Optimal optimisation under Solvency II
Frameworks for strategic and tactical allocations

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Executive summary

To apply established portfolio optimisation techniques to the problem of finding efficient portfolios under Solvency II, insurers must first resolve a number of issues, and the final optimised asset allocation can differ significantly from a purely economic optimisation. In particular, the Solvency II Standard Model uses specific cross-asset correlations and does not recognise any diversification benefits within a single asset class, elements which are important drivers of the differences in optimised allocations.

In this paper, we describe a framework for optimisation under Solvency II at the asset allocation level, and another at the portfolio level. Their aim is to help identify the trade-offs that exist between the economic and regulatory optimisations. Of course, these challenges will be different for each insurance company – some will be more capital-constrained, while others will prioritise predictability of regulatory capital usage over capital efficiency. Others still may decide to build their own internal model under Solvency II to achieve a better alignment between regulatory and economic capital.

Yet, while choices will depend on each insurer’s specific profile and requirements, we conclude that the overall investment decision-making is far more effective when optimising at the economic level first, and adding an SCR filter or constraint second, rather than beginning with an SCR objective and trying to optimise from an economic perspective as an afterthought.

In addition, some of the limitations to quantitative optimisation techniques apply to both economic optimisation and optimisation under Solvency II, such as the tendency of the algorithms to produce highly-skewed portfolios. Insurers should be aware of this, so they can make proactive decisions to meet these challenges. Inevitably, each of these decisions will be a trade-off, and being aware of their impact is important for insurers who want to fully understand their asset allocation decisions.
Introduction
Producing efficient allocations

2016 was the first year when European insurance companies started building a real-life experience of operating under Solvency II. Insurance investors have become extremely focused on their SCR ratio and its movements and, as a consequence, they have started to desire a degree of predictability around this ratio. This applies to both internally and externally-managed money and, as a result, insurance companies increasingly require asset managers to manage portfolios within specific SCR constraints or budgets. They also look for strategies which are optimised for Solvency II.

This raises the question of how to design and execute such an optimisation, both at the asset allocation level and at the portfolio level, within specific asset classes. In this white paper, we discuss some of the challenges surrounding portfolio optimisation under Solvency II and explore various ways to deal with them.

The challenges of optimisation under Solvency II

Optimising allocations and portfolios on an economic risk/return basis involves using actual asset-class correlations. In contrast, optimising for Solvency II Standard Model forces us to use the fixed correlations featured in that model, making it difficult to find solutions that are efficient from both an economic and regulatory perspective.

Not only are Solvency II allowances for correlation limited across asset classes, but neither is there any benefit to diversifying within single-asset-class portfolios – that is, apart from avoiding a capital penalty for concentration risk at the overall company level.

This leads to very different results when running a purely quantitative economic optimisation and when optimising for Solvency II. Typically, the portfolios designed under a Solvency II optimisation will be more concentrated.

Of course, many insurance companies would prefer to manage their investments on an economic capital basis, under which they could aim for far more diversified portfolios than those which the basic quantitative Solvency II optimisation can produce.

The challenge is to add the right constraints to the optimisation process, so as to produce efficient asset allocations and investment portfolios that make sense not only under Solvency II, but also from an economic perspective.

There are different ways to approach this problem, for asset allocation on the one hand, and at the portfolio level on the other.
Optimising a strategic allocation under Solvency II
Mean-variance versus SCR constraint

To optimise a strategic asset allocation under Solvency II, we must begin by clearly defining the investment objectives, in particular because they are multidimensional. Typically, an insurance company will either aim to achieve the best possible expected return for a given budget of regulatory capital, or to achieve the lowest SCR for a given expected return target. We can optimise for both of these objectives by using a mean-variance optimisation approach, using the Solvency II standard formula as the targeted-risk function instead of the traditional variance measure:

$$w^* = \max_w \left( w' \mu - \frac{\lambda}{2} w' \Sigma w \right)$$

Where:

- $\mu$ is the vector of 10-year, long-term expected returns derived from our proprietary valuation models
- $\lambda$ is the risk-aversion parameter
- $\Sigma$ is the long-term historical covariance matrix (under the mean-variance optimisation)
- $\Sigma$ is the SCR-adjusted correlation matrix between risk modules (under the Solvency II standard model)
- $w$ is the assets’ nominal weights vector
- and $w'$ is the transpose of the weights vector

The main difference between the two optimisations therefore resides in the $\Sigma$ matrix, which is the historical variance-covariance matrix in the standard mean-variance optimisation, while it represents the SCR weighted correlation matrix in the SCR optimisation framework.

