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Staff Working Paper No. 664
The impact of Solvency II regulations on life insurers' investment behaviour

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Abstract

This paper provides a means of estimating how 'Solvency II' regulations — introduced in the European Union in January 2016 — might affect UK life insurers' incentives to hold different types of financial assets, and how these asset holdings are likely to vary in the face of hypothetical changes to market prices. To do so, it sets out a structural model of firms' equity to assess their investment behaviour under different regulatory regimes. It finds that, while Solvency II may partly protect insurers' solvency positions from falls in risky asset prices, the new regulations might encourage certain types of UK life insurers to de-risk — that is, move to holding safe assets in place of risky — following falls in risk-free interest rates. This behaviour is driven by changes in the so-called 'risk margin', which, under its current design within the Solvency II framework, reduces insurers' solvency positions following falls in risk-free interest rates, thereby encouraging them to sell risky assets to reduce their probability of regulatory insolvency. The model also suggests that, once Solvency II is fully implemented by 2032, UK life insurers may have markedly reduced their holdings of long-term, risky assets. In the model, this behaviour is also driven by the risk margin, which, by increasing the volatility of insurers' solvency, encourages them to de-risk to reduce the variance of their asset portfolios.

Key words: Insurance, procyclicality, regulation, Solvency II, liquidity.

JEL classification: G11, G12, G18, G22, G23.

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1 Introduction

Life insurers provide a broad selection of savings and pension-type products, through which consumers and businesses can invest for the future and manage their finances through retirement. In providing such services, they also play an important role in the provision of market-based finance.

In the UK, life insurers hold £1.7 trillion of financial assets (Bank of England (2016.a)). These account for a significant proportion of total assets outstanding in several UK securities markets (**Table 1**). Understanding how insurers make their asset allocation decisions is therefore interesting from a financial stability perspective.

Table 1: Estimated UK life insurers' asset holdings for selected asset classes

Asset class	UK life insurers' total holdings (£ billion)	Share of outstanding amounts (%)
UK government bonds	258	18%
UK corporate bonds	262	47%
UK equities	338	16%

Source: Bank of England 2016.a

For example, given the materiality of their financial investments, changes in life insurers' asset allocations have the potential to induce changes in financial market prices. If they were to invest in a *procyclical* manner – that is, sell assets as prices fall and buy as prices rise – they might amplify changes in financial markets and potentially cause markets to overshoot. Sharp and sustained falls in prices – particularly in markets that play an important role in extending funding to the real economy – may reduce the ability of some companies to service or refinance their debt, threatening their solvency.

In recent years, the literature related to procyclical investment behaviour and its implications for market-based finance has grown substantially. For example, in 2014, the Bank of England established an industry working group to examine the investment behaviour of insurers and pension funds (Bank of England and the Procyclicality Working Group (2014)). This work found some evidence of procyclical investment behaviour by UK life insurers following the dotcom equity market crash, but somewhat less compelling evidence of procyclical behaviour following the financial crisis of 2007-08. Other papers have found evidence of 'herding' behaviour by institutional investors when deciding on their asset allocations, which could pose similar risks to market functioning (Blake (2002) and Greenwood and Vayanos (2010)).

Most of the papers examining such investors' propensity to invest procyclically are empirical and compare historical changes in asset holdings to changes in market prices. In contrast, little work has been undertaken to examine such questions using micro-founded, theoretical models, which can be used to produce predictions of future investment behaviours, and identify the drivers of those behaviours. This paper helps to fill that gap by applying an adapted version of Merton's (1974) structural model to the balance sheet structures of UK life insurers.

Under our approach, insurers' asset allocation decisions between risky and safe assets are driven by their desire to maximise future shareholder profits, subject to them being mindful of the risk of breaching their regulatory capital requirements. Specifically, shareholders' claims are modelled as hypothetical call options with payoffs equal to the difference between the value of insurers' assets and liabilities. These hypothetical call options are also assumed to be of the 'knock-out' type, with barriers set at levels commensurate with the value of the insurers' regulatory capital requirements. If breached, the insurers' equity holders are assumed to incur significant costs associated with run-off.

Such a theoretical approach can be used as a guide towards the future expected investment behaviours of UK life insurers. This is particularly relevant with the introduction, in January 2016, of 'Solvency II' regulations in the EU (European Commission (2009)). These regulations introduced a number of measures that have a bearing on insurers' investment behaviour, including:

(i) New countercyclical solvency measures, including the so-called 'matching adjustment', which cushions insurers' capital resources against short term fluctuations in the value their assets that are driven by changes in the liquidity premia on fixed-income securities.

(ii) The so-called 'risk margin' that is incorporated into the value of a firm's liabilities to reflect the compensation another firm might require to accept the transfer of its liabilities, were it to fail. The risk margin varies over time and has a bearing on insurers' solvency positions and could therefore affect investment behaviour, as well as risk management decisions.

(iii) Increased market transparency, and – in particular – the requirement that insurers regularly disclose their solvency positions to regulators and market analysts. This might incentivise firms to build capital buffers above regulatory requirements and increase their resilience to shocks. But it might also incentivise less capitalised firms to dispose of risky assets during times of stress.

Given these changes, Solvency II has the potential to alter insurers' propensity to invest procyclically and/or their willingness to invest in long-term, risky assets (Bank of England (2016.b)). There has, however, been little published work examining how insurers' investment behaviour might be affected under the introduction of Solvency II. Insurers are currently able to use so-called 'transitional measures on technical provisions' (TMTPs), which gradually phase in Solvency II's impact over sixteen years. There is therefore a need for a framework to assess the implications of Solvency II – leading up to its full implementation in 2032 – on insurers' asset allocation decisions.

To isolate the impact of the new measures introduced under Solvency II, we have developed two versions of our model with parameter values and dynamics that we vary to reflect differences in two regulatory regimes applicable for UK insurers: the previous 'Independent Capital Adequacy Standards' (ICAS), and new Solvency II regulations. Throughout, we focus on two types of UK life insurer. First, non-profit insurers that, amongst other things, sell annuity products that provide guaranteed, annual payments to policyholders on their retirement. The values of annuity payments to policyholders are fixed over time, and are therefore insensitive to movements in the values of the underlying assets; the entirety of the associated investment risk therefore resides with the insurer. Second, with-profit insurers that typically sell accumulation (i.e. savings) products, under which policyholders receive some partial protection from changes in asset prices; investment risk is therefore shared between the insurer and policyholder.

