WOAS IJFAEMA JOURNAL
International Journal of Financial Accountability, Economics, Management, and Auditing
ISSN (2788-7189)
Int. J. Fin. Acc. Eco. Man. Aud. 6, No.1 (January-2024)
https://doi.org/10.5281/zenodo.10626844

Insurance asset allocation and regulatory compliance in the Moroccan context : analysis of the effects of proportions

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Abstract : The implementation of Moroccan Solvency II is nearly completed. The draft circular on the new prudential framework for Risk-Based Solvency will result in higher capital requirements. The aim of this work is to optimize the asset allocation of an insurance company in the context of classical portfolio theory when the firm has to comply with new regulatory requirements in terms of market risk capital. The analysis begins with a brief examination of the basic Markowitz model and the standard formula as provided by the regulator. We then estimate the risk-return pairs for the main asset categories held by a Moroccan life insurer, which serves as our case study, and execute two optimization programs: one with no proportional constraints and the other with proportional constraints. Subsequently, we incorporate the capital charges covering market risk and execute two additional optimization programs. Our results exhibit significant differences in terms of returns. Models based on the new regulatory constraint prove to be more profitable than those based on classical theory. However, strategic adjustments are necessary to balance the level of capital and portfolio returns.

Keywords : Asset allocation, life insurance, Markowitz, solvency capital requirement, standard formula, market risk, proportion constraints.

1. Introduction

In most economies, the insurance sector is subject to strict regulation. However, the increasing risks have prompted almost all developed economies to significantly revise their regulatory frameworks for solvency control in the insurance sector, placing greater emphasis on risk-oriented regulation (K. Lakhdar, 2023). The need to regulate the insurance industry has been analyzed by (G. J. Stigler, 1971), (S. Peltzman, 1976), (P. Munch & D.E. Smallwood, 1980), (D. Cummins et al., 1995), (Robert W. Klein, 1998). The systemic risk associated with the bankruptcy of an insurance company can cause major market disruption if it reaches sufficient scale (C. Jeffrey, 2002), hence the need for rigorous regulation.

Following the example of the European Union's 2016 insurance supervision reform, Solvency II, Moroccan insurance supervision will also be overhauled. The new risk-based capital standards, known as Risk-Based Solvency (SBR), with effective implementation scheduled for 2024, aim to revise the solvency rules to which insurance and reinsurance companies are subject by incorporating all incurred risks, including market risk. The core of prudential regulation is designed to ensure that insurance companies operate efficiently, preserve their financial stability, and validate the contracts they issue. Regulation is therefore designed to protect the interests of policyholders by preventing fraud and insolvency, improving the quality of insurance services and encouraging the insurance sector to play an active role in the economy. The regulator has provided insurance companies with a standard formula for calculating capital requirements. The Solvency Capital Requirement (SCR) is calculated on the basis of an instantaneous shock to the company's assets and liabilities. As a result, asset allocation decisions can be influenced. For G. Christian (2006), the new prudential standards make it possible to ensure optimal management of funds deposited by policyholders, while at the same time enabling the insurance sector to fulfill its role in the economy on a macroeconomic scale. In this article, we examine the impact of capital charges on the strategic choice of a life insurer's portfolio. Inadequate proportion constraints can lead to disadvantageous asset allocations. Ultimately, a delicate balance between reducing capital charges and meeting return targets is required. The question, then, is to what extent the new prudential standards are changing the way insurers, particularly life insurers, manage their investment portfolios to maintain their solvency and achieve their return objectives. First, we explore modern portfolio theory by developing two basic models: the Markowitz model without proportion constraints, followed by the Markowitz model with proportion constraints. These models were used on the basis of data from a Moroccan life insurance company to analyze its strategic allocation, with a focus on reducing portfolio volatility. Next, we incorporated the regulatory capital requirement constraint into the optimization model by developing two additional models: one without proportion constraints, followed by one with proportion constraints. The results showed significant differences in terms of return. Lastly, in order to meet the company's financial requirements, we introduced an additional optimization model, based on the constraint of not exceeding 85% of the previous SCR level. The aim was to find a balance between reducing the level of capital and maintaining a sufficient return. Our conclusion is that the model based on the regulatory capital requirement constraint is more profitable than the one based on Markowitz theory. However, strategic adjustments are required to balance capital levels and portfolio returns.

2. Literature Review

While many studies have been conducted on various aspects of Solvency II, few have examined the relationship between the standard market risk formula and the investment strategy of insurance companies.

N. Rudschuck et al. (2010) argued that the new regulatory framework would encourage insurers to reduce their exposure to equities, making it more difficult to achieve the necessary returns in a low interest rate environment. For their part, D.V. Bragt et al. (2010) demonstrated that the portfolio composition and maturity of assets held by insurers had a significant impact on their capital requirements. D. Höring (2013) examined whether insurance companies would reorganize their investment portfolios under the new regulatory framework. In particular, he noted that the Standard & Poor's (S&P) rating model appeared to be more conservative than the standard Solvency II formula, which would reduce the strain on insurers' asset management.

