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# Living with Solvency II: An economic capital perspective from recent history



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## EXECUTIVE SUMMARY

There is little doubt that Solvency II (SII) will have a significant impact on many aspects of how insurance companies operate in the future. Much has been written already about this and it remains fertile ground for discussion as debate continues over many details of the regulation.

The purpose of this report is not to go over this ground again in terms of the technical detail of the regulations. Instead, what appealed to us was the idea that we might bring some of the implications of Solvency II alive by:

- Creating a simplified but realistic UK *Model Life Company* (MLC)
- Imagining a world where Solvency II had been implemented before the global financial crisis (GFC)

The analysis undertaken in this report was made possible by marrying modelling techniques refined in industries outside the financial sector with significant advances in computing technology to gain insights that would previously have been out of reach. This report offers an illustration of how advanced modelling approaches can expand the body of actionable information to support management decision making.

The business questions we have considered and the results of the analyses undertaken so far are presented in this report, and a brief summary is provided below.

### **How would the capital requirements and solvency position of our Model Life Company have evolved during the turbulent market conditions of the GFC and its aftermath, and would it have remained solvent?**

To address this key question, we undertook a *daily* calculation of own funds and the solvency capital requirement (SCR) looking back in time through six calendar quarters when markets were under significant stress. Our results illustrate that:

- In a market value balance sheet world, balance sheet volatility can be acute, leading to highly material changes in solvency position over a short time frame.
- Despite being comfortably capitalised for the majority of the analysis period, our MLC would nevertheless have been technically insolvent (in breach of its SCR) during most of the first half of 2009.
- There is a genuine need for high-frequency solvency monitoring in this environment, both as an early warning system and also to provide a timely indication of the efficacy or otherwise of management responses to solvency threats.

### **How much difference will the matching adjustment really make to the level and dynamics of our MLC's solvency position?**

The final rules are not yet settled and at the time of writing the long-term guarantee assessment (LTGA) exercise has just commenced in an attempt to move the debate forward. However, we felt sufficient clarity existed around the general approach to enable its effect to be modelled and evaluated. We found that:

- The matching adjustment (MA) is likely to have a very significant positive impact on MLC's solvency position. In particular, its introduction would have enabled MLC to avoid breaching its SCR during 2009.

- The MA can provide substantial mitigation of credit-spread-driven balance sheet volatility, through a wide range of financial conditions. For example, during the first half of 2009, the range of variation in the surplus capital of our MLC would have been reduced by around 70%—a result we are not aware of having been previously calculated using a fully functional economic capital model.

### **Internal model approaches to the evaluation of economic capital capture balance sheet dynamics across thousands of multivariate risk scenarios. How can this information be leveraged to aid management in understanding the risk profile of the business, not only at specific points in time, but also in light of regulatory or market change?**

As an extension to the historical balance sheet analysis, we aimed to get further insight on these issues by drilling down into the characteristics of the individual scenarios driving the SCR through history.

- Of the thousands of scenarios executed each day, only a few regularly drive the SCR, but the exact scenarios which dominate change over time with financial conditions. Analysing these *dominant* scenarios, we found it possible to identify a very small number which provide a robust proxy for MLC's solvency position. Such scenarios could provide baseline reverse stress tests for MLC which are consistent with the internal model. They can also serve as a powerful tool to build intuition about the business.
- We studied the level of the individual risk factors within the scenarios driving the SCR to evaluate the reasonableness of the internal model. For example, we were able to consider the directional exposures to interest rate and inflation risks, how they changed with underlying market conditions and whether this could be reconciled with known features of our MLC's portfolio of assets and liabilities. The ability to consider this across a large number of business days (360 in this case) provides much greater confidence than can be obtained through infrequent formal valuation points.
- Regulatory changes can impact a company's risk profile and necessitate prompt management action to realign risk profile with risk appetite. We looked for evidence of this on introducing the matching adjustment into our MLC's balance sheet, finding interest rate exposure to be a particularly interesting illustration of this point. Being slightly long on duration, the MLC is generally exposed to a rise in interest rates, and this is a key feature of the scenarios driving its SCR. When the MA is introduced, it acts to shorten the liabilities, exacerbating the mismatch, which increases the influence of interest rate stresses in determining the SCR. Thus, understanding these effects can allow asset portfolios to be rebalanced in response.
- However, while the MA at least should have a degree of permanence, we note that the counter-cyclical premium (CCP) is likely to be particularly challenging, which is due to its transient nature. There is a risk here that upon its introduction many insurers will seek to implement similar asset rebalancing strategies, resulting in exaggerated shifts in market prices—it would indeed be ironic if the CCP itself were to generate an element of pro-cyclicality.

### **Can we validate the reasonableness of the SCR using historical experience?**

The short answer is *yes*. With data available over 360 business days, we are able to perform a statistical back-test based on a daily equivalent of the SCR. The SCR, being a 99.5% VAR measure, would contemplate two breaches over this period, and we noted that our MLC did indeed experience two breaches. Had the number of breaches been materially higher, for example, then this should raise a warning flag identifying potential mis-calibration of the internal model and the need for close monitoring and possible subsequent review. Hence, the ability to undertake such tests on a regular basis provides comfort over the reasonableness of the MLC's SCR.

## INTRODUCTION TO MLC

Our MLC is a relatively simple operation with a single life fund. The MLC's historical focus has been on nonprofit business, in particular:

- Fixed annuities in payment
- Inflation-linked annuities in payment (RPI, LPI types)
- Deferred annuities
- Unit-linked pensions business with minimal guarantees

Our MLC's approach to asset management has traditionally been to match liabilities quite closely using a diverse portfolio of bonds, money market instruments and derivatives. Duration is monitored and matched within a set tolerance using a combination of conventional and index-linked gilts, corporate bonds with both fixed and floating coupons across a wide range of credit grades, and interest rate swaps. The portfolio is currently slightly long, though duration remains within the target range. Liquidity requirements are managed by holding roughly three months' of annuity outgo in cash or money market instruments (term deposits, CDs, commercial paper). Mitigation of inflation risk is addressed through holdings of UK index-linked gilts and zero-coupon inflation swaps. The deflation floor in the annuity liabilities is currently unhedged. Currently, the liabilities are denominated solely in sterling and so investment has been constrained to sterling-denominated assets. Finally, within the constraints imposed by risk management, the MLC seeks to enhance portfolio yield where possible to improve returns to both shareholders and policyholders.

### Advancing modelling capabilities with Milliman ECSight

Solvency II preparations had a significant impact on our MLC's actuarial systems. The Solvency II programme has consolidated and rationalised traditional cash-flow asset-liability management (ALM) work, resulting in a more robust, streamlined and automated cash-flow valuation process.

Building on these foundations, to further align the modelling function with the business process, our MLC sought a solution to extend modelling capabilities in a way that provided senior management with valuable and actionable model-based data, as frequently as daily, to make informed business decisions. Specifically to:

- Provide a daily or, in stressed market conditions, even more frequently updated view of certain risk and capital metrics such as:
  - Capital resources/own funds
  - Capital requirements and excess capital levels on both a regulatory and internal basis
  - Risk exposures (Greeks)
- The objective is to enable our MLC to track closely its solvency position and react very quickly to any material changes.
- Investigate our MLC's solvency experience through the use of actual historical scenarios and also looking forward via projections of excess capital to provide insights into balance sheet volatility and the effectiveness of the MLC's current ALM strategy.
- Analyse the impact of potential regulatory change. For example, the introduction of measures such as the matching adjustment and counter-cyclical premium currently under investigation by the European Insurance and Occupational Pensions Authority (EIOPA).
- Deliver a validation of the SCR using an approximate daily back-test over an extended period.

- Model assets at an individual level to enable the MLC to evaluate the impact on risk and capital of detailed refinements to individual asset selection and quickly road-test the impact of a range of potential management decisions which might be taken. (This area of analysis is outside the scope of the current paper.)

To address these requirements, our MLC adopted ECSight™ from Milliman. Further information about ECSight is provided in the appendix.

### MLC financial position at 30 December 2011

Our MLC has calculated its market value balance sheet under Solvency II, and on 30 December 2011 the results were as shown in Figure 1.

