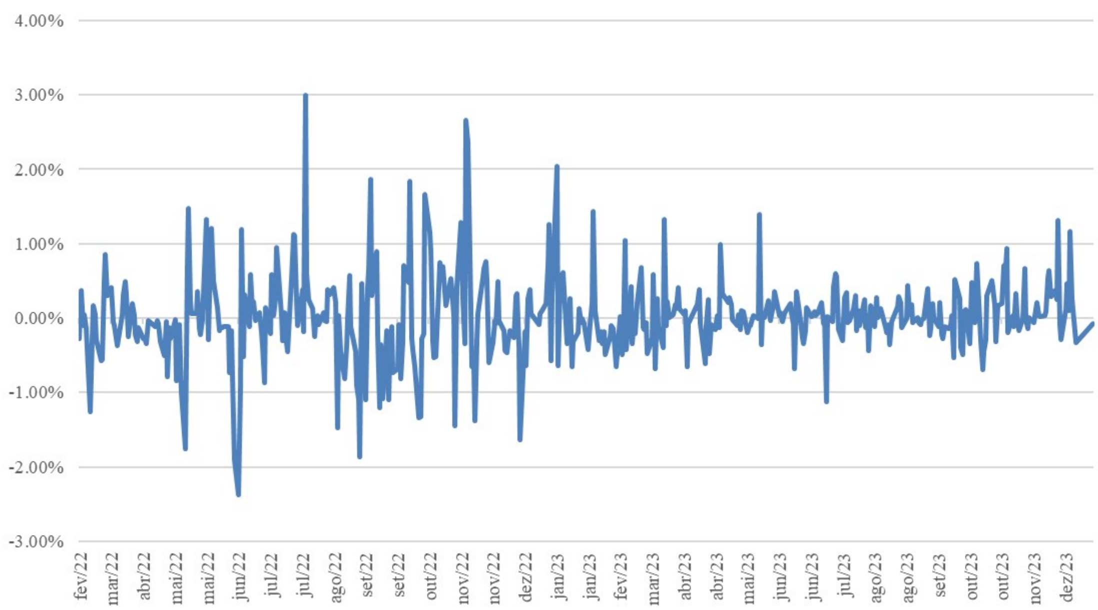

Figure 13: Daily Realised Returns

Also, the daily realised returns of the portfolio have the distribution presented in Figure 14.

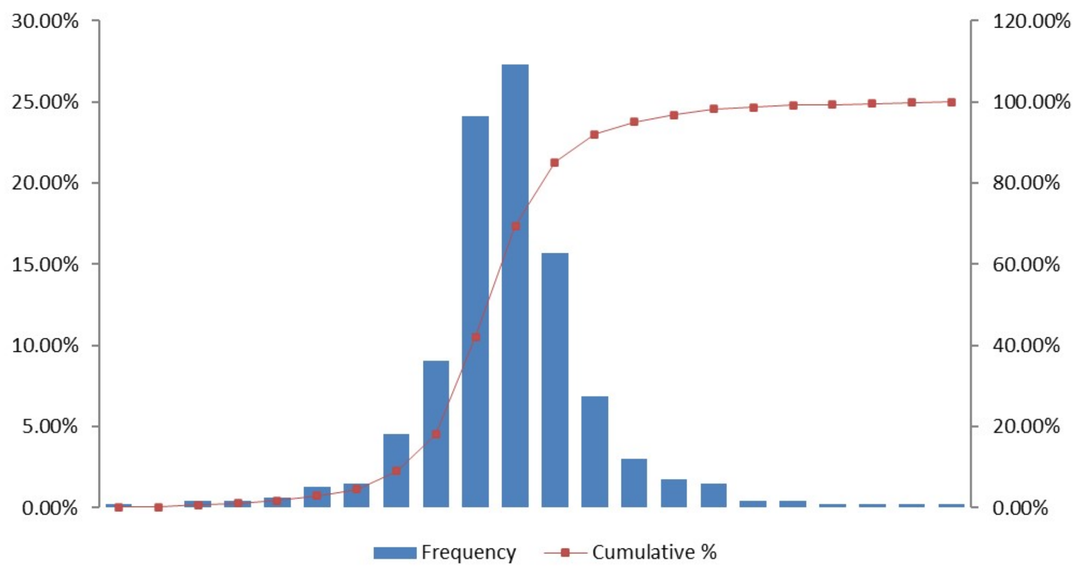

Figure 14: Portfolio's Distribution

In terms of return-at-risk the realised value for a level of 5% is of -0.80%. We can state that the worst 5% scenarios of this portfolio have negative returns which indicates periods where the portfolio underperformed whatsoever while daily returns provide insights, we should consider the long-term trends. A few bad days might not heavily impact long-term performances if the overall trend is positive.