F. Ratings (2011), in its report on the impact of Solvency II on insurance company asset allocations, anticipated major repercussions on European debt markets. Practical studies published by Ernst & Young (2011) also addressed portfolio construction opportunities resulting from regulatory changes. N. Gatzert & M. Martin (2012) highlighted the close correlation between asset allocation and solvency capital requirements, while underlining the potential importance of market risk. K. Fischer & S. Schlütter (2015) examined how the calibration of the equity risk module affected the regulatory capital and investment strategy of an insurance company seeking to maximize value for its shareholders. Their results showed that more conservative stress scenarios could lead to both a reduction in the equity portfolio and the company's financial cushion. A. Braun et al. (2014) compared the capital requirements for risk capital investments under the Solvency II standard approaches to market risk and the Swiss Solvency Test, contrasting them with the results of an internal model. They concluded that the standard approaches excessively penalized this asset class. M. Eling et al. (2009) have carried out an in-depth assessment of portfolio optimization constraints in the context of Solvency II. They introduced an alternative standard model that establishes company-specific limits for assessing investment performance. This model uses factors such as probability of ruin, expected policyholder deficit and Value at Risk (VaR). Their results are therefore of particular interest to non-life insurers. A. Braun et al. (2015) optimized the asset allocation of a life insurance company in the context of classical portfolio theory, in line with Solvency II market risk capital requirements. Their results showed that the standard formula suffers from serious shortcomings. Finally, they found that the introduction of Solvency II in its current form is likely to have a negative impact on certain parts of the European insurance industry.

In the Moroccan context, insurance companies are preparing for the effective implementation of SBR. The introduction of capital requirements related to market risk represents a new constraint for asset managers. Our analysis focuses on the optimal allocation based on modern portfolio theory when insurance companies need to maintain sufficient capital to cover market risk. Then, using empirical data from a Moroccan life insurance company, we calculate the risk-return profiles for the different asset classes in which it invests. Finally, we integrate the capital requirement corresponding to market risk, calculated according to the standard formula. Our aim is to determine how insurance companies can optimize their portfolios while complying with the new regulatory constraints.

3. Data and methodology

We optimize the asset allocation of a Moroccan life insurance company in the context of classical portfolio theory (Markowitz) when the company has to conform to the market risk capital requirements of the future regulatory framework (SBR). In this study, we develop five distinct optimization models. The first two models are based on Markowitz theory, while the other three focus specifically on the capital requirement constraint. Our database includes the returns of the four asset classes (equities, bonds, real estate and foreign exchange) from 2017 to 2022, as well as their allocations in the studied portfolio (table 1).

Table 1: Returns and asset allocations over the period 2017-2022 (%)

Period t	Listed stocks		Unlisted stocks		Interest Rate		Property		Currency	
	R_i	w_i	R_i	w_i	R_i	w_i	R_i	w_i	R_i	w_i
2022	-0.83	6.35	11.00	0.47	3.91	85.71	0.32	2.91	1.97	4.56
2021	8.84	5.45	11.27	0.06	3.75	88.50	0.31	3.03	1.48	2.97
2020	-8.96	4.74	12.36	0.06	4.04	91.06	0.31	3.20	1.93	0.94
2019	6.45	5.15	12.13	0.07	4.20	90.22	0.35	3.52	2.36	1.03
2018	6.04	4.71	12.30	0.08	4.35	90.15	0.35	3.95	2.36	1.11
2017	13.35	4.98	12.38	0.08	4.40	89.90	0.35	4.33	2.45	0.71

Markowitz's (1952) theory describes how a rational investor should behave in constructing a portfolio. It is mainly based on the assumption that it is possible to characterize agents' preferences by means of utility functions that are a function only of the expected return and the variance of the portfolio return. Let's define the context. We assume that the returns on the assets in the portfolio, as random variables, follow the same distribution as a normal distribution.

$$r_A \sim N(\mu_A , \sigma_A)$$

Based on a discrete approach, the value of the assets at time t=1 can be expressed as follows:

$$\tilde{A}_1 = A_0(1 + r_A)$$

Where :

$\tilde{A}_1$: stochastic market value of the assets at time t=1

A_0 : deterministic market value of the assets at time t=0

r_A : stochastic return on the assets between t=0 and t=1, determined by the following weighted average

$$r_A = \sum_{i=1}^{n} \omega_i . r_i = w^* R$$

Where :

ω_i : portfolio weight for asset class i

r_i : return of asset class i

w^* : vector of portfolio weights

R : random vector of asset class returns

The distribution of asset values at time t=1 depends naturally on the expected return $E(r_A)$ and variance Var(r_A).