**FIGURE 1: MV BALANCE SHEET 30/12/11**

MV BALANCE SHEET 30/12/11			
NON-PROFIT FUND		£M	£M
ASSETS	9,630	LIABILITIES	8,630
DEFERRED TAX	80	BEST ESTIMATE LIABILITY (MODELLED)	8,290
INVESTMENTS	8,560	ORDINARY BRANCH	8,290
CASH	130	PENSIONS	8,290
CORPORATE BONDS	4,100	CONVENTIONAL NON-PROFIT	7,270
CQSTEP0	480	ANNUITY (INFLATION LINKED)	1,210
CQSTEP1	460	ANNUITY (NOT INFLATION LINKED)	5,490
CQSTEP2	1,600	DEFERRED ANNUITY	570
CQSTEP3	1,030	UNIT-LINKED	1,020
CQSTEP4+	530	UNIT RESERVES	890
DERIVATIVES	240	STERLING RESERVES	130
INTEREST RATE SWAPS (IRS)	230	OTHER LIABILITIES	120
SWAPTIONS	10	RISK MARGIN	220
ZERO-COUPON INFLATION SWAPS	10		
EQUITIES	5		
GOVT BONDS	4,090		
LINKED ASSETS	910		
OTHER ASSETS	90		
REINSURANCE RECOVERABLE	-		
		<b>CAPITAL RESOURCES / OWN FUNDS</b>	<b>1,000</b>

Capital resources, on an SII basis, are more than £300 million lower than under the current Solvency I valuation basis, which is primarily due to the removal of the allowance for an illiquidity premium on the bond portfolio in establishing the valuation interest rate to be applied to the liabilities. The additional risk margin required under Solvency II was at least partially offset by the removal of margins for adverse deviation from the current valuation basis.

Our MLC calculates the solvency capital requirement (SCR) on the basis of an internal model. The approach has been to analyse the MLC's assets and liabilities and identify the key risk drivers for the business. Multivariate risk scenarios are then developed to capture the behaviour of these risks and the dependencies between them (capital for some risks, e.g., operational risk, is to be assessed outside of this process using specialist models). The process is then to generate a distribution of capital results using thousands of these multivariate risk scenarios from which the SCR (99.5% VAR) can be derived.

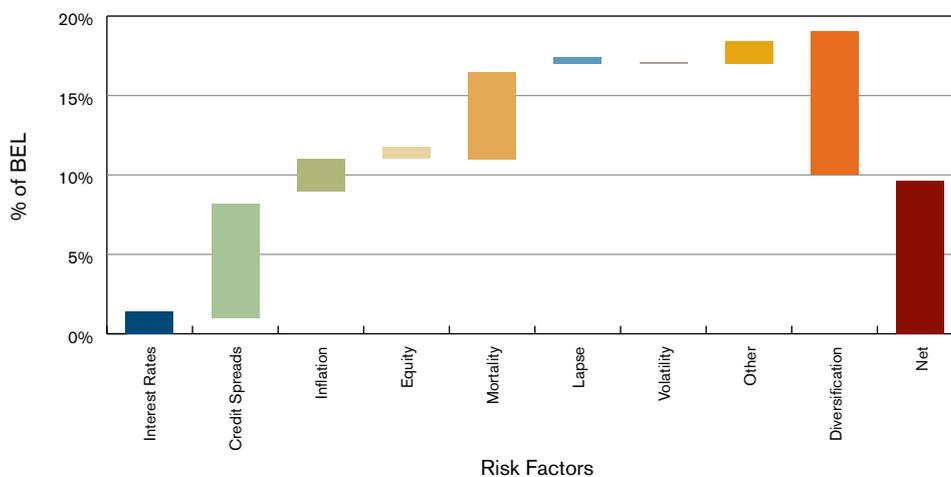
## Hands-On With ECSight: Calibration Steps

Our MLC calibrated ECSight. This involved:

1. Uploading the in-force asset portfolio and calibrating to current market values.
2. Generating liability values from the cash-flow ALM under a range of multivariate scenarios to provide fitting points for the proxy model of liabilities. The proxy model employs multi-dimensional spline interpolation using radial basis functions to provide estimates of liability values as both market and non-market risk factors vary. See the Appendix for more detail.
3. Uploading fitting data and ensuring that the resulting proxy model meets accuracy tolerances.
4. Reviewing the parameterisation of the risk scenario generator (RSG), producing the required multivariate risk scenarios and up loading them to the system.

A breakdown of our MLC's SCR at 30 December 2011 is illustrated in Figure 2, where BEL is best estimate liability excluding unit reserves.

FIGURE 2: SCR AS A % OF BEL



The current statutory minimum solvency margin (SMSM) under Solvency I is just over £300 million. The SCR which would apply under SII exceeds £600 million and consequently Solvency II represents a significant increase in our MLC's required capital. Combining the impacts on capital resources and required capital and defining the *regulatory capital coverage ratio* (RCCR) as capital resources/required capital, we see a reduction from more than four times cover under Solvency I to 1.6 times under Solvency II. This reduced level of capital buffer, together with the increased balance sheet volatility anticipated under Solvency II, is a significant area of concern for our MLC's board and senior management.

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## SOLVENCY II BALANCE SHEET THROUGH THE FINANCIAL CYCLES

In addition to the 30 December 2011 snapshot of the Solvency II balance sheet, our MLC management wanted to understand the potential volatility of the balance sheet as market conditions change. This information is crucially important to the MLC in order to set capital buffer targets and to develop a course of action to manage the volatility.

For this analysis, our MLC could have utilized ECSight to develop balance sheet results under a range of *what-if* market scenarios. However, recent history actually provided sufficiently *interesting* experience without the need to invent challenging scenarios, and also ensured that analysis was based on realistic market situations. The MLC chose to analyse three historical market periods, each spanning two quarters.

### Period 1: April-October 2008

Build-up in the banking crisis arising from losses in the sub-prime mortgage market culminated in the bankruptcy of Lehman Brothers Holdings Inc. investment bank in mid-September.

Falling equity markets and increasing equity implied volatility were seen. The FTSE 100 hovered around 6,000 early in the period but finished below 5,000.

Interest rates were relatively stable, with a downward-sloping LIBOR swap curve rising slightly around the middle of the period but subsequently falling back again.

Credit spreads widened over this period. The spread on AAA-rated instruments more than doubled from around 20 bps to more than 45 bps by the end of September. For BBB-rated instruments, the impact was relatively less but in absolute terms much higher, with spreads rising about 90 bps over the period (from 260 to 350).

### Period 2: January-June 2009

The banking crisis has deepened. The UK government bails out the Royal Bank of Scotland (RBS), credit spreads blow out to historic highs, US house prices fall into a trough and AIG files the largest reported quarterly loss in corporate history.

Equity markets continue to fall, with the FTSE 100 reaching a nadir of 3,500 in early March before recovering to finish the period at 4,200.

Interest rates fall significantly, with short rates falling most, to produce a steeply upward-sloping yield curve at the short end. Further out, the curve was flat, with little difference seen between 10- and 30-year LIBOR swap rates.

Credit spreads widen further, in spectacular style. The spread on AAA-rated instruments reached 100 bps—five times their level in spring 2008, just a year earlier. For BBB-rated instruments, the impact was relatively less but in absolute terms much higher, with spreads reaching 700 bps, up from around 250 bps a year before.

### Period 3: April-October 2011

The sovereign debt crisis in the Eurozone has intensified in the run-up to the second bailout of Greece in October.

Stable UK equity market levels (with the FTSE 100 around 6,000), with implied volatility relatively low around 20%. This picture prevails until August, when the FTSE 100 falls rapidly to around 5,000 and volatility spikes up toward 30% again, as uncertainty takes hold with concerns over the bailout of Greece and a possible break-up of the Eurozone.

## Hands-On With ECSight: Historical Analysis

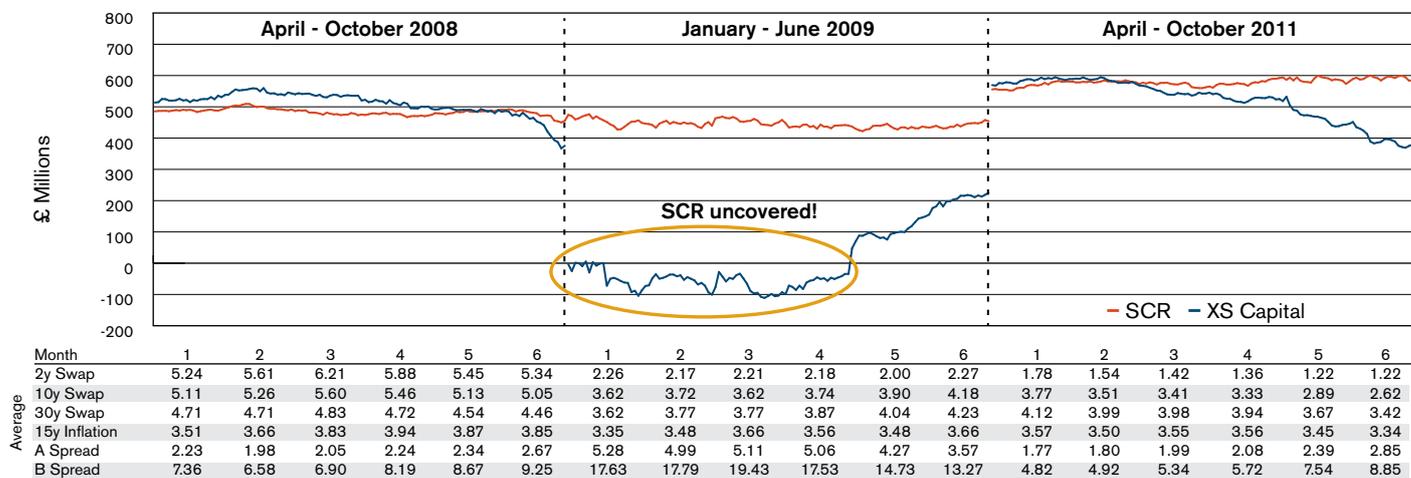
We first supplied ECSight with daily data for each historical period and for all market risk factors to form a set of daily baseline valuation scenarios. These baseline scenarios were then combined with the multivariate risk stresses, required for the calculation of the SCR, to develop the full set of valuation scenarios required.