The findings of this work are broadly twofold, and extend those discussed in the Bank of England's Financial Stability Report in November 2016 by describing insurers' investment behaviour in a wider range of financial market settings (Bank of England (2016.a)):

First, we use the model to estimate how the two types of UK life insurers' allocations between risky and safe assets vary in response to different types of changes in financial market prices. That is, we estimate their *propensity to act procyclically* as a result of the regulatory regime. Here, we find that both types of insurers are expected to invest only *modestly* procyclically under both ICAS and Solvency II regulations following a fall in risky asset prices caused by an increase in liquidity premia or by a deterioration in credit fundamentals. The more limited investment response under Solvency II is partly driven by the matching adjustment – described above – which cushions insurers' capital resources in the face of changes in risky asset prices. In contrast, we find that, once Solvency II is fully implemented by 2032, both types of insurers are expected to dispose of large quantities of risky assets, and therefore potentially act procyclically, following falls in risk-free interest rates. This latter behaviour is driven by the risk margin – described above – which reduces insurers' solvency positions following falls in interest rates and thereby encourages them to dispose of risky assets to reduce their probabilities of default.

Second, we use the model to estimate insurers' willingness to invest in long-term, risky assets. Here, we find that, once the effects of Solvency II are phased-in completely by 2032, both types of insurer are likely to have markedly reduced their holdings of such assets compared to under ICAS. This behaviour is also driven by the risk margin, which increases the volatility of insurers' solvency positions and thereby encourages them to de-risk to reduce the variance of their asset portfolios.

The paper's applications to public policy are broadly threefold:

- First, its results provide an estimate of the degree to which insurers can be expected to act procyclically following changes in financial market prices. It may therefore serve as a quantitative risk assessment tool for any authority interested in assessing risks associated with insurers' investment behaviour.

- Second, it offers a framework to consider how insurers' propensity to act procyclically varies under different regulatory regimes. In particular, the framework can be used by policy makers to consider how particular regulatory changes introduced under Solvency II (including the risk margin, new formulaic countercyclical tools and the introduction of greater market transparency) might affect insurers' investment response functions.

- Third, this work offers a framework to consider how potential, future policy adjustments might impact insurers' investment behaviour. One example of this possibility would be to test the impact of alternative designs of the risk margin on insurers' investment behaviour.

The paper proceeds as follows. The next section provides a brief review of the literature that seeks to examine insurers' investment behaviour, and discusses other theoretical papers that have employed structural models to estimate the value of contingent liabilities. We then provide some institutional background on UK insurers in **Section 3**. **Section 4** then introduces our formal model methodology, which we use to assess insurers' asset allocation decisions. We then present the model parameterisation and calibration, and then the model results in **Sections 5** and **6**, respectively. A final section concludes.

2 Literature review

This paper applies an adapted version of Merton's (1974) structural model to balance sheets representing UK life insurers, and uses this framework to assess their investment behaviours under different regulatory regimes. Two strands of the existing academic literature are therefore relevant to this work. The first is past work on insurers' investment behaviour, and the second is papers on structural balance sheet models. This section examines each in turn.

Insurers' investment behaviour

Several empirical papers find that institutional investors display tendencies to 'herd' when deciding upon their asset allocations over time (Blake (2002) and Greenwood and Vayanos (2010)). Hence, if these investors were to invest in a procyclical manner – that is, sell assets as prices fall and buy as prices rise – they might amplify changes in financial markets and potentially cause markets to overshoot.

There is a modest stock of literature that has sought to examine insurers' investment behaviour and the degree to which they have acted procyclically in the face of past changes in market prices. For example, work by the Bank of England's 'Procyclicality Working Group' (2014) finds some evidence that UK life insurers invested procyclically in equity markets following the dotcom equity market crash, but somewhat less compelling evidence of procyclical behaviour following the 07/08 financial crisis.

Impavido and Tower (2009) also find some evidence internationally for procyclical behaviour following the dotcom crash, but – in contrast to the Bank's 2014 report – finds even stronger evidence of such behaviour following the 07/08 financial crisis.

The Bank of England and Procyclicality Working Group (2014) discuss a number of potential drivers of procyclical investment behaviour by insurance companies. In particular, it provides a stylised example of how a risk-sensitive capital regime, when combined with mark-to-market valuation, can encourage insurers to act procyclically. Under it, insurers' capital resources change procyclically, but their capital requirements are less sensitive to changes in asset prices. During periods where market prices are increasing, insurers are therefore 'capital-rich' and are incentivised to increase their holdings of risky assets in an attempt to boost profits, and *vice versa*. Such behaviour can have the effect of amplifying changes in market prices.

Merrill et al (2012) find empirical evidence in support of this reasoning. They show that, between 2006 and 2009, capital-constrained US insurance companies sold more non-agency, residential mortgage-backed securities, and at lower prices, than their peers who were less capital constrained. Such behaviour might be consistent with insurers being incentivised to sell risky assets during periods of market stress to improve their capital positions.

Most of the papers examining insurers' propensity to invest procyclically take empirical approaches by comparing historical changes in asset holdings to changes in market prices. In contrast, little work has been undertaken to examine such questions using micro-founded, theoretical models. Next we discuss a particular type of theoretical model that we employ in the paper.

Structural models of corporate balance sheets

Another strand of literature uses structural models to estimate the value of firms' liabilities. Such models typically estimate the value of firms' liabilities using option pricing theory in the spirit of Black and Scholes (1973) and Merton (1974). In their models, the values of firms' assets are typically assumed to follow Geometric Brownian Motions (GBM), and the values of firms' debt and equity are modelled as the values of hypothetical options written on the value of the firms' assets, with a strike price at the face value of the firms' debt.

Later work has adapted this simplistic approach by estimating the value of equity using path-dependent options (Black and Cox (1976), Leland (1994), Anderson and Sundaresan (2000), and Episcopos, (2008)). This adapted form of the original structural model can be applied to most limited liability companies, including financial institutions. For example, focusing on banks, Episcopos (2008) models the value of equity as the value of a barrier option, whereby the value of equity ceases to exist when the firm's asset value breaches a prescribed barrier which is related to the regulatory capital constraint.

However, whilst a large number of papers have employed structural models as a means to value firms' equity and other liabilities, there are no existing papers that use such a framework to model the *investment behaviour of UK insurers*. This paper is therefore unique in applying an adapted structural model to the balance sheet structures of UK life insurers, and using this framework to assess their investment behaviours under different regulatory regimes, including new 'Solvency II' regulations.

3 Institutional context

This section provides some context around the two types of UK life insurers that we model in this paper. We start by providing an overview of how their business models differ, including their contrasting typical asset holdings, and then discuss the regulations to which they are subject. This context is relevant for our modelling framework discussed later in **Section 4**.