Running the optimisation to find the highest expected return for a large number of SCR budgets generates an efficient frontier of long-only and fully-invested allocations, where for each SCR level we maximise the expected return. We have named this optimisation “Allocation under SCR constraint”.

Running a parallel standard mean-variance optimisation and Solvency II optimisation which produce the same SCR in parallel shows the differences between these two approaches. Figure 1 illustrates this for an SCR level of 12.5%.

We can make a number of observations on these charts. First, because we did not specify any constraint as to how close the portfolio should stick to the benchmark, both optimised portfolios deviate significantly from most insurers’ expected benchmark portfolio. As expected, the optimal allocation under the SCR constraint exhibits the highest expected return (ER=1.8%)4. Its resulting Sharpe ratio is equal to 0.22 for a 12.5% SCR level, outpacing the optimised mean-variance allocation, which exhibits an expected return of 1.4% and a Sharpe ratio of 0.17 for the same SCR.

1 While shrinkage and resampling are well-known numerical techniques used to overcome the non-invertibility problem, or the estimation bias of the historical covariance matrix, under the mean-variance approach, there is no similarly robust technique for an SCR optimisation.
2 For the purposes of this example, we selected 12.5% as the reference SCR level, for a benchmark allocation of 30% Euro Developed Equities and 70% Euro Aggregate Bond.
3 These optimisations ignore the liability side of the insurer’s balance sheet. The only constraints applied are to have only positive weights and no leverage.
4 The expected return is derived from HSBC Global Asset Management’s proprietary valuation models for a 10-year horizon as per end of August 2016. Our models are regularly updated, so the optimal portfolios may change over time. In practice, to overcome the variability of expected return signals, it is recommended to mix these expected returns with those derived from very long-term historical Sharpe ratios.
Optimising a strategic allocation under Solvency II
Mean-variance versus SCR constraint

Yet this forward-looking advantage of the SCR-constrained allocation comes at a price: its resulting volatility is higher than in the mean-variance portfolio. Whether this is an issue will depend on individual insurance companies’ level of tolerance to volatility.

Meanwhile, the optimised allocations both fail to produce well-diversified portfolios. Mean-variance practitioners will be very familiar with this phenomenon, but in our example the mean-variance optimisation also produces skewed portfolios when using an SCR risk measure. Interestingly, the portfolio optimised for Return on SCR is better diversified, because its tolerance to volatility is higher (since the risk objective is the SCR and not the volatility level).

Comparing the two sets of results also highlights how both the favourable treatment of OECD government bonds and the home currency bias affect the SCR:

1. The weight of government bonds varies from 16% in the mean-variance allocation to 45% in the SCR-constrained one. In contrast, investment-grade (IG) euro credit, which at 70% is the dominant asset class in the mean-variance approach, has a much smaller allocation – just 10% – in the SCR-constrained optimisation.

2. The foreign-currency exposure resulting from the optimised SCR-constrained allocations is less diversified across assets than the exposure in the mean-variance allocation. We should stress here that the currency element of an allocation plays a major role in investment decision-making under SCR – probably a more important one than under the mean-variance approach.

Figures 2 and 3 illustrate the impact of currency exposure and currency hedging on the risk side of both optimisations. We can see that, while a currency hedge significantly reduces the SCR figures, it does not reduce the volatilities in the same proportion, particularly in the case of equity-like assets.

For the purposes of this paper, we focused on the implications of optimisation on an unhedged investment universe. However, considering the impact of currency hedging on both SCR and volatility, but also on returns (which would deserve a paper in its own right and is not described here), insurers will no doubt include a robust currency exposure policy within their asset allocation framework.