We next performed 360 daily own-funds and SCR calculations (1.8 million balance sheet valuations in total). Leveraging the Microsoft Azure cloud, computational resources can be scaled quickly and easily on demand (more than 3,000 compute nodes were utilised for our MLC's analysis).

In less than six hours, we obtained granular data for all components of the balance sheet for each day's baseline and all stresses, a result which would have been unattainable with prior-generation tools.

Interest rates continue to fall across the term structure, now most pronounced at the long end, with the 10-year LIBOR swap rate falling from close to 4% in spring 2011 to 2.5% by the end of September. Credit spreads have eased back from the highly elevated levels seen in 2009, with AAA-rated instruments back to around 50 bps and BBB-rated to 250 bps. However, starting in August, spreads widen once again out to 65 bps for AAA-rated instruments and 365 bps for BBB-rated by the end of Q3.

FIGURE 3: DAILY HISTORICAL SCR AND EXCESS CAPITAL POSITION



### Observations

Our MLC's senior management could take some comfort from the reasonably sizable excess capital position resulting during the first period. However, towards the end of the period there is evidence of deterioration. Having been still fairly comfortably capitalised just one quarter beforehand, we find the MLC starting 2009 technically insolvent and remaining in that parlous state until early May.

The general pattern of experience from April 2011 to October 2011 for our MLC has similarities to its experience in the 2008 analysis period—a healthy initial position in the early stages showing a marked decline as time progresses. In this case, solvency is actually stronger through April and May, but the decline after that is faster and more pronounced than during the same period in 2008.

For our MLC's senior management, this analysis confirmed earlier concerns about potential balance sheet volatility in a post-Solvency-II world and the consequent need to be able to monitor its solvency on a highly frequent basis to provide both an early warning of adverse changes and a timely indicator of the efficacy or otherwise of management's responses.

## IMPACT OF MA AND CCP

The reduction in our MLC's regulatory solvency from the elimination of the allowance for an illiquidity premium in the valuation of liabilities is a major concern. However, the prospect exists for some mitigation through two measures currently being hotly debated as part of the SII implementation process, namely:

- **Matching adjustment (MA):** Essentially an illiquidity premium implemented by adjusting upwards the basic risk-free interest rates used to value liabilities under SII. The adjustment is most clearly applicable to classes of illiquid liabilities such as traditional annuities in payment.
- **Counter-cyclical premium (CCP):** Similar to the MA, this is an adjustment to the risk-free interest rates used to value liabilities under SII. The CCP is aimed at preventing pro-cyclicality during times of market stress by reflecting depressed market values of assets in the value of liabilities. The introduction and removal of the CCP will be determined by regulators and the adjustment cannot be applied to any blocks of business already taking credit for the MA.

Potential formulations for both measures are the subject of the forthcoming long-term guarantee assessment (LTGA) exercise sponsored by EIOPA and now under way.

Given the likely materiality to our MLC of the MA in particular, and given its substantial book of annuity business, it was deemed a priority to investigate and understand the potential beneficial impact of the introduction of these measures. The fine detail of how the measures are to be specified is still to be confirmed, but based on current understanding of the likely methodology, the MLC adopted the approach described below.

### Quick background and key assumptions

At the time of development, it was unclear how (or even if) the MA would be adjusted in some way when calculating the SCR. A proposal is now emerging as part of the LTGA impact testing exercise and will be added to our MLC's assessment in due course. For the time being, the MA remains unchanged in the SCR stresses.

Our MLC also considered the impact of a CCP. The derivation of the level of any CCP is still to be set out by EIOPA, so the MLC adopted a benchmark CCP of 100 bps as an uplift to the risk-free curve in the valuation of all liability types. When further details of the CCP derivation become available, the intention is to build the ability to track the potential CCP over time so that the impact of it being *switched on* can always be judged. Similarly to the MA, the approach to be taken to the adjustment of any CCP under stress conditions has been the subject of debate and conjecture. At the time of writing it appears that the CCP may be completely eliminated when calculating the SCR, thus wiping out the great majority of the benefit to capital resources via a largely offsetting increase in required capital. For this reason, the results presented focus on the more meaningful impact of the matching adjustment.

## Hands-On With ECSight: MA Analysis

First, the in-force asset portfolio was reviewed to establish which assets would not be eligible to contribute towards the MA. Assets flagged as ineligible included callable bonds, floating rate bonds and some corporate bonds with ratings below credit quality step 3 (essentially BBB).

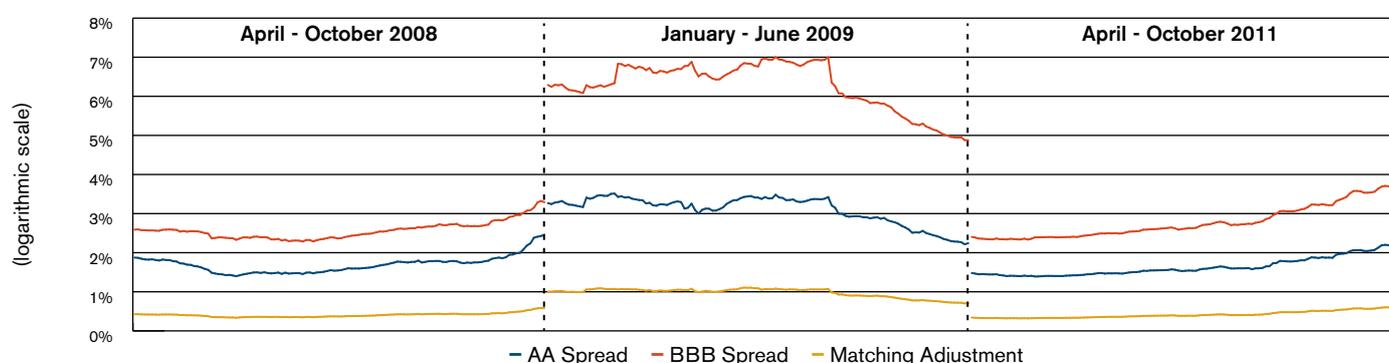
Both the tagged asset portfolio and assumptions regarding fundamental spreads for the various eligible bond types were uploaded to the system.

The initial MA spread from our MLC's asset portfolio was then calculated and applied as a level uplift to the risk-free curve when valuing annuity liabilities.

## MA and spread evolution

The MA is a weighted average of the spreads on eligible bonds and so it will not track any particular spread index exactly. However, considering spreads on AA- and BBB-rated bonds, it can be seen that the matching adjustment follows the general shape of progression on spreads. Given our MLC's significant exposure to credit fluctuations, these results point towards a material counter-cyclical effect which should help to stabilise the company's excess capital, reducing both its standard deviation and range of variation. Figure 4 provides some insight into this effect as it illustrates the progression of the matching adjustment itself over the period considered.

**FIGURE 4: EVOLUTION OF MATCHING ADJUSTMENT AND SPREAD**



## MLC balance sheet impact of the MA at 30 December 2011

The MA increased our MLC's capital resources by £450 million, while the increase from the CCP was more than £800 million. In both cases, there was a small offsetting increase in the SCR: £5 million for the MA and around £30 million under the CCP.