Non-profit and with-profit insurers

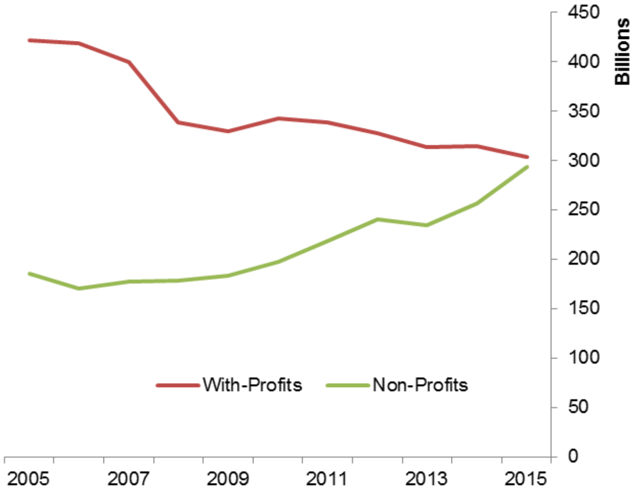
We model two types of UK life insurers in this paper: non-profit and with-profit insurers:

- Non-profit insurers typically write decumulation products, where the values of policyholders' claims are fixed over time and market risk on assets resides with insurers. Examples include annuity products, where insurers agree to make fixed payments to policyholders during their retirement until their deaths.
- With-profit insurers, in contrast, largely write accumulation (i.e. savings) products, where policyholders receive protection from market movements, such that the values of their policies are 'smoothed' over time. Here, the investment risk is shared by insurers and policyholder.

Both types of insurers have asset holdings that are significant; at end-2015, both types of insurers held around £300 billion of assets (**Chart 1**). However, there are some notable differences in the compositions of their asset holdings.

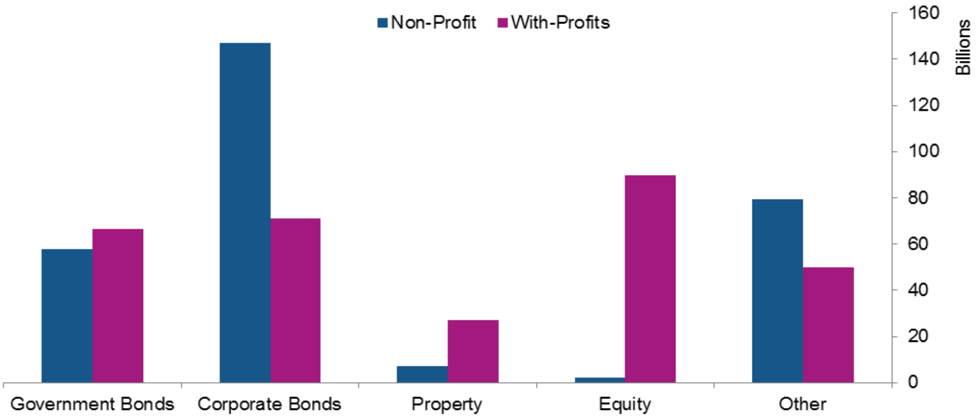
Non-profit insurers invest mainly in fixed-income securities in an attempt to match the cash-flows of their liabilities. In contrast, with-profit insurers typically hold more balanced portfolios of fixed-income securities and other risky assets, including equity and property (**Chart 2**). As discussed in **Section 4**, under our model these differences affect each insurer's assumed investment choices. In particular, whilst non-profit insurers are assumed to choose between fixed-income securities of differing levels of risk and return, with-profit insurers are assumed to choose between a safer fixed-income security and a combined portfolio of riskier assets, including risky fixed-income securities, equities and property.

Chart 1: UK insurers' aggregate asset holdings by type of insurance product



Source: S&P Synthesis data

Chart 2: UK non-profit and with-profit insurers' aggregate asset holdings by asset class, end-2015



Source: S&P Synthesis data.

Regulation

From 2005 to 2015, UK insurers, including the two types modelled in this paper, were regulated under 'Individual Capital Adequacy Standards' (ICAS). Under the ICAS regime, there were several distinctive features that are relevant to our model:

- Regulatory capital requirements. All insurers were subject to biting regulatory capital requirements that, if breached, would result in increased regulatory scrutiny and possibly insolvency (sometimes referred to as 'run-off'). As discussed in **Section 4**, we allow for a regulatory barrier in our structural model framework.

- Countercyclical solvency measures. UK insurers – both non-profit and with-profit – benefitted from the so-called 'illiquidity premium', which allowed them to look through a portion of risky asset price movements when valuing their liabilities. This reduced the sensitivity of their solvency positions to changes in risky asset prices, and therefore, at the margin, reduced the need to change the composition of their asset portfolios following falls in risky asset prices.

In January 2016, however, UK insurers became subject to 'Solvency II' regulations (see, for example, Lloyd's of London (2010)). Solvency II is a harmonised prudential regulatory regime for European insurance companies, and the first forward-looking, risk based regime to be applied across Europe. It aims to improve the resilience of the insurance sector and enhance the level of policyholder protection (European Commission (2009)).

As well as applying comparable regulatory capital requirements, three aspects of Solvency II are likely to have a particular bearing on insurers' investment behaviour:

- New, more countercyclical solvency measures for non-profit insurers. For example, the so-called 'matching adjustment' cushions non-profit insurers' capital resources by enabling them (subject to conditions and prior approval) to look through certain short-term asset price movements when valuing their liabilities. This may therefore limit the need for non-profit insurers to change the composition of their asset holdings materially following falls in risky asset prices.

- The introduction of the so-called 'risk margin' – an additional liability, applicable to both non-profit and with-profit insurers, to reflect the compensation another firm might require to accept the transfer of an insurer's liabilities in the event of its failure. Under its current design, the risk margin is calculated by multiplying a cost of capital (which is invariant to changes in financial market conditions) by the net present value of future capital requirements (see **Annex 1** for more detail). Hence, as risk-free interest rates fall, and as the net present value of future capital requirements increases, the value of the risk margin increases, which acts to worsen insurers' solvency positions. The risk- margin's sensitivity to risk-free interest rates increases the volatility of insurers' solvency positions, which may encourage insurers to adjust their asset portfolios in times of market stress.

- Greater market transparency. All insurers, including both non-profit and with-profit insurers, are required to disclose their solvency positions to regulators and market analysts on a regular basis. This might incentivise firms to build capital buffers above regulatory requirements and increase their resilience to shocks. But it might also incentivise less capitalised firms to dispose of risky assets in times of stress, to improve their published solvency positions.

Given these changes, Solvency II has the potential to alter insurers' propensity to invest procyclically and/or their willingness to invest in long-term, risky assets (Bank of England (2016.b)). There has, however, been little, if any, examination of how insurers' behaviour might be affected under the introduction of Solvency II. This may be in part due to UK insurers currently being able to use so-called 'transitional measures on technical provisions' (TMTPs), which act to gradually phase in

Solvency II's impact over sixteen years. So whilst effects on investment behaviour may have been masked by TMTPs, there is a need for a framework to assess the implications of Solvency II – leading up to its full implementation in 2032 – on insurers' asset allocation decisions.