5. Conclusion

This study aims at presenting the objectives and challenges associated with MREL. Its main goal is to ensure financial stability by mitigating the risk of bank failures and reducing reliance on public financial support. It also guarantees that shareholders and creditors, rather than public funds, bear the financial burden during a bank's resolution. This aligns with the broader regulatory aim of maintaining financial stability and protecting taxpayers. MREL requirements are tailored to the specific characteristics of each bank, considering factors such as size, business model, funding structure, and risk profile. EU resolution authorities set MREL targets following consultations with prudential supervisors. These targets must be met by banks by the end of any designated transitional period, which is bank specific.

However, compliance with MREL can have significant financial implications for banks. The introduction of MREL requirements can lead to reduced income and pressure on net interest margins, affecting banks' profitability and lending capacity.

Banks face several challenges in meeting MREL requirements, including the need to issue additional eligible liabilities and the potential lack of investor demand for these instruments. To address these challenges, banks can adopt investment strategies that utilize the proceeds from MREL issuances. By investing in a diversified portfolio with expected returns higher than the costs of debt issuance, banks can cover these costs and optimize their financial position.

In the empirical part of this dissertation, we consider a typical MREL issuance and propose ways to build investment portfolio to cover that issuance.

Through cash flow matching, we use a fixed-income securities portfolio to cover the liabilities while minimizing expenses. We ensured that the cash flows from the assets match the liabilities at the minimum cost. The optimal weights for the bonds were determined, resulting in a cost-efficient portfolio. Indeed, for an issuance of five hundred million euros, only 435 million euros are needed to cover all liabilities leaving sixty-five million to be invested freely.

The results showed that it is possible to construct a diversified portfolio with expected returns higher than the costs of debt issuance, thereby covering the costs and optimizing the bank's financial position using Mean-Variance Theory that focus on constructing efficient portfolios that achieve the best balance between risk and return. In addition to mean-variance optimization, safety criterions are considered to ensure that portfolios meet certain risk management objectives and are fulfilled. The tangent portfolio not being the most diversified portfolio has a higher Sharpe ratio which makes it a logical option to invest the sixty-five million euros and expect profitable returns.

Future research could explore broader asset classes, multi-assets portfolios and dynamic and different market conditions.

We can finally conclude that by adopting investment strategies that utilize the proceeds from MREL issuances in a diversified portfolio, banks can cover these costs and enhance their financial resilience, nonetheless various assumptions were made what converting this theory to the real life would not be an easy task, since a change of a bond in a portfolio can give different results.

Bibliographic References

European Central Bank (2024). Euro Area Yield Curves. Available at:

https://www.ecb.europa.eu/stats/financial_markets_and_interest_rates/euro_area_yield_curves/html/index.en.html

Single Resolution Board (2023). Minimum requirement for own funds and eligible liabilities (MREL), May 2023. Brussels: Eurostat. Available at: https://www.srb.europa.eu/system/files/media/document/2023-05-15_SRB_MREL_Policy_2023_final%20_clean.pdf

Ernst & Young LLP. (2021). MREL: Financial implications for mid-size and challenger banks. Available at: [https://assets.ey.com/content/dam/ey-sites/ey-com/en_uk/topics/financial-services/ey-mrel-financial-implications-mid-size-challenger-banks.pdf]

Simon Hills (2021). A response to the Bank of England's Discussion Paper on its approach to setting a minimum requirement for own funds and eligible liabilities (MREL). Available at:

https://www.ukfinance.org.uk/system/files/MREL-DP-response.pdf

Banco de Portugal (June 2020). Financial Stability Report. Available at: Interaction between regulatory minimum requirements and capital buffers (special issue in Financial Stability Report - June 2020) (bportugal.pt)

White & Case (20 March 2019). Financial Regulatory Observer. Available at:

https://www.whitecase.com/sites/whitecase/files/files/download/publications/banks-face-steep-climb-mrel-issuance.pdf

Ángel Berges, Alfonso Pelayo & Fernando Rojas (2018). Spanish banks ahead of MREL: Estimating projected issuance for compliance. [Online] Available at: https://www.funcas.es/wp-content/uploads/Migracion/Articulos/FUNCAS_SEFO/036art05.pdf

Dr. Steve Levkoff, Ph.D. (2014). Cash Flow Matching Liabilities with Fixed Income Securities.

Elton E.J., M. J. Gruber, S. J. Brown, and W. N. Goetzmann (2014), Modern Portfolio Theory and Investment Analysis, 9th Edition, Wiley.

During the development of this project, AI tools were employed as follows: Generative AI tools were used for brainstorming and outlining purposes. However, all final writing, synthesis, and critical analysis are entirely my own work. I have ensured that the use of AI tools did not compromise the originality and integrity of my work. The ethical use of AI in research and writing has been a guiding principle throughout the preparation of this project. I understand the importance of maintaining academic integrity and take full responsibility for the content and originality of this work.

Gonçalo Balsemão Pires

October 13th, 2024