While the MA calculation is developed based on individual asset-by-asset valuations, it is possible to get a general sense of what drives MA at an aggregate level. For example, let's consider the balance sheet on 30 December 2011. As of that date:

- The eligible assets are (by market value) about 50% sovereign, 15% corporate BBB-rated bonds, and 35% corporate A- through AAA-rated bonds (proxied by AA class).
- The BBB index spread is around 3.89%, the AA index spread is around 1.85%.
- Our market-weighted fundamental spread for BBB- and AA-rated bonds in our portfolio is estimated to be 1.57% and 0.54%, respectively.<sup>1</sup>

Because about half of our eligible portfolio is sovereigns, only about 50% of the spreads will actually flow through to the MA. We estimate that our spread contribution within eligible bonds would be about 0.65%, or 50% of (1.85% - 0.54%), if our corporate bond portfolio consisted of a representative AA-rated bond. This compares to 1.16%, or 50% of (3.89% - 1.57%), if it was a representative BBB-rated bond. Factoring in the actual portfolio allocation, we arrive at a value close to the actual MA contribution from eligible bonds, which on that day was calculated to be 0.72% (which further reduced to 0.60% following a pro rata adjustment to reflect the presence of some ineligible assets).

<sup>1</sup> The fundamental spread represents an allowance for the risk default and downgrade.

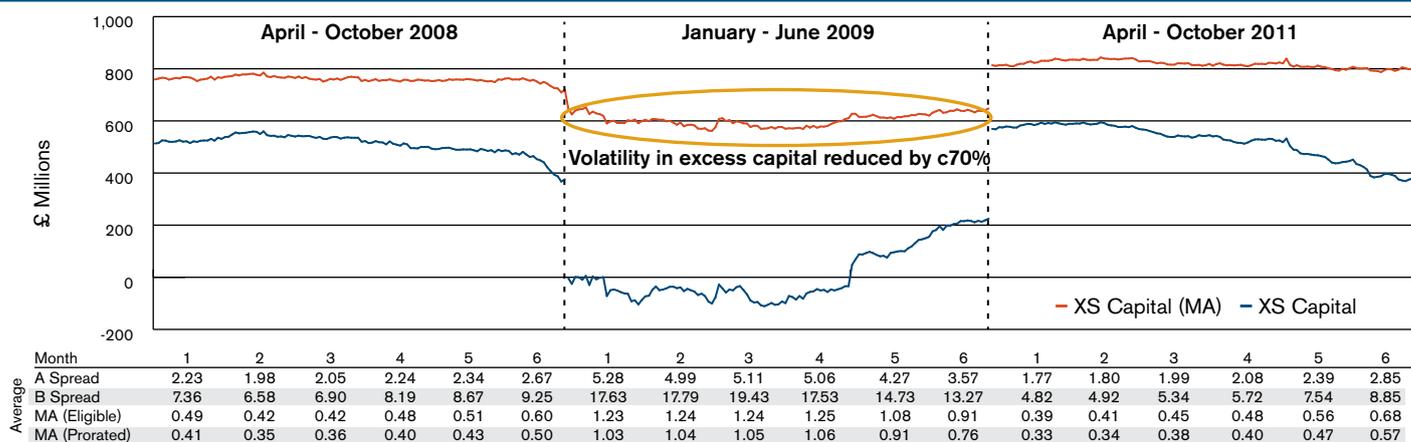
As such, we see that the asset allocation between credit classes is strongly reflected in the MA, and that allowance for MA within the regulatory framework could have a significant impact on management considerations about investing in specific bond types and credit classes to optimize trade-offs between incremental returns and capitalization requirements.

#### MLC balance sheet impact of the MA through the financial cycles

Incorporating derived matching adjustments into historical valuations, our MLC can now evaluate the relationship between its solvency position and changing market conditions and the extent to which the MA in particular could be expected to provide mitigation in times of stress. Figure 5 illustrates the following:

- **XS Capital:** Represents the daily surplus of the MLC's own funds over its SCR, again on an unadjusted risk-free rate basis
- **XS Capital (MA):** Sets out the same result but allowing for the introduction of the matching adjustment in the valuation of the MLC's liabilities

**FIGURE 5: EFFECT OF MATCHING ADJUSTMENT ON DAILY HISTORICAL EXCESS CAPITAL POSITION**



**FIGURE 6: VOLATILITY OF EXCESS CAPITAL MOVEMENTS (£M)**

PERIOD	RANGE		STDEV	
	NO MA	MA	NO MA	MA
APR - OCT 2008	193	76	38	11
JAN - JUN 2009	336	90	104	24
APR - OCT 2011	226	56	69	14

### Observations

In the first period, the impact of the matching adjustment is significant and its introduction would have improved our MLC's excess capital by around 50%, from c£500 million to c£750 million. In particular, the elevated solvency seen on an unadjusted basis from May to July is largely eliminated by a lower MA during these months. Conversely, when unadjusted solvency begins to fall quickly from late August, the inclusion of the MA provides significant mitigation. For example, from August 15 until September 26 unadjusted excess capital fell 22% from £483 million to £376 million, but inclusive of the MA the reduction was a mere 5%, down from £755 million to £720 million; the increase in the level of the MA driving this support can be seen in Figure 6.

During the second period, once again, the matching adjustment would have been highly effective at both enhancing and stabilising the solvency position of our MLC. Excess own funds have been maintained around £600 million, a reduction from the £750 million seen in the less stressed period in 2008 but still a reasonable position given the very challenging market conditions at the time.

Even more dramatically, the extent of variability in the excess capital position has been cut by around 70%.

Credit spreads during the first half of 2009 had roughly doubled from those experienced in the 2008 analysis period. In line with this, we see the matching adjustment running at about 120 bps compared with the earlier level of around 50 bps. This elevated matching adjustment has provided substantial support to our MLC's solvency position. From early May 2009, the matching adjustment begins to fall as spreads tighten once again, and this dampens the rapid improvement in the MLC's solvency, which is observed on an unadjusted basis.

In the third period, once again, the matching adjustment has operated effectively to stabilise the position.

The MA has been effective in delivering the twin benefits of improved recognised solvency levels and mitigation of spread-driven volatility in our insurer's market value balance sheet.

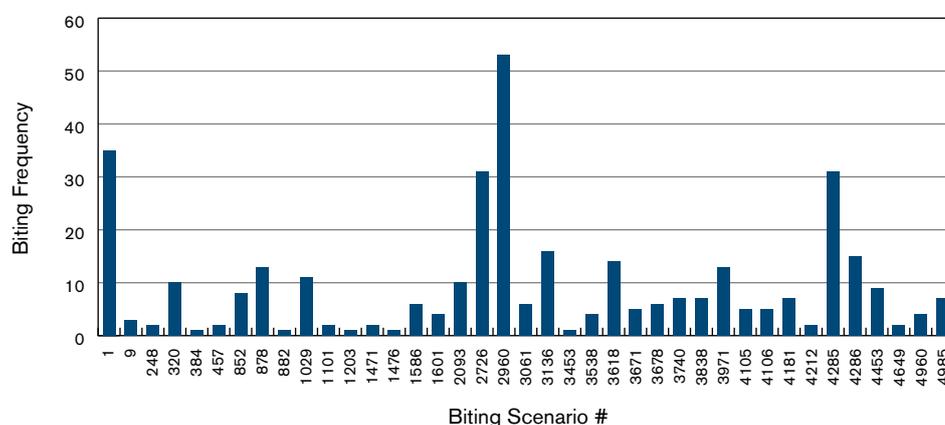
## UNDERSTANDING THE RISK PROFILE THROUGH HISTORICAL SCR ANALYSIS

In this section we turn our attention to the risk scenarios which generate the SCR and explore the informational content to support further analysis and decision making.

### How many scenarios actually bite, which ones are they, and what are their characteristics?

The first step was to consider the extent to which the biting stress scenario (i.e., the scenario generating the 99.5% VAR result for the SCR) changed over time.

FIGURE 7: HISTORICAL ANALYSIS: SCR BITING SCENARIOS



The simple histogram in Figure 7 illustrates that, over the 360 business days considered, 39 different stress scenarios drove the 99.5% SCR value for our MLC. However, what is clear from Figure 7 is that there was a much smaller number of scenarios which bit on a regular basis. Taking, arbitrarily, a cut-off value of 10 days, then we find 11 *dominant* scenarios. Looking further into this we also find that the dominance of these scenarios changes markedly over the different periods, as shown in Figure 8.

HISTORICAL ANALYSIS - SCR BITING SCENARIOS BY PERIOD

SCENARIO #	Q2-Q3 2008	Q1-Q2 2009	Q2-Q3 2011
1	0	35	0
320	0	10	0
878	0	2	11
1029	0	11	0
2093	0	10	0
2726	12	0	19
2960	18	0	35
3136	0	0	16
3618	2	0	12
3971	12	0	1
4285	31	0	0

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The rows in Figure 8 have been marked to characterize different types of scenarios. Grey is for scenarios dominant in Period 1 but with little biting power afterward. Green is for scenarios dominant in Period 2 but with little biting power before or after. Orange is for scenarios dominant in Period 3 but with little biting power before. And blue is for scenarios dominant in both Periods 1 and 3 but not Period 2.