$$E(r_A) = E[\sum_{i=1}^{n} \omega_i . r_i] = \sum_{i=1}^{n} \omega_i . \mu_i = w^* T \text{n}$$

$$Var(r_A) = Var[\sum_{i=1}^{n} \omega_i . r_i] = \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_i . \omega_j . \rho_{i,j} . \sigma_i . \sigma_j = w^* \sum w$$

Where :

μ_i : mean return of asset class i

T : vector of mean returns

σ_i : return volatility of asset class i

$\rho_{i,j}$ correlation between the returns of asset classes i and j

$\sum$: variance-covariance matrix of returns

As for assets, we define the value of liabilities at time t=1 as follows:

$$L_1 = L_0(1 + \delta_L)$$

Where :

L_1 : stochastic market value of the liabilities at time t=1

L_0 : deterministic market value of the liabilities at time t=0

δ_L : stochastic growth rate of the liabilities between t=0 and t=1. It is supposed to be normally distributed:

$$\delta_L \sim N(\mu_L , \sigma_L)$$

The Markowitz model suggests that optimal diversification should focus on reducing systematic risk, since it is the only risk that cannot be eliminated. This method, known as "Efficient Frontier with Systematic Risk", is based on the idea that diversification should be based on the level of systematic risk, which depends primarily on the covariances between different market assets:

$$\rho_{AB} = \frac{Cov(R_A, R_B)}{\sigma_A . \sigma_B}$$

Starting with the selection of assets with moderate correlations with the market or with each other, the investor calculates the weights. The optimal portfolio constructed is positioned on the efficient frontier with the systematic risk previously determined.

In practice, investors can introduce various constraints based on their objectives, risk tolerance and investment preferences, in order to limit the allocation of their portfolio to certain assets. For example, an investor may decide to invest no more than 20% of capital in a single stock, in order to further diversify the portfolio. As a result, this proportion constraint limits investment choices and makes the optimization problem more complex.

Our approach consists of two steps: first, we will optimize our portfolio without taking into account the proportion constraints (Optimization problem 1), and then we will adjust it taking into account the specific constraints set by the company (Optimization problem 2). This two-step approach is necessary to compare two scenarios and make informed asset allocation decisions.

According to Markowitz, the investor can allocate any proportion of his capital in each asset without restriction. Let's consider a function $R_P(X)$ that represents the return on our portfolio to be optimized, where X is a vector of variables that determines the weights of the different allocations. The objective is to find the value X that maximizes the return, while respecting the constraint previously established by the insurance company, which stipulates that the level of risk must not exceed 35%. By noting :

R_p and σ_p : respectively the portfolio's return and volatility ;

σ_L : the limit volatility ;

X_{ls} : proportion of listed equities ;

X_{us}: proportion of unlisted equities ;

X_{ir}: proportion of bonds ;

X_p:proportion of real estate ;

X_c:proportion of foreign exchange.

The optimization problem [1] is written as follows:

$$\begin{cases} Max(R_p) = X_{ls}.R_{ls} + X_{us}.R_{us} + X_{ir}.R_{ir} + X_{pr}.R_{Pr} + X_c.R_c \\ \mathrm{X_{ls} + X_{us} + X_{ir} + X_{pr} + X_c} = 100\% \\ \sigma_\mathrm{P} < \sigma_\mathrm{L} = 35\% \end{cases}$$

However, in line with current regulatory guidelines, it is imperative to take into account the proportional limits imposed on investment allocation, which can make the optimization problem more complex. The aim is to determine the optimal asset allocation while respecting the percentage constraints set by the insurance company. Mathematically, the optimization problem with proportion constraints [2] becomes :

$$\begin{cases} Max(R_p) \\ X_{ls} < 7\% \,;\, X_{us} < 1\% \,;\, X_{pr} < 3.5\% \,;\, X_c < 5\% \\ X_{ls} + X_{us} + X_{ir} + X_c = 100\% \\ \sigma_p < \sigma_L = 35\% \end{cases}$$

While modern portfolio theory focuses on optimizing the risk-return couple to maximize investment returns, the future regulatory regime emphasizes prudent risk management, particularly market risk. Insurers are obliged to allocate sufficient financial resources to cover this risk. As a result, this can lead to a more conservative approach to asset allocation, focused on reducing risk rather than seeking higher returns. In terms of calculation, a standard formula is available to insurance companies. The risk map adopted by the regulator is shown in the figure below.