Last but not least, the comparison of our two strategic asset allocation examples highlights the opportunity presented by using local-currency emerging market debt as a substitute for equities under the Solvency II regime. This asset class is quite attractive in the SCR optimisation, because it is less solvency-capital-intensive than equities while offering a better expected return.
Optimising a strategic allocation under Solvency II
Incorporating liabilities into the process

Insurance companies calculate their Solvency II capital requirements in an integrated manner across both sides of their balance sheet. Some risk variables, such as interest rate risk, apply to both sides at the same time. For life insurance companies, which have very long-dated liabilities, it is particularly important to strike a balance between reducing the SCR, by hedging interest rate risk via bonds and/or derivatives, and investing in higher-return assets.

Insurers can take one of several approaches to optimise the allocation in a way that will take long-dated liabilities into account. The first involves splitting the relevant fixed income asset classes into a set of sub-asset classes with different maturity buckets, or durations, and to determine an expected return for each one. This allows us to optimise the trade-off between expected returns and SCR at a more granular level.

A second approach stems from the fact that, beyond a certain maturity or duration, the asset classes that can offset liabilities’ interest-rate risk are essentially reduced to government bonds and swaps. By analysing both sets of hedging instruments, we can see whether is it more efficient to allocate a significant part of the investable funds to an asset with an expected return (government bonds), or to use derivatives. Using the latter will cause some of the investable funds to be kept in cash for future collateral movements, but most of the funds can be incorporated in the Solvency II optimisation.

Taking 15 years as an example cut-off point, we can calculate the present value of the total government bonds required for a full hedge beyond this period. We can then optimise the remainder of the available funds as described above, taking into account all the liabilities shorter than 15 years. This allows us to use standard benchmarks for all the asset classes for which we have defined expected returns. Finally, we combine the portfolio resulting from the optimisation with the portfolio of government bonds designated for long-term hedging (i.e. over 15 years in our example).

We can also modify this approach slightly, to allow us to use interest-rate swaps instead of government bonds to hedge long-dated liabilities. We must set aside a certain amount of cash (e.g. 10% of the present value of the long-dated liabilities) to use as collateral, in order to hedge the counterparty risk stemming from movements in interest rates. This amount will only earn cash returns but, compared to hedging with government bonds, this approach frees up a much larger proportion of the overall funds to be invested in asset classes offering higher expected returns.

For non-life insurers, the process described above is not relevant because the duration of their liabilities is much shorter (typically two to four years). Therefore, the optimised asset allocations generally produce sufficient duration to fully offset the interest-rate risk on the liability side, and a non-life insurer will often even post a net negative sensitivity to rising rates.

On the other hand, part of their liabilities may be subject to inflation risk. For example, in a home insurance policy whereby the insurer undertakes the repairs instead of paying out a lump sum, the insurer is exposed to inflation risk from the moment they accept a claim to when they pay the final invoice on repairs. Insurers can cover this risk by maintaining a minimum amount of inflation-linked bonds in the allocations.
Solvency II portfolio optimisation
Integration in investment processes

At the portfolio level, results from a full mathematical optimisation under Solvency II may have a few shortcomings. For example, a fixed income portfolio may be skewed, since Solvency II grants no diversification benefit within a single asset class. In addition, a pure mathematical optimisation has no room for the investment manager to provide added value if the starting point is the overall investment universe.

In practice, we must therefore define certain requirements for an “optimal” portfolio, beyond the simple mathematical optimisation:

1. It must be well balanced and diversified
2. We must conduct periodical rebalancing to ensure we continue to meet the portfolio’s desired characteristics, alongside low turnover and therefore low transaction costs
3. The portfolio must have the flexibility to include additional restrictions and requirements

Under Solvency II, six market risks – and counterparty default risk – can affect asset portfolios. In this paper, we will focus on the three that are SCR Spread, SCR FX and SCR Equity. This is because incorporating SCR Interest requires information on the liabilities of the insurance company, which is usually not available to the asset manager. However, to cater for this requirement, the insurance company can provide its asset manager with a target duration for the investment portfolio. Another option is to exclude any SCR Interest constraints at the level of the individual portfolio, and instead hedge the overall interest-rate risk through an overlay management approach.