To isolate the impact of the new measures introduced under Solvency II, we have developed two versions of our model with parameter values and dynamics that we vary to reflect the previous UK regulatory regime for insurers, the 'Independent Capital Adequacy Standards' (ICAS), and new Solvency II regulations. We describe this further in **Section 4**.

4 Model methodology

In this Section, we outline the modelling framework we have developed to assess the asset allocation decisions of two types of UK life insurers. In particular, we model the behaviours of representative non-profit and with-profit insurers. And, to differentiate between the regulatory regime previously applicable to UK insurers, ICAS, and the new regulatory regime, Solvency II, we develop two versions of the model. We first outline the 'baseline' ICAS model in detail, and then outline the key changes that we make for the 'Solvency II' model.

'Baseline' model under ICAS

In practice, non-profit and with-profit insurers' balance sheets contain a large number of separate components, which can evolve very differently over time. But to simplify our model, we assume that the assets and liabilities of the two representative insurers can be decomposed into a handful of balance sheet components, which we illustrate in **Figures 1 and 2**.

Figure 1: Stylised non-profit insurer's balance sheet under the 'Baseline' ICAS model

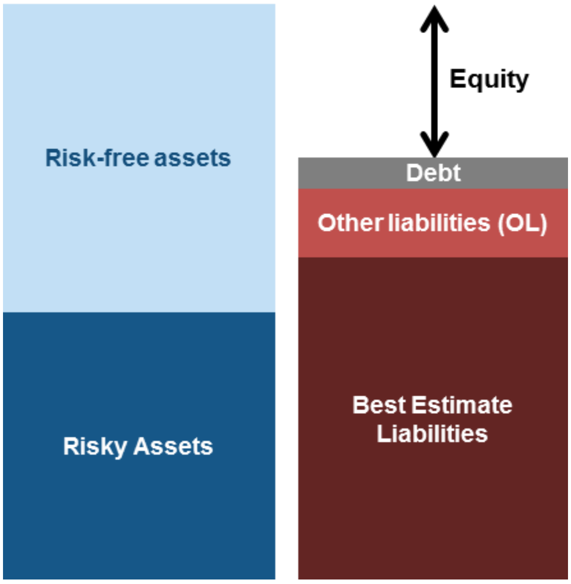
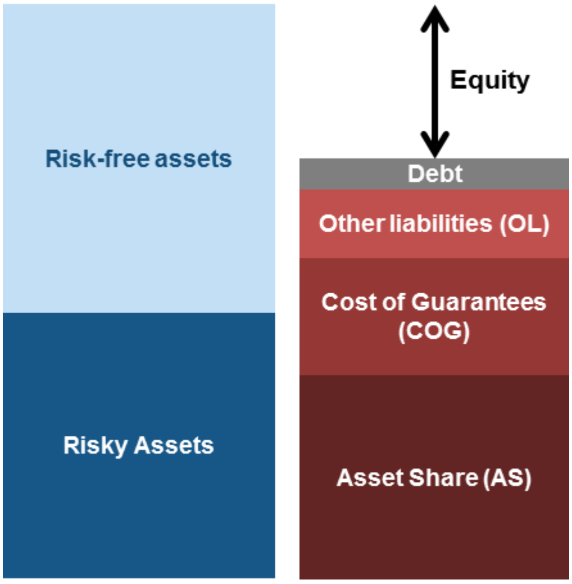


Figure 2: Stylised with-profit insurer's balance sheet under the 'Baseline' ICAS model



We next discuss how we model each component of these balance sheets in turn, and then discuss the optimisation function that is assumed to inform the insurers' investment behaviour.

Assets and interest rates:

For simplicity, we assume that insurers hold two types of asset: risky assets, A^R, and risk-free assets, A^{rf}. Total assets, A, are therefore the sum of the insurers' holdings of risky and risk-free assets:

$$A_t = A_t^R + A_t^{rf}. \quad (1)$$

We assume that the value of **the risky asset** follows a Geometric Brownian Motion (GBM). In particular, it is assumed to grow on average at a rate determined by the sum of the risk-free rate, r^f, and a risk premium, ξ^R. But growth in the risky asset value also has a stochastic component, with shocks that follow a standard normal distribution scaled by an ex-ante, time-varying parameter, σ^R; that is:

$$\frac{dA_t^R}{A_t^R} = \left(r_t^f + \xi_t^R\right)dt + \sigma_t^R dz_t^R. \quad (2)$$

We assume that the volatility of the risky asset, σ_t^R, reverts deterministically towards its long-run average, Φ^R. And noting the empirical link between risk premia and volatility, we assume that the risk premium, $\boldsymbol{\xi}^R$, varies in proportion to the volatility of the value of the risky asset, σ^R; that is:

$$d\sigma_t^R = \alpha^R(\Phi^R - \sigma_t^R)dt, \qquad where \quad (3)$$

$$\xi_t^R = \beta^\xi \sigma_t^R. \qquad and\ \alpha^R, \Phi^R, \beta^\xi > 0 \quad (4)$$

We parameterise the risky asset's dynamics differently for non-profit and with-profit insurers to reflect the differing compositions of their asset holdings. In the model of non-profit insurers, we parameterise the risk premium on the risky asset, and the volatility of its return, using historical data on UK A-rated corporate bonds. In the model of with-profit insurers, we instead parameterise these variables using historical data on a mixed portfolio of UK equities, property and A-rated corporate bonds (with portfolio weights determined by observed asset holdings in regulatory data).

For the risk-free asset, we assume that its value grows in line with risk-free interest rates, which are assumed to follow a one-factor Vasicek process with a time-independent mean.

$$dr_t^f = \alpha^{rf}\left(\beta^{rf} - r_t^f\right)dt + \sigma^{rf} dz_t^{rf}. \quad (5)$$

We parameterise the Vasicek process using historical yields on ten-year UK Gilt rates. We then apply Ito's Lemma to the value of a zero-coupon risk-free asset, in a world where interest rates follow a Vasicek model, to solve for the growth of the risk-free asset value: [1]

$$\frac{dA_t^{rf}}{A_t^{rf}} = -\frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\alpha^{rf}\left(\beta^{rf} - r_t^f\right)dt - \frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\sigma^{rf} dz_t^{rf} + \frac{1}{2}\left\{\frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\right\}^2 {\sigma^{rf}}^2 dt. \quad (6)$$