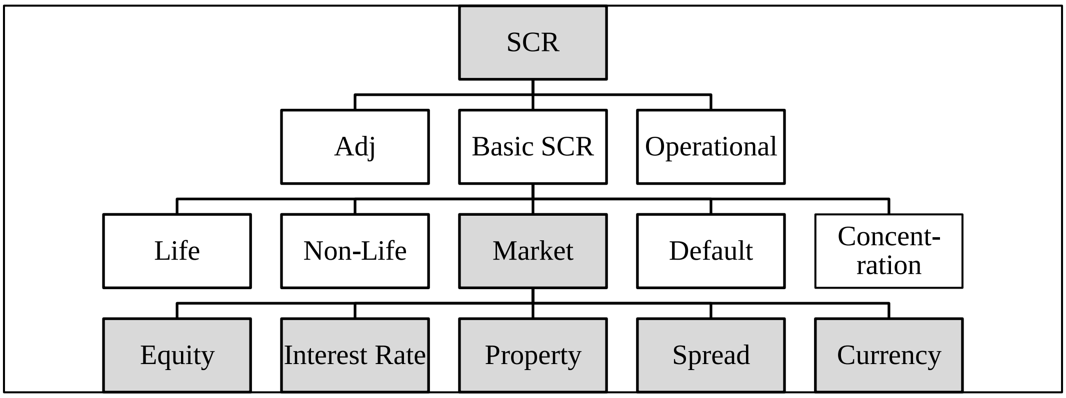

Figure 1: The risk mapping for calculation the capital requirement in the Moroccan context

The standard formula is adjusted on the basis of two fundamental concepts: historical data reflecting a Value at Risk (VaR) with a 99.5% confidence level over a one-year period, and stress tests assessing losses resulting from unlikely but plausible scenarios that could affect the financial markets. Market risk represents one of the most important risk categories in the insurance industry. The difference between the market values of assets (A) and liabilities (L) is known as own funds (OF). Variations in OF, noted ΔOF, are caused by stress factors and reflect the impact of disruptions on financial markets. They are calculated as follows:

$$\begin{aligned}\Delta OF &= \max\left(OF - (OF|\text{shock}), 0\right)\\ &= \max((A-L) - \left((A-L)\middle|\text{shock}\right), 0)\\ &= \max\left(A - (A|\text{shock}), 0\right)\end{aligned}$$

The assessment of the capital requirement for market risk, denoted $\mathrm{SCR_{mkt}}$ is divided into five risk sub-modules (Figure 1). In our study, we limit our analysis to equity, interest rate, real estate and foreign exchange risk, noted respectively as follows: SCR_{eq}, SCR_{int}, SCR_{prop} et SCR_{fx}.

The SCR for interest-rate risk includes two distinct scenarios:

$$\mathrm{SCR_{int}^{up}} = \Delta\mathrm{OF}|_{\mathrm{up}}$$

$$\mathrm{SCR_{int}^{down}} = \Delta\mathrm{OF}|_{\mathrm{down}}$$

$\mathrm{SCR_{int}^{up}}$ and $\mathrm{SCR_{int}^{down}}$ represent upward and downward interest rate shocks respectively. In both scenarios, stress factors are applied to the yield curve as follows:

$$\Delta \mathrm{r_t^{up}} = \mathrm{r_t}.(1 + \mathrm{i_t^{up}}) - \mathrm{r_t}$$

$$\Delta \mathrm{r_t^{down}} = \mathrm{r_t}.(1 + \mathrm{i_t^{down}}) - \mathrm{r_t}$$

Where r_t is the interest rate for maturity t, and i_t^{up}, i_t^{up} represent upward and downward stress factors respectively. It is therefore essential to measure the interest-rate sensitivity of assets and liabilities, by measuring duration.

The SCR for equity risk measures the potential volatility of equity investments in the insurance company's portfolio. We distinguish between two categories: listed and unlisted equities. To do this, two steps are necessary. First, we apply the predefined stress factors for each category:

$$\mathrm{SCR}_{\mathrm{eq,c}} = \max\left(\Delta\mathrm{OF}|\text{equity shock}_{c}; 0\right)$$

Where $c \in \{\text{listed stocks}\ ;\ \text{unlisted stocks})$. The capital requirement corresponding to equity risk is calculated as follows:

$$SCR_{eq} = \sqrt{\sum_{i}\sum_{j}\rho\llcorner_{cj}.SCR_{eq,c}.SCR_{eq,j}}$$

Where $j \in \{\text{listed stocks}\ ;\text{unlisted stocks})$ and $\rho\llcorner_{cj}$ represents the correlation coefficient between the two categories in question. A lowSCR_{eq} implies that the portfolio is less sensitive to stock market movements, and inversely.