Similarly, as an asset manager, we typically do not know an insurance company’s overall exposure to SCR Concentration or SCR Counterparty default risk, neither of which we will explore here. In addition, exposures at portfolio level do not generally exceed the relevant threshold for SCR Concentration, while the impact of SCR Counterparty default risk would likely be negligible for an insurance company at portfolio level.

5 We have excluded SCR Property from this analysis, as we are focused on more liquid asset classes for the purposes of this paper.
To illustrate the problem of skewed portfolios under Solvency II, we compare a minimum-SCR fixed income portfolio with a classical minimum-variance portfolio.

A minimum-variance portfolio will skew heavily towards instruments with low volatility. The correlation effect, however, usually leads to the potential inclusion of positions with higher volatility, which helps reduce the overall portfolio variance. Yet in the world of Solvency II, this is not the case: because Solvency II does not take into account the correlation in spread instruments, the portfolio with the lowest SCR Spread will have a 100% weight for the bond with the lowest SCR. The same problem arises when we maximise the yield of a fixed income portfolio for a given SCR level.

A fixed income portfolio with a single bond in it may well be optimised for SCR but is otherwise very unattractive, so it stands to reason to apply some sensible constraints. Once again, there are different ways to deal with this problem.

### Optimising a diversified portfolio

One approach is to start with a well-diversified portfolio, based on a robust analysis of market and issuer fundamentals, so as to represent an optimal solution prior to the introduction of Solvency II considerations.

Our task is then to remain as close as possible to this portfolio while enhancing its Solvency II characteristics. To achieve this, we apply constraints on the SCR (e.g. SCR Spread should not exceed 10%), and we use a target function which limits the discrepancy between the initial portfolio and the enhanced portfolio. To maximise the similarity between the two portfolios, we can set up the algorithm, using additional optimisation constraints, so as to force the enhanced portfolio to maintain certain key characteristics, such as the same average duration and yield as the starting portfolio.

This type of deviation target function achieves several objectives simultaneously:

- It avoids skewed portfolios – of course, provided they are not skewed to begin with, and if restrictions are not too tight
- It limits turnover – and therefore trading costs
- It ensures a low tracking error relative to the starting portfolio

Figure 4 illustrates that, the bigger the difference is between the starting and optimised portfolios, the more the SCR Spread can be reduced through the optimisation process. Yet incremental improvements become gradually smaller. Investors must find the balance between reducing SCR Spread as much as possible and incurring the additional trading costs that will stem from a greater tracking error.

Figure 4: Reduction of SCR Spread versus differences in starting & optimised portfolios

Source: HSBC Global Asset Management

To constrain the portfolio, we can use a variety of factors such as duration, credit quality step (i.e. the bond rating in Solvency II), or time to maturity. We can also include individual constraints such as a minimum or maximum amount of specific bonds or limits on the exposure to an industry sector. Of course, if the optimisation includes foreign-currency bonds, we will also have to take currency risk into account.

By including appropriate constraints in the optimisation process, insurers can design an optimised portfolio which offers the benefits of a diversified investment as well as securing a more attractive treatment under Solvency II. In addition, it can help avoid significant trading costs on any periodical rebalancing required to maintain the portfolio’s Solvency II efficiency.

Figure 4 measured as the sum of the squared difference in portfolio weights
Solvency II portfolio optimisation
Fixed income and credit portfolios

Optimising from a universe of investable securities

Instead of using a starting portfolio, we can also begin with a broader approach, using an approved and screened universe of investable securities. In this case, we can apply alternative optimisation approaches to avoid concentrated portfolios in a Solvency II framework.

One approach is to set constraints based on the relative yield-to-SCR attractiveness of investments: for example, if the yield of "bond A" is twice the yield of "bond B" for a given SCR, we can set the weight of "bond A" to be double that of "bond B". We can combine this with maximum weight constraints for individual securities and/or industry sectors. This approach places an even stronger focus on the Solvency II perspective by giving the relative yield-to-SCR values of bonds a central role in the optimisation process. On the downside, it ignores fundamental or economic considerations and concerns beyond the initial universe screening.