The dynamics of the insurer's total assets are then described by the sum of two processes: the standard GBM governing the risky asset dynamics, and the process governing the evolution of the risk-free asset based on the Vasicek evolution of risk-free interest rates; that is:

$$\frac{dA_t}{A_t} = w_t^R\left\{\left(r_t^f + \xi_t^R\right)dt + \sigma_t^R dz_t^R\right\} + (1 - w_t^R)\left\{-\frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\alpha^{rf}\left(\beta^{rf} - r_t^f\right)dt - \frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\sigma^{rf} dz_t^{rf} + \frac{1}{2}\left\{\frac{1-e^{-\alpha^{rf}(T-t)}}{\alpha^{rf}}\right\}^2 {\sigma^{rf}}^2 dt\right\}, \quad (7)$$

with

[1] For details, see 'Term structure models' by Martin Hough, 2010.

$$w_t^R = \frac{A_t^R}{A_t}, \quad and \tag{8}$$

$$d\sigma_t^R = \alpha^R(\Phi^R - \sigma_t^R)dt, \quad and \tag{9}$$

$$\xi_t^R = \beta^{\xi}\sigma_t^R. \tag{10}$$

Liabilities:

For simplicity, we assume that each representative insurer's non-equity liabilities can be decomposed into a handful of components. For the **representative with-profit insurer**, we decompose its non-equity liabilities into four components:

- The Asset Share, AS. These are with-profit insurer's expected policyholder obligations whose values are not guaranteed by the insurer. The value of the Asset Share tends to move one-for-one with the value of the insurer's asset portfolio. This means that changes in risky or risk-free asset prices lead to parallel changes in the value of the Asset Share.

- The Cost of Guarantees, COG. This is the cost to the insurer of meeting its guarantees to policyholders. The value of the Cost of Guarantees tends to increase as interest rates fall (e.g. as minimum investment return guarantees become more onerous) and as asset prices fall (e.g. as minimum total return guarantees become more onerous).

- Other Liabilities, OL. These consist of numerous residual balance sheet items, including some unit-linked liabilities, which share economic similarities with those of open-ended investment funds (OEICs). And, as the investment risk associated with unit-linked liabilities is transferred to policyholders, changes in the value of these Other Liabilities are assumed to closely match changes in the value of insurer's asset holdings.[2]

- Debt, D. This can be decomposed into two components to differentiate between that which counts towards an insurer's regulatory capital resources (i.e. capital-eligible debt, CED) and that which doesn't (i.e. capital-ineligible debt, CID). For simplicity, we assume that the values of both types of debt are fixed over time.

Total liabilities, L, is given by:

$$L_t = (AS_t + COG_t + OL_t) + (CED + CID). \tag{11}$$

Whilst for simplicity we assume that the values of both types of debt are fixed over time, we assume that the face values of the insurer's other liabilities change mechanically in response to changes in two variables: the insurer's asset value and risk-free interest rates. In particular, the sensitivity of each liability to changes in these two variables is captured by a set of elasticities.[3] These elasticities are assumed to remain constant over time. Hence, the dynamics of the with-profit insurer's total liabilities is given by the sum of the changes of its parts, as follows:

$$dL_t = dAS_t + dCOG_t + dOL_t; \tag{12}$$

or

$$\frac{dL_t}{L_t} = \left\{E_{AS,A}\frac{dA_t}{A_t} + E_{AS,r_f}dr_t^f\right\}\frac{AS_t}{L_t} + \left\{E_{COG,A}\frac{dA_t}{A_t} + E_{COG,r_f}dr_t^f\right\}\frac{COG_t}{L_t} + \left\{E_{OL,A}\frac{dA_t}{A_t} + E_{OL,r_f}dr_t^f\right\}\frac{OL_t}{L_t}. \tag{13}$$

[2] We assume that the value of Other Liabilities, which consists partly of unit-linked business, changes only to reflect changes in financial market prices. That is, amongst other things, we assume that net inflows to unit-linked business is zero.
[3] As discussed in **Section 5**, these elasticities are parameterised (in part) using historical regulatory data. Hence, their estimated values will reflect firms' past use of derivatives to hedge their insurance liabilities.

We model the **representative non-profit insurer** in the same way by decomposing its non-equity liabilities into three liabilities:

- Other Liabilities, OL (as in the with-profit model);

- Debt, D (as in the with-profit model);

- Best Estimate Liabilities, BEL. This is an additional balance sheet component that (largely) represents annuity business. The present value of the insurer's annuities, and therefore of their Best Estimate Liabilities, depends on the life expectancy of policyholders (which affects how long the annuities will be paid for) and the rate used to discount the expected future payments to policyholders. Under the ICAS regime, this discount rate is equal to the sum of the risk-free rate and the so-called 'illiquidity premium' – a countercyclical solvency measure that allows insurers to look through a portion of risky asset price movements when valuing their liabilities.

Hence, for non-profit insurers:

$$L_t = (BEL_t + OL_t) + (CED + CID). \tag{14}$$

Similarly, the dynamics of the non-profit insurer's total liabilities is given as follows:

$$\frac{dL_t}{L_t} = \left\{E_{BEL,A}\frac{dA_t}{A_t} + E_{BEL,r_f}dr_t^f\right\}\frac{BEL_t}{L_t} + \left\{E_{OL,A}\frac{dA_t}{A_t} + E_{OL,r_f}dr_t^f\right\}\frac{OL_t}{L_t}. \tag{15}$$

<u>Default Condition</u>

Under the ICAS regime, an insurer's viability from a regulatory point of view is determined by its capital ratio. This is calculated as the insurer's capital resources, or the sum of its equity, E, and capital eligible debt, CED, divided by the Regulatory Capital Requirement:

$$Capital\ Ratio_t = \frac{E_t + CED}{Regulatory\ capital\ requirement} = \frac{Capital\ resources}{Regulatory\ capital\ requirement}. \tag{16}$$

If the value of the insurer's capital ratio falls below some critical level, which we take as one (or equivalently 100%), the insurer enters the so-called 'ladder of intervention'. This means that it must develop a plan to restore compliance and may eventually be unable to write new insurance business and therefore cannot generate future value for shareholders. In the model, in the event of default, we deduct a fixed proportion – denoted $\mathrm{x\%}$ – from the value of the insurer's total assets to reflect bankruptcy costs. This reduces the payoff to shareholders to the maximum of zero and $(1 - \mathrm{x\%})$ of the insurer's total assets less total liabilities – that is: $\mathrm{Max}\left(0, (1 - \mathrm{x\%})\mathrm{A}_{\mathrm{t_{def}}} - \mathrm{L}_{\mathrm{t_{def}}}\right)$, where $\mathrm{t_{def}}$ is the time of default.