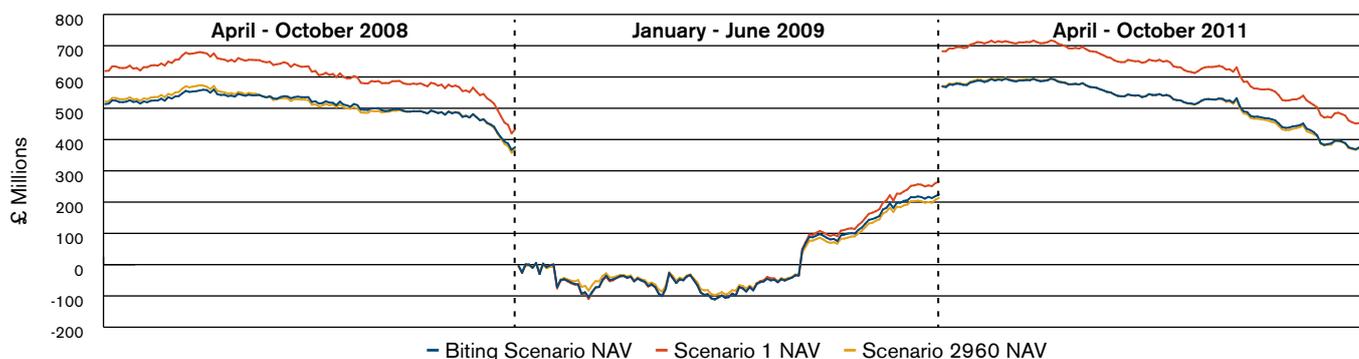
### Observations

- These results echo the general nature of market conditions and point to a tendency for a small number of stress scenarios to be problematic for our MLC. But the problem scenarios change as underlying financial conditions move.
- The dominant scenarios can be quite different in character. Taking the two *blue* scenarios (to which we will return later), we find that:
  - Scenario 2726 exhibits inflation up, spreads widening, a steepening of the yield curve (long-end up) and increasing longevity.
  - Scenario 2960 exhibits inflation down, spreads widening more than Scenario 2726, steepening of the yield curve (short-end up) and increasing longevity.
  - Clearly, biting scenarios, even those which dominate within a particular period, do not reflect any unique combination of risk-factor outcomes, which implies they would be difficult to identify reliably in advance.
- The results set out are based on the SCR calculated using unadjusted risk-free rates, i.e., excluding the matching adjustment. With the matching adjustment included, there appears to be a tendency for the number of scenarios which bite to fall and for those scenarios which do bite to differ from those in the unadjusted case. A likely driver of this different behaviour is that implementing the MA also changes (shortens) the duration of our MLC's liabilities. For the same asset portfolio, the MLC is now a little more mismatched. Recall that the MLC was already slightly long on duration, and so has greater exposure to rises in interest rates.

As we said earlier, it is challenging to establish, in advance, specific scenarios which will bite to drive the SCR. However, the modelling output did enable our MLC to investigate the *dominant* scenarios to establish if one could be found which would have provided a very good proxy for the SCR over the analysis period considered.

Figures 9 examine two *dominant* biting scenarios and illustrate our MLC's excess capital under each of those scenarios on each business day, compared with the excess capital under the actual biting SCR scenario. Scenario 1 is a *green* type of scenario (per Figure 8) and bites regularly during the 2009 period but not outside that. On the other hand, Scenario 2960 is a *blue* type, biting frequently in the first and last but not in the middle period.

FIGURE 9: SCR PROXY SCENARIO ACCURACY



The analysis illustrates the quite different behaviour of these two biting scenarios. Scenario 1 clearly tracks the SCR NAV level closely during the majority of the 2009 period. However, outside of this period the NAV calculated on this scenario is materially higher than the SCR. The behaviour of Scenario 2960 is rather different. During 2008 and 2011 it can be seen to track the NAV level of the SCR closely—this is consistent with our biting results and classification. However, unlike Scenario 1, Scenario 2960 also tracks the SCR NAV well during the period in 2009 during which it does not actually appear at all as the biting scenario. The other *blue* type is Scenario 2726 and this exhibits slightly poorer but similar performance to Scenario 2960.

In summary, Scenarios 2726 and 2960 appear to offer a robust proxy for our MLC's solvency position under the SCR as illustrated in Figure 10.

FIGURE 10: PROXIES FOR MLC SOLVENCY POSITION

SCENARIO	MEAN ABS DAILY ERROR V SCR (£M)	MAX ABS DAILY ERROR V SCR (£M)
2726	6	22
2960	12	35

- There are a small number of dominant scenarios which drive the SCR.
- The dominant scenarios vary with market conditions and exhibit different risk factor characteristics, making ex ante identification very difficult.
- Historical analysis can reveal dominant scenarios able to act as a powerful *proxy* for the estimation of the SCR, which can:
  - Facilitate baseline reverse stress tests consistent with the internal model
  - Aid in developing intuition about the business in an efficient and accessible manner

**Is the nature of the scenarios which drive the SCR consistent with management's expectations?**

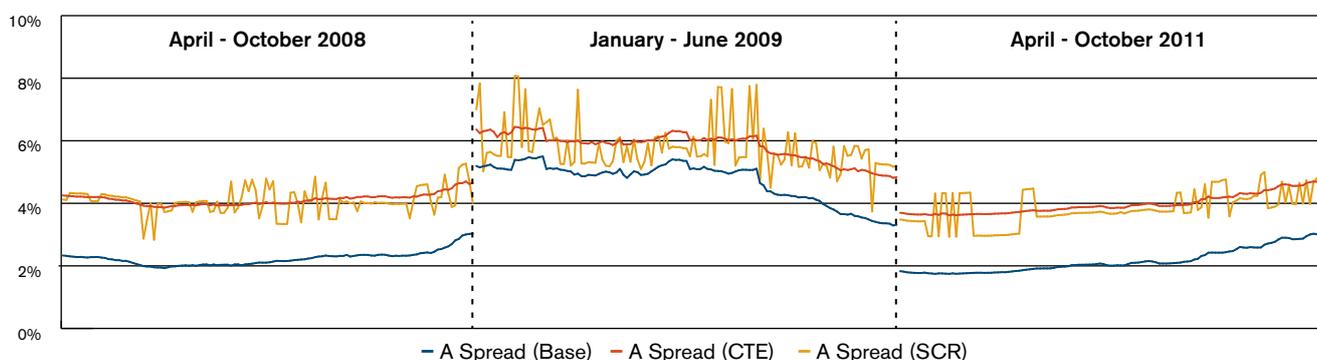
Considering the nature of the SCR biting scenarios more broadly, our MLC undertook an analysis of the parameter values of certain key risk factors within each biting scenario to ascertain whether the values of these risk factors were broadly consistent over time or not and whether they *made sense* in light of management's understanding of the business.

In Figures 11 to 14 we illustrate, for a variety of risk factors:

- **Base:** Observations in the base scenario (i.e., prior to any stresses being applied) on each day
- **CTE:** A weighted average of observations in the tail (worst 0.5% of scenarios) on each day
- **SCR:** Observations in the biting SCR scenario (99.5% VAR) on each day

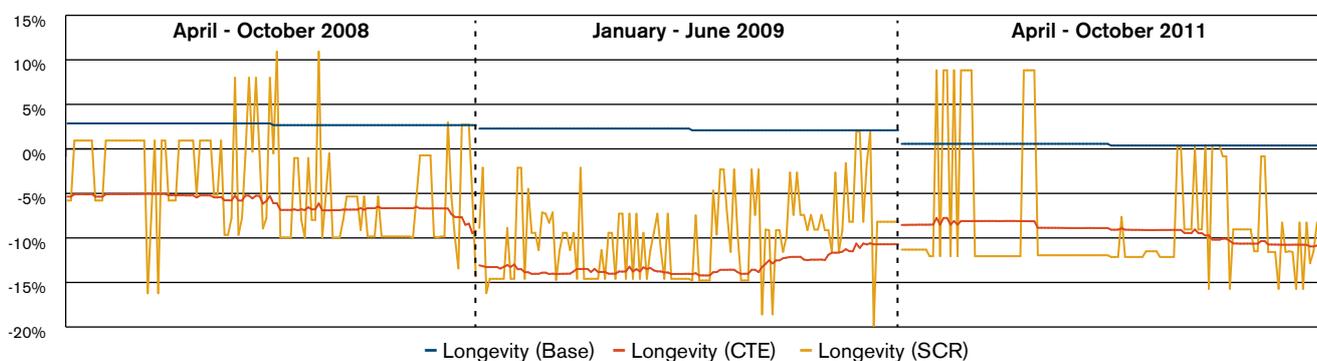
Looking first at credit spreads, we see in Figure 11 that the SCR biting scenarios are, as expected, associated with substantial increases in credit spreads. The generally similar conditions in the first and last periods are clear, as is the very different and much more volatile experience within the 2009 period.