Currency Risk

SCR for currency risk applies an adverse shock of 25% to all currencies outside the insurer’s base currency (typically euro or sterling). Because each currency is shocked independently against the insurer’s base currency, the total SCR for currency risk can be very high. Most developed-market currencies do not offer enough yield pickup against the euro to justify so much additional regulatory capital, which generally induces insurers to set up FX hedging.

There are three exceptions, however:

1. Holding currencies with significant yield pickup (e.g. certain emerging-market currencies)
2. If a portfolio manager is able to deliver a significant return on SCR FX through directional trades
3. Using correlation benefits (e.g. a correlation coefficient of 0.25 to other SCRs)

Insurers rarely use pure FX products as a strategy to increase investment returns, and including them in a numerical optimisation may not make sense. In this kind of strategy, it is more efficient to use options rather than delta-one instruments, since any loss is limited to the option premium – which is typically far smaller than 25%. However, the strategy will have to take the specific characteristics of the options into account, such as time decay.

Insurers can make further Solvency II enhancements for bond portfolios that include foreign-currency bonds. First, we can use the method described earlier to optimise the SCR Spread of the portfolio. If we set an overall limit to the SCR, we might be able to allocate more “SCR budget” to FX, to enhance the expected return on SCR where risk budget is available. If we hold currencies with enough yield pickup, or where the strategy allows a partial substitution of FX and spread (as might be the case in some emerging markets strategies), we can also perform a numerical optimisation.
Solvency II portfolio optimisation
Equity portfolios

There are only three types of equity stresses under Solvency II: type 1 for EEA and OECD equities, type 2 for others, and a lower shock for infrastructure. This limits the possibilities in terms of numerical optimisations, but investors can take a discretionary approach.

Equity options can also play an important role in optimising a portfolio’s SCR Equity. Not all put options can be used for hedging under Solvency II: they must meet certain requirements to be recognised as a hedge. Where investors cannot use put options, they can use a call option instead of holding equity with a put option. The SCR for the relevant call option will be limited to the option premium, which will usually be substantially lower than the Solvency II equity stress of 39% (±10%).

As shown in Figure 5, choosing the right derivatives strategy to hedge the equity exposure will depend on the implied volatility, and on the symmetrical adjustment of the equity stress (high or low equity shock).

The strategy can also be static or dynamic – in a dynamic strategy, the investor will periodically re-strike the option, while taking into account the different volatilities related to the maturities. This is to minimise the negative carry of the equity exposure. For example, in periods of high volatility, short puts can be a Solvency II efficient way to gain equity exposure. This flexibility can allow insurers to tailor their equity exposure and hedging strategy to their specific requirements while optimising for SCR Equity.

<table>
<thead>
<tr>
<th>Simplified decision matrix</th>
<th>Implied volatility high</th>
<th>Implied volatility low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity shock high (e.g. 49%)</td>
<td>Options expensive, equity shock high</td>
<td>Options cheap, equity shock high</td>
</tr>
<tr>
<td></td>
<td>➔ Buying puts and selling options to finance puts (partly)</td>
<td>➔ Buying puts</td>
</tr>
<tr>
<td>Equity shock small (e.g. 29%)</td>
<td>Options expensive, equity shock small</td>
<td>Options cheap, equity shock small</td>
</tr>
<tr>
<td></td>
<td>➔ Selling puts with low strike to generate equity exposure and hedge of equities via future (hedging programme required)</td>
<td>➔ Buying puts</td>
</tr>
</tbody>
</table>

Source: HSBC Global Asset Management
Solvency II portfolio optimisation
Multi-asset portfolios

Multi-asset strategies typically employ a wide variety of instruments to achieve their target return within an economic risk budget. This flexibility can make it difficult to achieve a predictable level of Solvency II capital, but some relatively small adjustments can significantly improve Solvency II efficiency. For example, insurers can employ a bottom-up approach to enhance their multi-asset portfolios from a Solvency II perspective. We can begin by optimising at the asset-class level, following the approaches described earlier. We then have to analyse the universe of investable instruments, and where possible replace instruments that are Solvency II inefficient with comparable and more efficient instruments.