<u>Long-term targeting of capital ratio</u>

In the medium-to-long-run, we assume that insurers target particular capital ratios above regulatory minima to avoid unwanted market discipline. Hence, observing the changes in the value of its assets and liabilities described above, the insurer adjusts the size of its balance sheet so that its capital ratio remains close to its exogenously-specified target ratio, Φ^{CR}. This ratio is assumed to be mean-reverting, because the insurer acts to move the capital ratio back towards target at a speed of adjustment governed by α^{CR}. The same idea may be found in Collin-Dufresne and Goldstein (2001).

This process of adjustment towards the optimal capital ratio is assumed to operate through changes in the value of the insurer's insurance liabilities, IL – that is, the insurer's total liabilities minus its debt. Changes in the insurer's insurance liabilities mechanically change the value of the insurer's total liabilities and total assets:

$$d\widetilde{L_t} = d\widetilde{A_t} = \alpha^{CR}(\Phi^{CR} - \ Capital\ Ratio_t)IL_t dt. \quad (17)$$

Hence, the inclusion of a long-term capital target leads to the following processes for assets and liabilities for the with-profit insurer:

$$\frac{dA_t}{A_t} = w_t^R\{(r_t^f + \xi_t^R)dt + \sigma_t^R dz_t^R\} + (1 - w_t^R)\left\{-\frac{1-e^{-\alpha^{r_f}(T-t)}}{\alpha^{r_f}}\alpha^{r_f}(\beta^{r_f} - r_t^f)dt - \frac{1-e^{-\alpha^{r_f}(T-t)}}{\alpha^{r_f}}\sigma^{r_f}dz_t^{r_f} + \frac{1}{2}\left\{\frac{1-e^{-\alpha^{r_f}(T-t)}}{\alpha^{r_f}}\right\}^2 \sigma^{r_f 2}dt\right\} + \alpha^{CR}(\Phi^{CR} - \ Capital\ Ratio_t)\frac{IL_t}{A_t}dt. \quad (18)$$

$$\frac{dL_t}{L_t} = \left\{E_{AS,A}\frac{dA_t}{A_t} + E_{AS,r_f}dr_t^f\right\}\frac{AS_t}{L_t} + \left\{E_{COG,A}\frac{dA_t}{A_t} + E_{COG,r_f}dr_t^f\right\}\frac{COG_t}{L_t} + \left\{E_{RM,A}\frac{dA_t}{A_t} + E_{RM,r_f}dr_t^f\right\}\frac{RM_t}{L_t} + \left\{E_{TMTP,A}\frac{dA_t}{A_t} + E_{TMTP,r_f}dr_t^f\right\}\frac{TMTP_t}{L_t} + \left\{E_{OL,A}\frac{dA_t}{A_t} + E_{OL,r_f}dr_t^f\right\}\frac{OL_t}{L_t} + \alpha^{CR}(\Phi^{CR} - \ Capital\ Ratio_t)\frac{IL_t}{L_t}dt. \quad (19)$$

<u>Model-implied equity price and optimisation problem</u>

Under our framework, the model-implied price of the insurer's equity is:

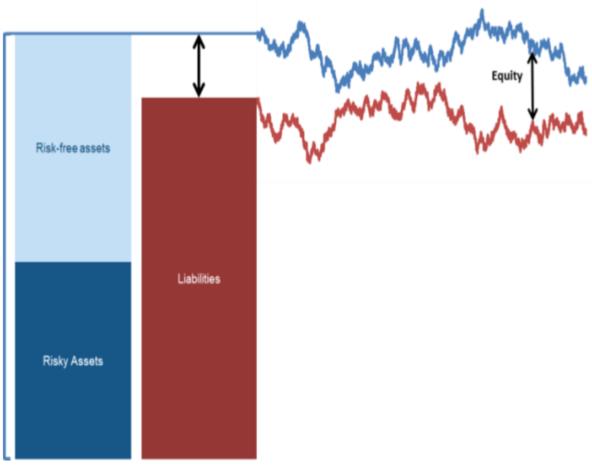
$$p_0 = E_0[\exp(-(r_0^f + \xi_0^{ERP})T)Payoff_t]; \quad (20)$$

where:

$$Payoff_t = \begin{cases} \exp(-(r_0^f + \xi_0^{ERP})T) * (A_T - L_T) & if\ \frac{E_t - CED}{Regulatory\ capital\ requirement} > 1, \forall t \in [0,T] \\ \exp(-(r_0^f + \xi_0^{ERP})(T - t_{def}))\max\{(1 - x\%)A_{t_{def}} - L_{t_{def}}, 0\} & otherwise \end{cases}. \quad (21)$$

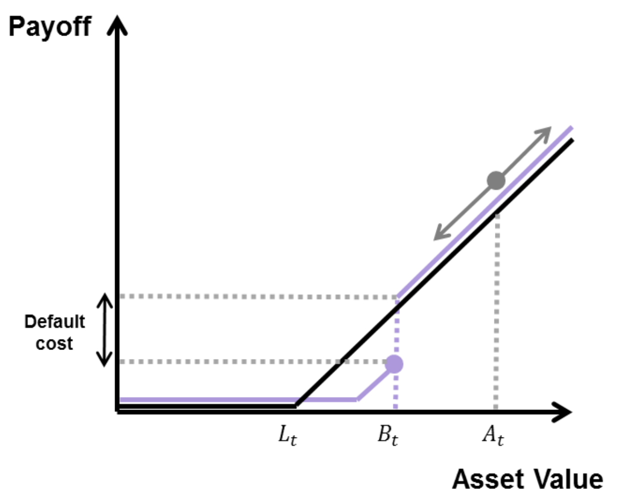
The insurer attempts to maximise the value of shareholder equity, whose value depends on the difference between the insurer's assets and liabilities at the equity holders' valuation horizon (**Figure 3**). But we also recognise that insurers are subject to ICAS regulations, which require insurers to maintain levels of capital resources above prescribed regulatory minima.

Figure 3: The payoff to the insurer's equity holders depends on the difference between the insurer's assets and liabilities at the equity holders' valuation horizon



Source: Stylised representation.

Figure 4: Payoff to the insurer's shareholders under a hypothetical 'knock-out' option on the value of assets, struck at the face value of liabilities



Source: Stylised representation.

We therefore assume that if, at any point prior to the equity holders' horizon date (see **Section 5**), the value of assets falls below a level commensurate with the insurer's regulatory capital requirement, the insurer is assumed to be placed into run-off, and its assets are assumed to fall by a certain percentage reflecting default costs (e.g. the administration costs of removing the firm's management and transferring its remaining assets and liabilities to a stronger insurer). Put differently, we apply barrier option pricing theory to model the payoff to shareholders. That is, the insurer's equity is valued as a hypothetical 'knock-out' option written on the firm's assets, A, struck at the value of its liabilities, L, with a barrier, B, set at a level commensurate with the value of its regulatory capital requirements (**Figure 4**).