The SCR for property risk assesses the sensitivity of the insurance company's portfolio to fluctuations in the property market. By applying a 15% stress factor (ACAPS), we obtain the capital required to cover this risk. The formula is given below:

$$\mathrm{SCR}_{\mathrm{prop}} = \max(\Delta\mathrm{OF}|15\%^{1}; 0)$$

The SCR for currency risk is designed to quantify the capital requirement corresponding to the loss generated by the effect of exchange rates on the value of foreign currency assets. As with interest-rate risk, the $\mathrm{SCR}_{\mathrm{fx}}$ is obtained by applying an upward and downward stress factor, set at 15% (ACAPS).

$$\mathrm{SCR}_{\mathrm{fx}}^{\mathrm{up}} = \Delta\mathrm{OF}|_{\mathrm{up}}$$

$$\mathrm{SCR}_{\mathrm{fx}}^{\mathrm{down}} = \Delta\mathrm{OF}|_{\mathrm{down}}$$

Lastly, the calculation of $\mathrm{SCR}_{\mathrm{mkt}}$ involves aggregating the SCRs by applying the square root formula, while taking into account the interdependencies between the various risk categories:

$$SCR_{mkt} = max(\sqrt{\sum_{i}\sum_{j}\rho SCR_{ij}^{up}.SCR_{i}^{up}.SCR_{j}^{up};\rho SCR_{ij}^{down}.SCR_{i}^{down}.SCR_{j}^{down}}$$

Where $\mathrm{i,j} \in \{\mathrm{eq;int;prop;fx}\}$ and $\rho\mathrm{SCR}_{\mathrm{ij}}^{\mathrm{up}}$, $\rho\mathrm{SCR}_{\mathrm{ij}}^{\mathrm{down}}$ are the parameters of the corresponding between different risks. Some risks may compensate for others when they occur simultaneously.

Table 2 : Correlations in the market risk module in the Moroccan context

Correlation Matrix	(1)	(2)	(3)	(4)	(5)
(1) Equity	1				
(2) Interest Rate	0.25	1			
(3) Property	0.25	0.25	1		
(4) Spread	0.25	0	0	1	

[1] Approach based on the calculation of the parametric VaR at 99.5% of the annual sliding returns of the real estate assets price index of the city of Casablanca which concentrates nearly 70% of the insurers' real estate assets, over the period 2005-2019 (source: ACAPS).

(5) Currency	0.25	0.25	0.25	0.25	1

Optimal asset allocation is now based on the SCR_{mkt} of an insurance company. This is a newly-introduced regulatory constraint for managers, which must not exceed a certain limit, denoted SCR_L, calculated on the basis of the sum of own funds (OF) and unrealized capital gains (UCG). Unrealized capital gains correspond to the positive difference between the current value of an asset and its initial acquisition price. Mathematically, we have :

$$\begin{cases} \text{Max}(\text{R}_\text{p}) \\ \text{SCR}_\text{mkt} < \text{SCR}_\text{L} \\ \text{SCR}_\text{L} = \text{CP} + \text{PLV} \\ \text{X}_\text{ls} + \text{X}_\text{us} + \text{X}_\text{ir} + \text{X}_\text{pr} + \text{X}_\text{c} = 100\% \end{cases}$$

Since the SCR_{mkt} is calculated from the weights of its sub-modules, we analyze the relationships between the various asset classes and these sub-modules. The following relations have been identified between the proportions of assets in the portfolio and the proportions of the SCR_{mkt} sub-modules. We denote:

$\text{X}_{\text{c}-\text{ls}}$; proportion of listed equities

$\text{X}_{\text{c}-\text{us}}$; proportion of unlisted equities

$\text{X}_{\text{c}-\text{ir}}$; proportion of bonds

$\text{X}_{\text{c}-\text{p}}$; proportion of real estate

$\text{X}_{\text{c}-\text{c}}$: proportion of foreign exchange

We obtain the optimization problem [3], which is based on the couple return-SCR_{mkt} , without consideration of proportion constraints :

$$\begin{cases} Max(R_p) \\ SCR_{mkt} < SCR_L \\ X_{c-ls} + X_{c-us} + X_{c-ir} + X_{c-pr} + X_{c-c} = 100\% \end{cases}$$

When executing the code and setting a lower limit SCR_L than previously set, we found that negative results appeared. This can be undesirable from an investment management point of view. To prevent this kind of problem, it is essential to consider the limit levels set for the different asset classes determined by the insurance company. The optimization problem with proportion constraints [4] becomes :

$$\begin{cases} Max(R_P) \\ X_{ls} < 7\% \ ; \ X_{us} < 1\% \ ; \ X_{pr} < 3.5\% \ ; \ X_c < 5\% \\ SCR_{mkt} < SCR_L \\ X_{ls} + X_{us} + X_{ir} + X_{pr} + X_c = 100\% \end{cases}$$

The reason for setting limits for each asset class is to ensure compliance with regulatory capital requirements, on the one hand, and to maintain an adequate return, on the other.