Avoiding inefficient instruments

One such category of inefficient instruments for a multi-asset portfolio is Type 2 equities, which include non-OECD equities as well as commodities, hedge funds and private equity. Generally, insurers will prefer to hold Type 1 equities that present similar return expectations, since their SCR stress is 10 percentage points lower than for Type 2, and since the diversification benefits of holding Type 2 are usually not enough to compensate for this.

Credit default swaps also tend to be inefficient under Solvency II. Selling CDS protection often leads to a higher SCR compared to an investment in a corresponding bond. Long-short strategies require SCR on both legs which is quite expensive in terms of capital. Further more Solvency II rules make it very difficult to consider credit default swaps to be an acceptable hedge for bonds.

Combining asset classes

After selecting the most Solvency II efficient format for each asset class, the next step is to combine the asset classes, for which Solvency II provides a fixed correlation matrix. It is important to be aware that these correlations are applied to an insurer’s overall investment portfolio, so some correlation benefits can occur at firm level. If the investment guidelines for the multi-asset portfolio incorporate the Solvency II correlations, and if the positioning within the portfolio does not constrain the overall positioning of the insurance company, there may be headroom to take on additional risk.

However, the extent of the correlation benefit depends on which Solvency II market risks are incorporated into the analysis. At the individual portfolio level, an external asset manager can only manage SCR Spread and SCR Equity without knowing overall exposures. They will not be able to manage SCR Interest, SCR Currency and SCR Concentration at the portfolio level, as other offsetting positions might exist elsewhere in the insurance company. Figure 6 outlines the overall process.

Figure 6: Multi-asset portfolio optimisation process for Solvency II

Selected universe of instruments and strategies for a multi-asset portfolio

Optimisation requirements and constraints
SCR Equity, SCR FX, SCR Spread and other constraints (e.g. modified duration, yield)

Elimination of Solvency II–inefficient strategies:
• Reducing universe and exposure (e.g. FX, commodities)
• (Different) use of derivatives
• Maximising diversification benefits

Optimised multi-asset portfolio

Source: HSBC Global Asset Management

Insurers can use the SCR calculations as a form of cross-asset risk measure, which can be dealt with in the same way as other traditional risk measures like Value-at-Risk or volatility. Investors can therefore apply traditional approaches, such as classical minimum SCR or maximum diversification approaches, within the Solvency II framework, to determine SCR-optimised multi-asset portfolios. Another option is to implement a modified SCR Risk Parity, in which the risk contribution of each SCR category (Equity, Spread, Interest) has the same contribution to total SCR. Of course, each insurance company will need to analyse and determine the approach that best meets their specific requirements and integrates within their general asset allocation process.

Note: For non-life insurers, it may be desirable to include SCR Interest Rate in the optimisation process if the insurer knows that the rest of its portfolio produces more than enough duration to offset the duration of liabilities. Any additional duration from a fixed income portfolio is then additive in terms of SCR, and the insurer may wish to limit this. This can be done within the strategy and without any further information on the interest rate sensitivity of the rest of the balance sheet.
Conclusion
A story of trade-offs

Because of the significant consequences of investment decisions on the capital requirements of insurers under Solvency II, it is no longer sufficient to optimise portfolios from a purely economic risk/return perspective. The good news is that insurers can use specific optimisation frameworks that take Solvency Capital Requirements (SCR) into account.

This paper has described two such frameworks. The first is designed to help insurers define their strategic asset allocation within a Solvency II context, while the second can help produce a more efficient tactical allocation at a portfolio level.

For both frameworks, we have also explored how to avoid some of the pitfalls of such optimisation exercises, such as asset concentration or skewed allocations, and identified some of the key trade-offs involved, both for strategic and tactical allocations.

Ultimately, each insurance company will need to design an investment strategy that achieves the right balance, for them, between the economic risk/return on the one hand, and the predictability and efficiency of Solvency II capital usage on the other.
Authors

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