In our simple model, the insurer chooses the proportion of its assets to invest in the risky asset in order to maximise the model-implied equity price. The insurer understands the stochastic processes governing the risky asset and interest rates, and understands how these processes influence the evolution of its assets and liabilities in the future, including if it should breach its regulatory capital requirement.

Solvency II model

The inclusion of Solvency II into the model involves the introduction of four new features compared to the baseline, ICAS model. The first three of these differences relate to both non-profit and with-profit insurers, whilst the fourth relates only to non-profit insurers. We describe each in turn below and provide a summary in **Table 2**.

- First, we introduce the so-called 'risk margin'. As described in **Section 3**, this is an additional liability introduced under Solvency II to reflect the compensation another firm might require to accept the transfer of an insurer's liabilities in the event of its failure. Under its current design, the value of the risk margin increases considerably when risk-free interest rates fall but is invariant to other changes in the risky asset price (see **Annex 1** for more detail).

- Second, we introduce transitional measures, or so-called 'transitional measures on technical provisions' (TMTPs), which act to gradually phase in Solvency II's impact over sixteen years until 2032. Regulatory data shows that the primary role of TMTPs is to reduce the impact of the risk margin in the early years of Solvency II's introduction. Hence, in our framework, we model TMTPs as negative liabilities that move inversely to the value of the risk margin.

- Third, we alter our assumption as to how the payoff to equity holders changes when insurers breach their regulatory capital requirements. In particular, under the 'Baseline' ICAS model we assumed that insurers only enter insolvency when they have breached their capital requirements for three consecutive months. In contrast, under the 'Solvency II' model, we assume that insurers enter insolvency immediately following a breach in capital requirements. This difference reflects the increased market transparency introduced under Solvency II, which increases market pressure on insurers that breach their capital requirements, and the reduced scope for regulatory forbearance by national regulators under Solvency II.

- Fourth, under Solvency II, and as discussed in **Section 3**, non-profit insurers benefit from the so-called 'matching adjustment' – a more generous, countercyclical solvency measure that protects their capital resources by enabling them (subject to conditions and prior approval) to look through certain short-term asset price market movements when valuing their liabilities. To reflect this difference in our model, we replace non-profit insurers' 'Best Estimate Liabilities', which benefitted from the countercyclical solvency measure available under ICAS, with 'Matching Adjustment Liabilities', which benefit from the matching adjustment.

Table 2: Key differences between the Solvency II and ICAS regulatory regimes captured in the model

Applicability	Change no.	ICAS	Solvency II
Non-profit **and** with-profit insurers	1	-	Include the risk margin
	2	-	Include the transitional measures (TMTPs)
	3	Insurers only enter insolvency when they have breached their capital requirements for three consecutive months	Insurers enter insolvency immediately following a breach in capital requirements
Only non-profit insurers	4	Non-profit insurers have 'Best Estimate Liabilities' that benefit from the illiquidity premium	Non-profit insurers have 'Matching Adjustment Liabilities' that benefit from the matching adjustment

We illustrate the stylised balance sheets of the representative non-profit and with-profit insurers under 'Solvency II' in **Figures 5 and 6**, respectively.

Figure 5: Stylised non-profit insurer's balance sheet under the 'Solvency II' model

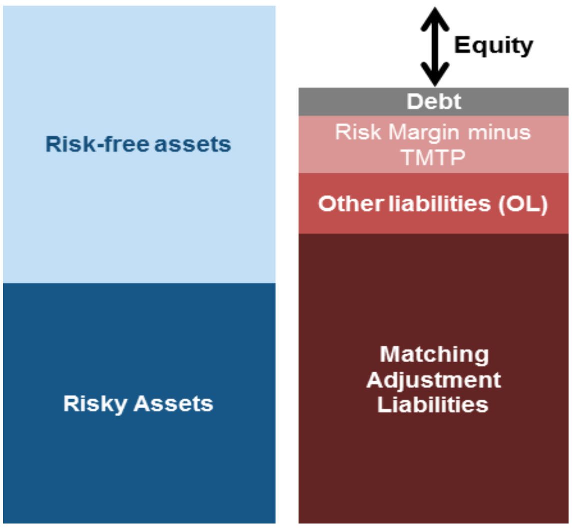
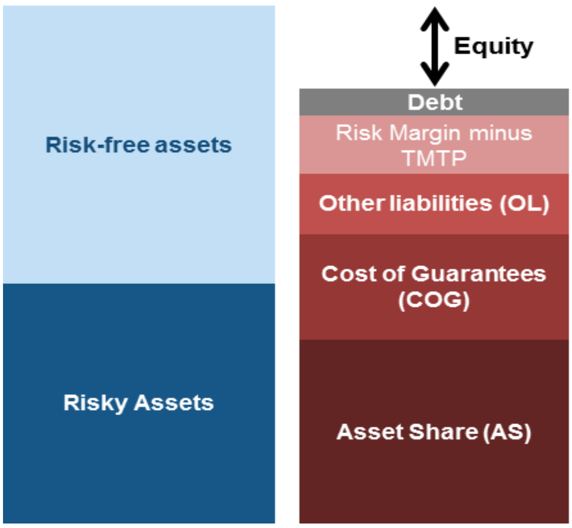


Figure 6: Stylised with-profit insurer's balance sheet under 'Solvency II' model



5 Model parameterisation and calibration

Our structural model of insurers' asset allocation decisions requires the input of multiple parameters. Broadly speaking, these parameters can be categorised into four buckets, which we outline in turn.

i. Parameters describing the overarching model structure

Our structural model includes a number of parameters that inform the overarching dynamics of the insurers' asset allocation processes. These include: the time increment in the model, the solvency ratio that insurers target over the long-term (and speed at which they attempt to achieve that target), and the assumed cost associated with insurers entering insolvency (upon breach of its regulatory capital requirement). Values for these parameters are determined using a combination of empirical evidence and intuition obtained from consultative interviews with colleagues in the Prudential Regulation Authority (PRA). These are summarised in **Table 3**.

Table 3: Model parameters that describe the overarching model structure

Type of parameter	Parameter	Description	Value
Time increment	dt	Time increment in the model	1 week
Long-term capital targeting	Φ^{CR}	Target capital ratio	140%
	α^{CR}	Speed of adjustment towards target capital ratio	During 'stressed' market conditions = 0 During 'normal' market conditions = 0.05
Insolvency cost	x%	Fall in value of insurance assets following breach of minimum capital requirements	40%

ii. Model parameters relating to the dynamics of the risky asset price and interest rates

The model includes parameters that inform the processes through which the risky asset price and the risk-free interest rate evolve. These are estimated using observed financial market pricing data, and are summarised in **Table 4**.