**FIGURE 11: A SPREAD: SCR BITING SCENARIO AND TAIL SCR-WEIGHTED AVERAGE**



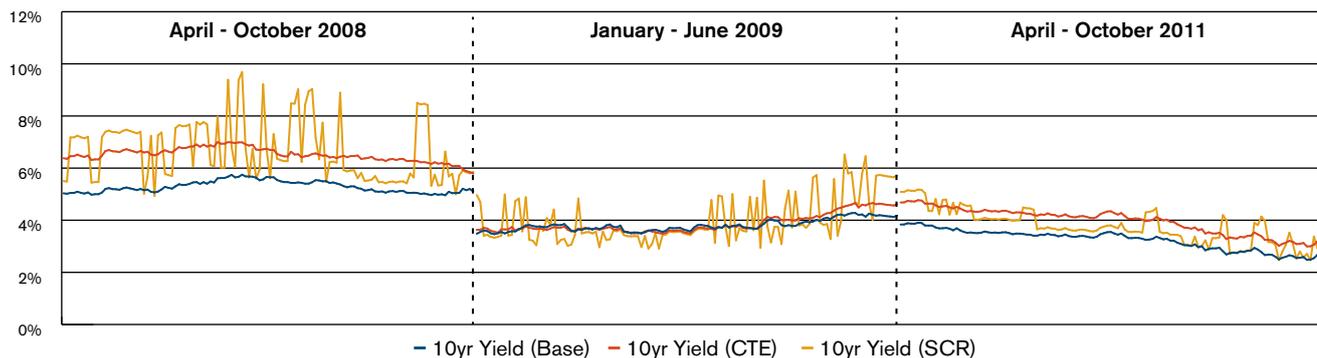
Turning next to longevity, we see in Figure 12 that improvements prevail in the SCR stresses, as expected. However, the extent of them in the biting stresses varies considerably and there are several instances where the biting scenario actually contains deterioration in longevity. However, considering Figure 11, it appears the relief from benign longevity was likely offset by particularly high stresses on spreads.

**FIGURE 12: SCR BITING SCENARIO AND TAIL SCR-WEIGHTED AVERAGE**



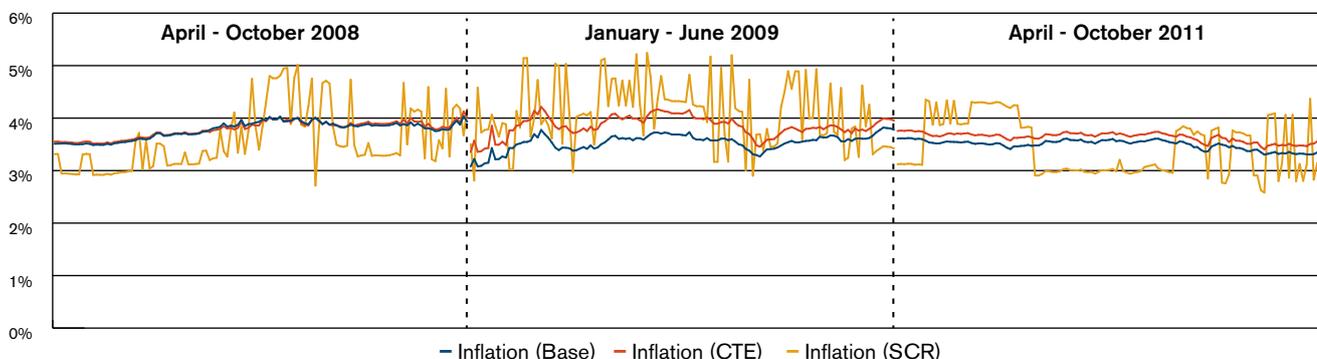
With interest rates, long rates have the most impact on our MLC and the 10- and 30-year rates display similar characteristics. The 10-year rates are illustrated in Figure 13. During the period in 2008, SCR stresses are very predominately associated with rates up—this is consistent with our MLC’s fixed income portfolio being slightly long. In the period in 2009, rates have fallen markedly and the interest rate component of the SCR stresses has become more balanced between rates up and rates down scenarios. This implies a closer matching between the MLC’s assets and liabilities. Such a position is plausible as credit spreads have widened significantly, reducing the overall duration of the fixed income portfolio without impacting the liabilities. With interest rates playing a less material role in the SCR over this period, other factors might be expected to come more to the fore. It can be observed that the level of the longevity stress is generally greater and more consistent in this period compared with 2008. There is also some evidence (in Figure 14) of a more consistent upwards stress to inflation being a feature of the SCR biting stresses during 2009. By 2011, spreads had tightened again and the general upward pattern of interest rate stresses in the SCR had reasserted itself.

**FIGURE 13: 10-YEAR YIELD: SCR BITING SCENARIO AND TAIL SCR-WEIGHTED AVERAGE**



Inflation patterns are shown in Figure 14.

**FIGURE 14: INFLATION: SCR BITING SCENARIO AND TAIL SCR-WEIGHTED AVERAGE**

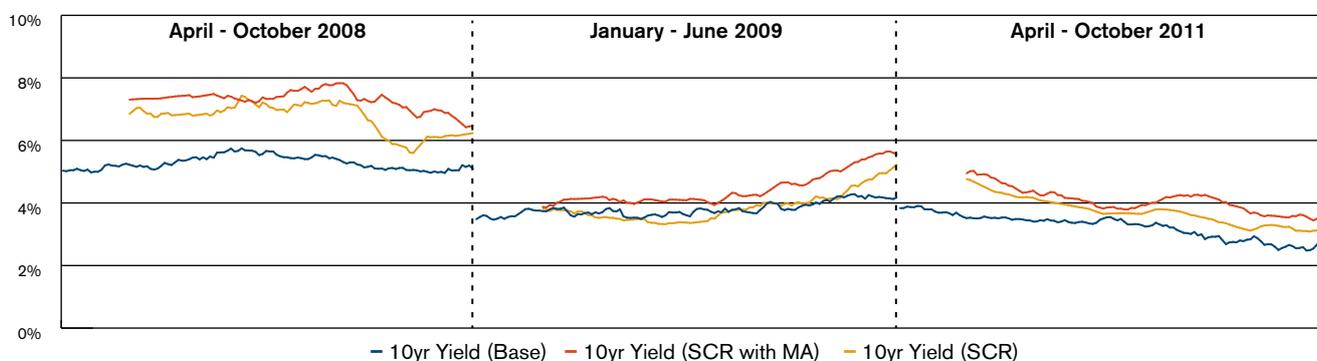


### What impact does MA have on MLC's risk profile and ALM?

The analysis has so far focused on the nature of the biting SCR scenarios in the absence of the matching adjustment, showing the level and variation in the key risk factors. In Figures 15 and 16, we explore the implications when the matching adjustment is introduced. To reduce the noise in the charts and make it easier to compare the results and draw conclusions, we show values based on a 20-day rolling average.