4. Results and discussion

Capital charges are calculated on the basis of the risks associated with the assets held by the insurer, which must be taken into account when deciding on the composition of its investment portfolio. The return and volatility of assets, determined respectively from the average of annual returns and the standard deviation of returns, are given in the following table :

Table 3 : Portfolio return and volatility over the period 2017 – 2022

	Listed stocks	Unlisted stocks	Interest Rate	Property	Currency
R_i (%)	3.89	11.89	4.10	0.33	2.06
σ_i^2(%)	7.21	0.56	0.23	0.02	0.34

Unlisted equities offer the best risk/return combination: they deliver high returns while maintaining acceptable volatility, making them an attractive choice. Generally, and with a higher level of volatility, equities tend to offer higher returns than bonds. However, our case demonstrates the opposite. This can be attributed to the economic disruption of 2020 and the fall in share prices, which favored investment in bonds.

Thus, historical returns enable us to assess the correlation between asset classes, represented by the correlation matrix below :

Table 4 : Correlation matrix between asset classes

Correlation Matrix	(1)	(2)	(3)	(4)	(5)
(1) Listed stocks	1				
(2) Unlisted stocks	-	1			
(3) Interest Rate	0.353	-	1		
(4) Property	0.603	-	0.886	1	
(5) Currency	0.292	-	0.949	0.914	1

Referring to table 3, it is clear that the two categories, unlisted equities and bonds, offer the highest returns of all, with relatively low volatility. Consequently, the results seem to encourage investment in unlisted equities and bonds, in line with the insurance company's expectations. Solving [1] and [2] leads us to the following results:

Table 5 : Optimal asset allocation according to Markowitz - portfolio return and volatility

Asset class	Optimization problem 1	Optimization problem 2
	Without proportion constraints	With proportion constraints
Listed stocks	3.00	3.00
Unlisted stocks	39.00	1.00
Interest Rate	52.00	90.00
Property	3.00	3.00
Currency	3.00	3.00
R_P (%)	6.96	4.00
σ_P (%)	0.35	0.34

Optimization of the problem [1] led to a diversified asset allocation, with a predominance of unlisted equities (39%) and bonds (52%). The portfolio posted a return of 6.96%, while risk is measured at 0.35%, indicating a moderate level of risk. However, once the constraints of proportions (optimization problem [2]) had been taken into account, the portfolio underwent significant changes. Unlisted equities are strictly limited to 1%, resulting in a high concentration in bonds (90%) and more modest allocations to listed equities (3%), real estate (3%) and currencies (3%). As a result, the portfolio's return fell considerably to 4%, reflecting diversification constraints, with a slight decrease in volatility due to the preponderance of investments in bonds, considered less risky. Asset weights can therefore have an impact on overall portfolio performance. Inappropriate asset allocation can lead to higher risk or lower returns. In the following, we maintain the same objective as before, but taking into account a new risk indicator, replacing volatility.

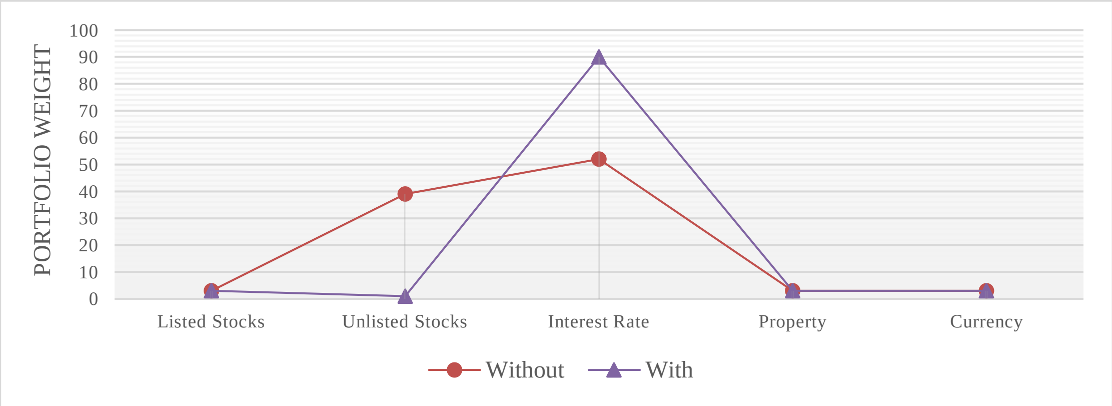

Figure 3: Asset allocation according to Markowitz – Optimization problem 1 & 2

The level of SCR required by the insurance company for the period 2017-2022 is shown in the table below:

Table 6 : Evolution of the SCR corresponding to market risk (in Mds Dhs)

	2022	2021	2020	2019	2018	2017
SCR_{mkt}	2 951	3 052	2 973	2 670	2 325	2 146

The resolution of problems [3] and [4] leads us to the following results:

Table 7 : Optimal asset allocation according to SBR - portfolio return and SCR_{mkt}