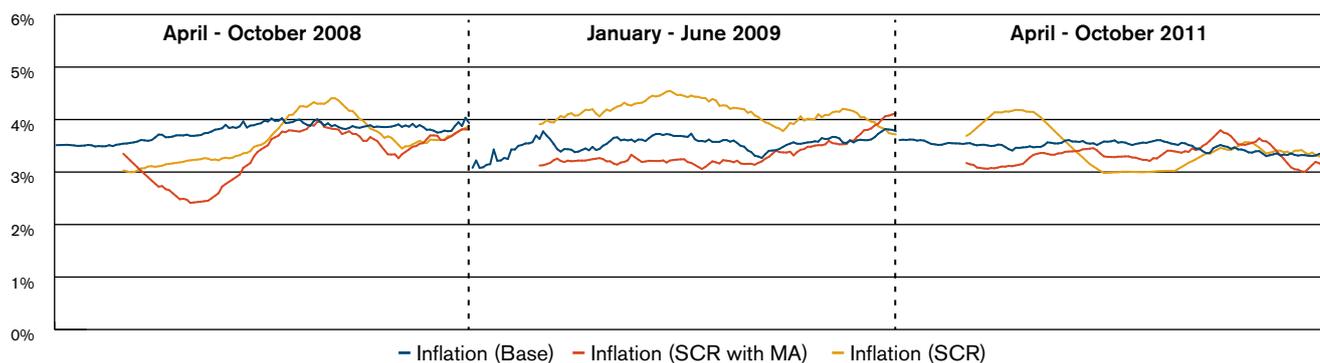
Regarding interest rates, when the matching adjustment is introduced, the biting scenarios feature a more consistent and exaggerated rates up bias. The matching adjustment increases the valuation interest rate and thus shortens the duration of our MLC's liabilities. The result is an increase in the duration mismatch between the MLC's assets and liabilities (recall that the MLC was already slightly long) and hence a greater propensity for adverse scenarios to reflect upward shifts in interest rates. Clearly, the matching adjustment may require that some changes be made to the MLC's asset portfolio. Provided that the matching adjustment is a permanent feature, this should not be overly onerous. On the other hand, this may generate some challenges in the context of the counter-cyclical premium which, by its nature, will be present at some times but not others. In light of current proposals to fully stress the CCP in the calculation of the SCR, the net benefit to solvency (excess of own funds over SCR) may already be quite low. However, if the introduction of the CCP also results in a deterioration of the MLC's matching position, and thus increased exposure and capital requirements from other risk factors, there is cause for concern that the final result is a negligible benefit, or possibly even detrimental for MLC—a classic unintended consequence.

**FIGURE 15: EFFECT OF MATCHING ADJUSTMENT ON BITING STRESS 10-YEAR YIELD (20-DAY ROLLING AVERAGE)**



As a final illustration, our MLC considered the impact of the matching adjustment on their exposure to inflation, as illustrated in Figure 16.

**FIGURE 16: EFFECT OF MATCHING ADJUSTMENT ON BITING STRESS INFLATION (20-DAY ROLLING AVERAGE)**



Before the introduction of the matching adjustment, there was no single direction to our MLC's inflation exposure. There were periods when inflation going up was the key risk, but others when inflation going down dominated. The matching adjustment again has an impact, resulting in the MLC's capital being far more driven by inflation going down. The primary impact comes from the MLC's block of inflation-linked annuity business, which was initially reasonably well matched with a combination of inflation-linked cash bonds and inflation swaps. Linked annuities have an even longer duration than conventional fixed annuities and so the reduction from the application of the matching adjustment would be even more pronounced. The outcome is now a mismatch, with the MLC's portfolio of linked assets now being too long for the shortened liabilities and a resulting exposure to a fall in inflation rates.

It is clear that the CCP in particular may introduce a new element of uncertainty into our MLC's asset-liability management strategy. To help address this, when the details become available, the MLC intends if possible to track the potential CCP using ECSight so that it can frequently test its potential impact and has plans in place to manage any adverse effects.

The nature of the risk factors driving the SCR via the biting scenarios is confirmed consistent with management's expectations, given our MLC's book of assets and liabilities. Changes in market conditions impact the relative influence of the different risk factors and this should be fed into the prioritisation process for capital management decisions. The MA impacts the MLC's matching position adversely and if introduced will require the asset portfolio to be adjusted as a counterweight.

Once the CCP is stressed in the SCR, and other potentially adverse impacts on required capital are taken into account, it is possible that its introduction would be of negligible benefit, or even detrimental for our MLC.

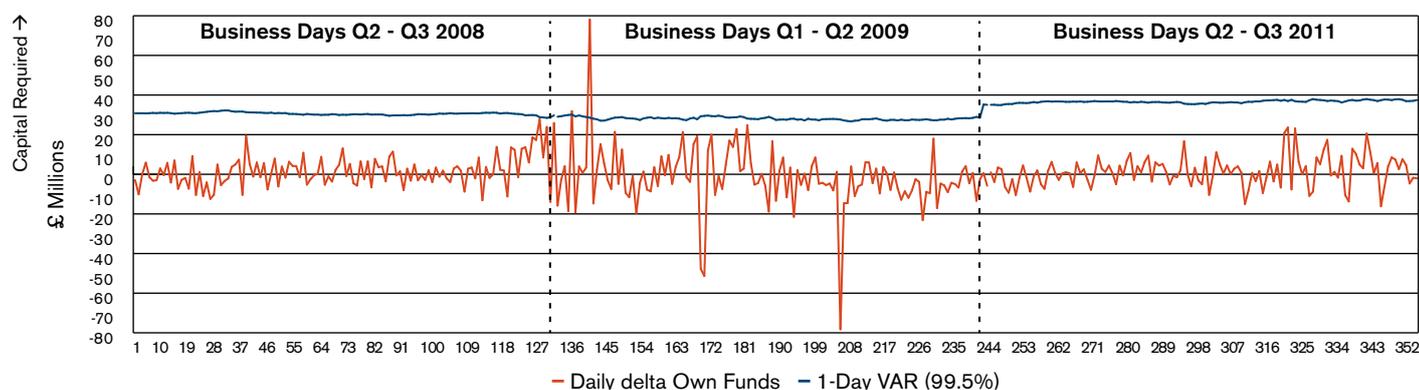
## DAILY VAR BACK-TEST FOR THE SCR

When considering solvency on an SII-style VAR basis, the question arises as to whether the stresses applied to generate the SCR produce a reasonable estimate of the capital required such that there is only a 1-in-200 chance that actual capital requirements will exceed that level (VAR 99.5%).

To address this question, our MLC was able to consider the results from the 360 days of historical information and develop an approximate daily back-test of its SCR. This involved comparing:

- The daily change in the MLC's own funds
- An SCR value adjusted to reflect a one-day risk period rather than the usual one year

FIGURE 17: 1-DAY VARS VS. DAILY DELTA OWN FUNDS



Over the 360 days considered, we would have expected two breaches of the 1-day VAR at the 99.5% level ( $0.005 * 360 = 1.8$ ). The results of the daily VAR back-test are shown in Figure 17 and we can see that there were indeed two observed breaches. Hence, the back-test provides support for the reasonableness of the required capital calculations on the basis of a 99.5% VAR confidence level. However, what can also be observed is that the 1-day VAR level can be breached by a hefty margin. With a 1-day VAR around £30 million, in early 2009 our MLC had one occasion on which own funds fell by close to £80 million, indicating that the MLC's economic capital distribution may have a very long left tail.

Our MLC's daily back-test supported the calibration of the internal model used to calculate the SCR.

## **NEXT STEPS**

Now that our MLC has ECSight up and running and armed with the initial round of analysis, a shopping list of additional investigations is already starting to grow. As additional analyses are undertaken, short updates to this report will be published.

## APPENDIX A: ECSIGHT SYSTEM OVERVIEW

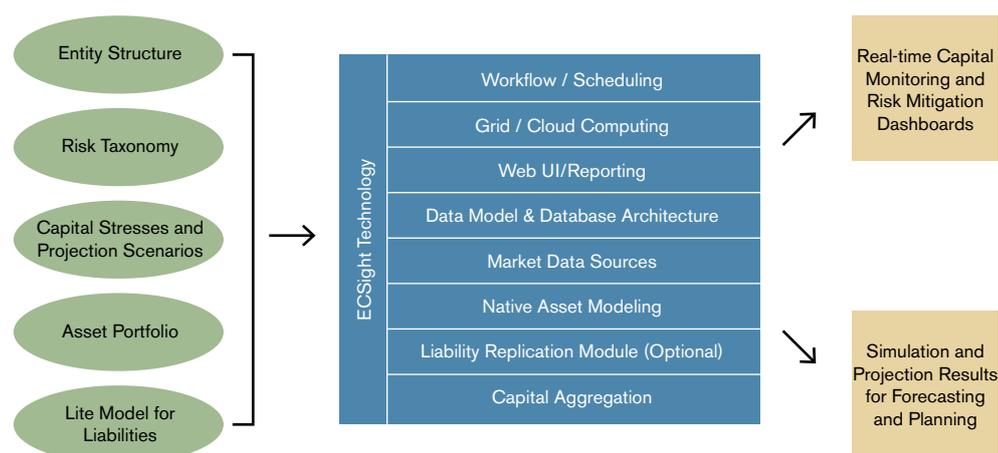
The analysis reported in the body of this report was derived from results obtained using Milliman ECSight. This is a cutting-edge software system that combines high-performance asset and liability modelling engines with scalable and efficient distributed computing technology to achieve the computing power needed to arrive at granular economic capital metrics over billions of valuation model points. An enterprise-scale relational database facilitates the storage, analysis and reporting of valuation results in sufficient detail to answer questions about how portfolio composition, market conditions and management actions drive capital requirements and shape risk profile.

ECSight also satisfies ubiquitous IT, business and regulatory demands for reliability, security and auditability. ECSight supports full versioning of all inputs and outputs; generation of audit trails; fault tolerance through the automatic failover of compute nodes; a browser-based interface complete with industry-standard authentication and role-based logical access controls; and output that can be viewed and analysed in standard formats, including HTML, PDF and CSV.

Data required for valuation are uploaded to the database via text files with simple, predefined formats and/or via custom extract, transform and load (ETL) processes. ECSight is also able to integrate market data from a variety of external data vendors such as Bloomberg, SuperDerivatives and MarkIT, subject to appropriate licensing arrangements. The ECSight data model captures relationships needed to map imported market data to the universe of risk drivers through a comprehensive risk taxonomy. The risk taxonomy establishes a hierarchical relationship between tens of thousands of risk factors, providing a data-driven mechanism for uniformly quantifying sensitivities to both market and actuarial risks. Because scenario definitions, asset and liability valuation models, and reporting functions are expressed in terms of this taxonomy, consistency and compatibility across all components of the system is ensured.

An architectural summary is illustrated in Figure A-1.

**FIGURE A-1: ARCHITECTURAL SUMMARY OF ECSIGHT**



Engineered specifically to address detailed balance sheet analytics as frequently as daily, ECSight offers several key technical advantages, specifically with regard to performance, scalability and flexibility.

### Performance

A compiled C++ asset valuation library with support for a wide range of asset classes facilitates seriatim asset valuation, while proxy (or *lite*) modelling techniques can be employed to value complex liabilities over multivariate risk scenarios. Data throughput bottlenecks are addressed with a Microsoft SQL Server database and performance-tuned to manage the distribution of valuation inputs and the collection of valuation results from multiple compute nodes running concurrently.

### Scalability

ECSight is capable of leveraging multiple high-performance computing environments through Milliman GridStep technology, including the Milliman C-Squared™ or Microsoft HPC Server grid computing platforms for in-house processing, and Milliman GridStep Cloud Edition for on-demand access to virtually unlimited computing resources in the cloud. Integration with the cloud is vital to leveraging scalability beyond capacity constraints typically encountered when deploying to conventional data centres.

With the ability to run streamlined asset and liability valuations in parallel on upwards of 3,000 compute nodes in Microsoft Azure, ECSight can deliver analyses on the distribution of economic capital over hundreds of thousands of multivariate risk factor scenarios and over hundreds of forward-projection or back-test time steps. The ability to provision resources on-demand leads to an efficient use of computing resources and lower operating costs while avoiding the compromise on accuracy and granularity imposed by the technology constraints of less scalable solutions.

### Flexibility

With a highly modular architecture, ECSight can be configured to utilize multiple asset and liability models. While the results of this report relied on radial basis functions (RBF) for *lite* modelling of liabilities, other *lite* model implementations can also be deployed on the ECSight platform. The use of highly decoupled interfaces between valuation models and the core system means accuracy, performance, change control and cost considerations can be addressed independently, without constraints imposed by system architecture.

Additionally, with integrated support for multiple distributed computing platforms, ECSight has the flexibility to utilize internal or cloud-based computing resources in whatever combination offers the optimal balance of performance, cost and security.

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## APPENDIX B: MODELLING APPROACH

### Asset modelling

ECSight employs an efficient, embedded asset modelling engine for seriatim asset valuation. This engine leverages the industry-standard QuantLib library for core valuation routines and covers an extensive range of asset classes *out-of-the-box*. For example:

- Fixed income: Gilts, corporates, fixed, floating, callable
- Money market: CDs, commercial paper, term deposits
- Growth: Equities, property
- Derivatives: Futures, forwards, interest rate swaps, swaptions, inflation swaps, cross-currency swaps, equity options

Because QuantLib drives asset valuation logic, the asset modelling engine is extensible.

### Liability replication and modelling

For proxy modelling, ECSight implements radial basis functions (RBFs) as standard to approximate the liability value given revised values for the market and nonmarket risk drivers. However, the modular nature of the system means that alternative approaches such as polynomial curve fitting or least squares Monte Carlo could also be used if required.

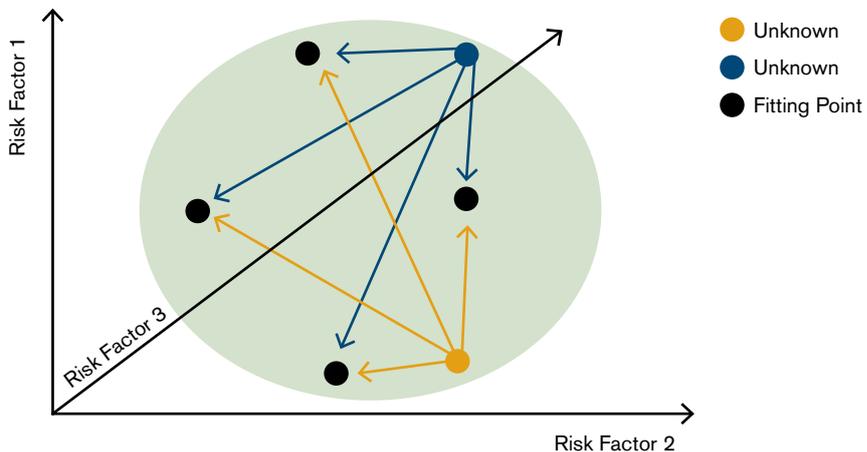
RBFs are a robust method for interpolating a multivariate, unknown function. They are a multidimensional generalisation of the idea of fitting an unknown function through a spline, and have been extensively used in a number of areas.

RBFs give a method of interpolation which:

- Is independent of the precise form of the unknown function
- Can work over an arbitrary number of risk drivers
- Can work with various form of fitting points, including randomly selected fitting points and a grid structure
- Have excellent convergence properties; selection of appropriate extra fitting points produces a better fit
- Can work with many risk drivers and the volume of fitting points required can scale favourably as risk drivers are added
- Requires no prescription as to where the fitting points need to be placed; assuming that the fitting points are distinct, the linear algebra involved is guaranteed to have a unique solution

RBF interpolation regards each scenario as a point in  $n$ -dimensional space, where  $n$  is the number of risk drivers. The RBF approximation to the true liability value for a particular scenario depends on the Euclidean distance between the scenario and the fitting points. This diagram in Figure A-2 illustrates for three risk drivers (so in three-dimensional space) with four fitting points and two unknown points.

FIGURE A-2: RBF INTERPOLATION



In order to fit the liability value via an RBF, it is assumed that the true liability value is known at a number of points. Some of these points are used as fitting points—because the RBF approach is an interpolation, the RBF approximation will equal the liability value at these points. The remaining points are used for out-of-sample testing to demonstrate the adequacy of the approximation. In most situations, the true liability values for sampling are derived using detailed actuarial models of the business. ECSight is agnostic to the source of this data and, as a result, can facilitate balance sheet aggregation across liabilities modelled on disparate actuarial systems.

## APPENDIX C: RISK SCENARIO GENERATION

ECSight is agnostic as to the precise design of the risk scenario generator (RSG). It can work with any externally provided RSG. For the purposes of the modelling for our MLC, a simple RSG was used which nevertheless was sufficient to capture the key characteristics of the MLC's risk profile.

Our MLC generated the RSG scenarios using the following steps:

1. Specifying the probability distribution for the underlying risk drivers
2. Specifying the dependency structure of the individual risk drivers
3. Generating scenarios in line with the desired joint probability distribution for each day in the investigation

The risks covered included market risks and insurance risks. Stress events were assumed to occur instantaneously at the calculation date.

Insurance risks were assumed to follow a normal distribution with zero mean and variance calibrated for consistency with the standard formula SCR as specified in the 5th Quantitative Impact Study (QIS5).

For market stresses, our MLC typically calibrated the stresses to historical data. The table in Figure A-3 shows the market data used in this calibration.

**FIGURE A-3: SOURCES OF MARKET DATA**

RISK	DATA SOURCE	TIME PERIOD
CREDIT SPREAD	IBOXX UK CORPORATE	2000-2012
INTEREST RATES	UK SWAP RATES	1990-2012
INFLATION	RPI INDEX	1948-2012
SWAPTION VOLATILITY	AT-THE-MONEY UK SWAPTION VOLATILITY	2002-2012
EQUITY	FTSE 100 TOTAL RETURN INDEX	1986-2012

A normal distribution was assumed for every market risk other than interest rates, where a lognormal model was used.

The risks were aggregated using a Gaussian copula and correlations consistent with QIS5.

## ACKNOWLEDGEMENTS

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Magnus Wilson, Associate - London





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