Asset class	Optimization problem 3	Optimization problem 4
	Without proportion constraints	With proportion constraints
Listed stocks	3.00	3.00
Unlisted stocks	40.00	1.00
Interest Rate	52.00	91.00
Property	3.00	3.00

Currency	2.00	2.00
SCR_{mkt} (Mds Dhs)	1 926	2 722
R_P (%)	7.06	4.02

Optimizing the portfolio without considering proportion constraints resulted in a diversified asset allocation, still predominantly in unlisted equities and bonds. The allocation was then adjusted to comply with regulatory guidelines. This limited the insurance company's ability to invest further in potentially more profitable assets, resulting in a significant reduction in the expected return to 4.02%. On the other hand, the SCR level has been doubled. The constraints have led to a more prudent asset allocation, with less exposure to potentially risky assets, which has increased the level of capital required to cover the risks associated with this allocation.

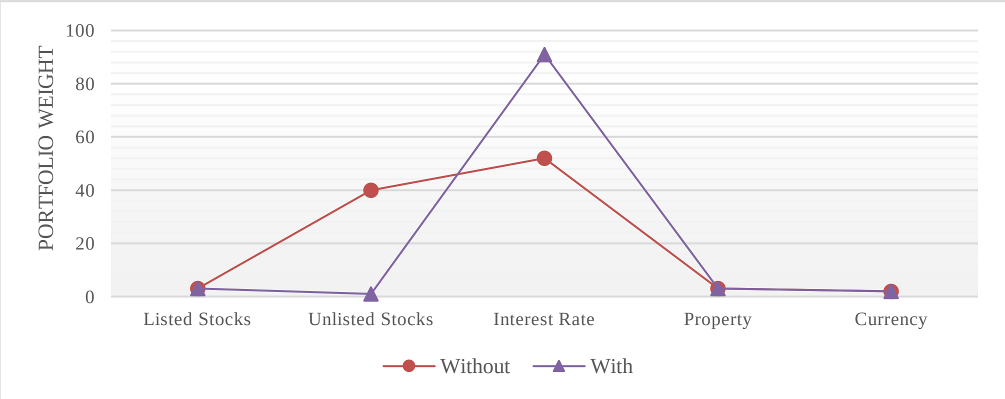

Figure 4 : Asset allocation according to SBR - Optimization problem 3 & 4

The insurance company is looking for a balance between reducing the level of the SCR_{mkt} and maintaining a sufficient return to meet the company's financial needs. The new SCR_{mkt} level does not exceed 85% of the previous SCR_Llevel. The optimization problem [5] becomes :

$$Max\ (R_p)$$
$$SCR_{mkt} < 85\%.SCR_L$$
$$X_{ls} < 7\%\ ;\ X_{us} < 1\%\ ;\ X_{pr} < 3.5\%\ ;\ X_c < 5\%$$
$$X_{ls} + X_{us} + X_{ir} + X_{pr} + X_c = 100\%$$

Table 8 : Optimal asset allocation according to SBR with 85% SCR_L – portfolio return and SCR_{mkt}

Optimization problem 5					
Assets	Listed stocks	Unlisted stocks	Interest Rate	Property	Currency
w_i (%)	7.00	1.00	83.50	3.50	5.00
SCR_{mkt}	2 591 Mds Dhs				
R_P	3.93 %				

The results of the optimization problem [5] after execution are shown in table 7. It appears that reducing the level of SCR_L entrains a decrease in the amount of SCR_{mkt} in the investment portfolio. However, it is important to note that this reduction is also associated with a lower potential return on the portfolio. The insurance company has readjusted its asset allocation in favor of assets considered less risky, in particular bonds and currency assets. These generally exhibit less volatility than equities, which has reduced the associated SCR_{mkt} . The reason for this reduction therefore lies in the reduced allocation to bonds, which has an impact on two sub-modular risks: the "spread" sub-module, which is characterized by a relatively low shock level, and the "rates" sub-module, which plays a leading role in reducing the level of SCR_{mkt} when the allocation to bonds is reduced. As a result, it is necessary to choose asset classes whose shock levels lie between those of the spread and the rate, particularly currency and real estate assets. Based on the results obtained, it becomes possible to identify the most appropriate method for the portfolio studied.

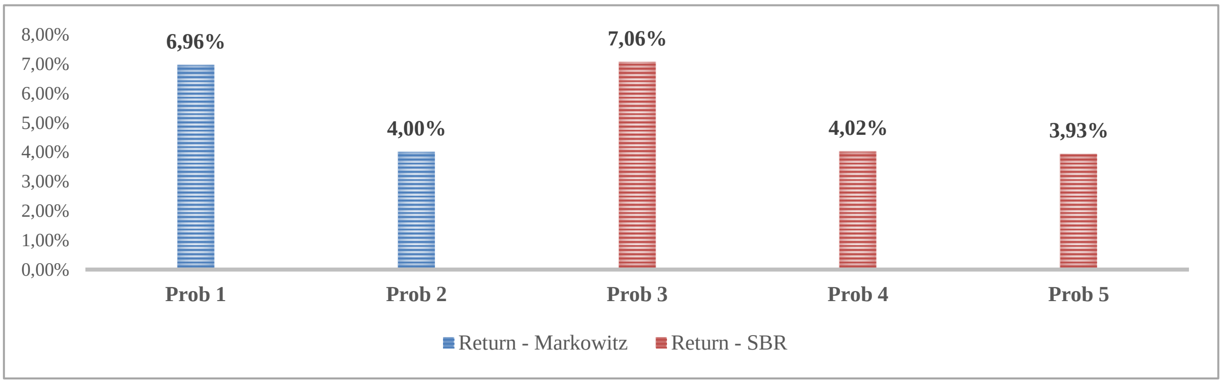

Figure 5 : Portfolio return according to the incorporation of proportion constraints

The results show significant differences in terms of return. The model based on the capital requirement constraint registered a return increase of 1.41%. However, as soon as we introduced the proportion constraint, return decreased significantly due to the reduction in the proportion of the most profitable assets in the portfolio. This constant is worrying, as it shows that adding a proportion constraint has a significant impact on the profitability of the investment portfolio, whereas our objective is to maximize it.

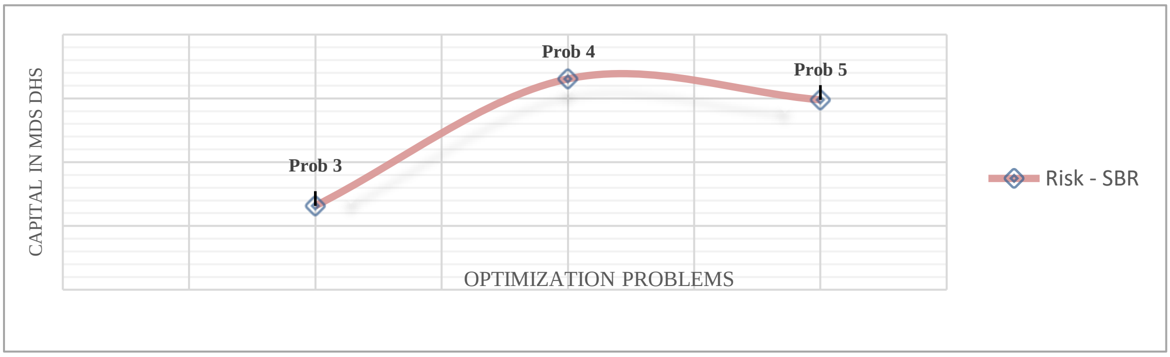

Figure 6 : Portfolio SCR_{mkt} according to the incorporation of proportion constraints

The SCR_{mkt} level increased by 41.32% due to the reduction in the proportions of assets dependent on SCR_{mkt} sub-modules, having lower shock levels. Ultimately, the incorporation of proportion constraints led to a more conservative allocation, with a reduction in expected return but better control of required capital. In addition, the objective of reducing SCR_{mkt} to no more than 85% of the previous level was achieved, due to strategic adjustments demonstrating the company's flexibility in the face of regulatory constraints, while optimizing their solvency position. In our case, the method based on the new regulatory constraint proved to be more profitable than the method based on Markowitz theory.

5. Conclusion

The implementation of risk-based solvency (SBR), scheduled for 2024, will change the insurance regulatory environment in Morocco. Our study aimed to shed light on the impact of the introduction of new regulatory constraints, particularly the solvency capital requirement corresponding to market risk, on insurers' asset allocation. According to classical portfolio theory, asset managers must take into account the financial resources required to cover market risk in their investment strategies. In this context, optimal allocation now requires control of the capital required to cover market risk, as a substitute for volatility. Strategic adjustments are therefore necessary, such as the incorporation of proportional constraints set by the insurance company, to maintain a balance between return and solvency. These findings underscore the need for strategic adaptations to maintain a delicate balance between portfolio returns and solvency requirements. As a result, insurance companies are encouraged to consider innovative approaches in their asset allocation, proactively incorporating regulatory constraints to maximize risk-adjusted returns.

The perspectives from our study pave the way for several avenues of development. Firstly, industry stakeholders can explore specific strategic that align with the new regulatory constraints while optimizing returns. Future research efforts could delve deeper into the approaches to provide more targeted recommendations for practitioners. Furthermore, the evolution of optimization models, taking into account the significant differences revealed in our study, could be a fruitful area of research. Practitioners may benefit from more sophisticated frameworks that effectively integrate regulatory capital requirements into asset allocation optimization processes.

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