Table 4: Model parameters that describe the dynamics of financial market prices

Type of parameter	Parameter	Description	Value
Dynamics of risky asset volatility	σ_0^R	Volatility of risky asset at time 0	0.0581
	Φ^R	Long-term average risky asset volatility	0.1876
	α^R	Speed of adjustment of risky asset volatility to long-term mean	0.0746
Dynamics of risk premium	β^{ξ}	Long-term proportional relationship between risk premium and risky asset volatility (e.g. Sharpe Ratio)	0.27039
Dynamics of risk-free interest rates and the risk-free asset price	r_0^f	Interest rate at time 0	Varies depending on assumed model start date
	β^{r_f}	Long-term average interest rate	0.0516
	α^{r_f}	Speed of adjustment of interest rates to time-dependent mean	0.1332
	σ^{r_f}	Volatility of risk-free asset	0.0114
	$T-t$	Constant time to maturity of risk-free asset	10

iii. Model parameters describing the two types of insurers' balance sheets

In the model, we develop hypothetical balance sheets for the two types of insurance companies. These are constructed by combining the balance sheets of around 20 of the largest UK insurance companies, using regulatory data from end-2015. The hypothetical balance sheets inform the initial solvency positions of the two insurers, together with their respective weights in the risky asset – that is, the proportion of the insurers' assets invested in the risky asset.[4]

[4] For confidentiality reasons, we are unable to report the initial balance sheet values of each hypothetical insurer.

Together with parameterising the initial balance sheets of the two types of insurers, our structural model requires estimates of how insurance liabilities respond to changes in financial market prices. As described in **Section 4**, we therefore develop a set of elasticities that describe how a given percentage change in the value of the insurers' assets, or given basis point change in risk-free interest rates, results in a consequent percentage change in the value of each insurance liability.

We estimate values for these elasticities using a combination of regulatory data, separate in-house financial models, and intuition provided by colleagues in the Prudential Regulatory Authority (PRA). For example, whilst the elasticities associated with the Asset Share and Cost of Guarantees are estimated using historical regulatory data, those associated with the Matching Adjustment Liabilities, the Risk Margin and TMTPs are estimated using separate in-house models. The estimated elasticity values are summarised in **Table 5**.

Table 5: Model parameters for the sensitivities of insurers' liabilities to financial market prices

Liability	**Representative non-profit insurer**		**Representative with-profits insurer**	
	Elasticity wrt. asset values	**Elasticity wrt. interest rates**	**Elasticity wrt. asset values**	**Elasticity wrt. interest rates**
Asset Share	N/A	N/A	1	0
Cost of Guarantees	N/A	N/A	-0.1	-0.1
Matching Adjustment Liabilities	Equals 0.97 when there is a liquidity shock, and 0.89 when there is a fundamental shock[5]	0	N/A	N/A
Risk Margin	0	-0.64	0	-0.64
TMTPs	0	0 < x < 0.64 (*depends on transitional run-off timetable*)	0	0 < x < 0.64 (*depends on transitional run-off timetable*)
Other Liabilities	0.5	0	1.4	0

i. **Unobserved parameters that we use to calibrate the model**

The last bucket of parameters included in the model contains those parameters that cannot be observed from data. These include:

[5] Under Solvency II, the sensitivity of the Matching Adjustment Liability's value to asset prices depends on the type of shock to asset prices. If asset prices fall for fundamental reasons (e.g. a deterioration in credit fundamentals), then the elasticity value is calculated at 0.89. This value is parameterised using observed changes in financial asset prices over the 2007-08 financial crisis. If instead asset prices fall due to an increase in liquidity premia, then the elasticity value is calculated at 0.97.

i. The equity holders' investment horizon – that is, the period over which equity holders typically hold an insurer's equity and therefore the time period over which they place a value on that equity;

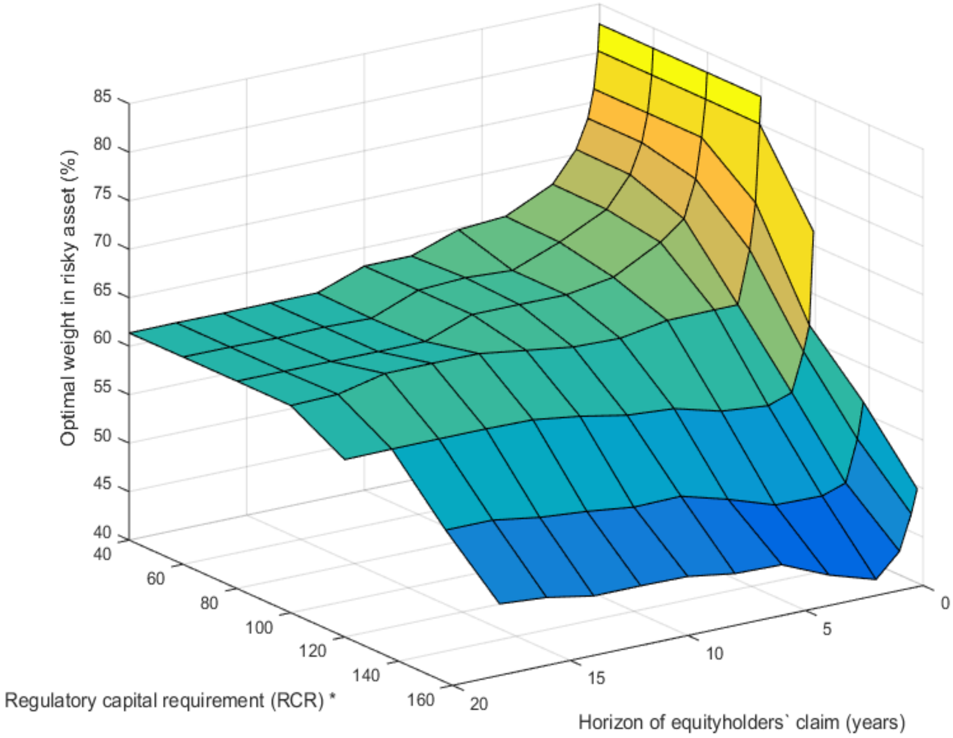
ii. The level of the regulatory barrier – or, put differently, the capital ratio below which insurers are assumed to be subject to increased regulatory scrutiny and enter run-off, thus limiting shareholder returns; and

iii. The level of exogenous balance sheet volatility brought about by non-market risk (e.g. operational risk). This has the effect of increasing the volatility of an insurer's liabilities and therefore impacts the volatility of its solvency position.

These three unobserved parameters are used to calibrate the model. That is, their values are varied until the representative insurer's optimal holdings of risky and safe assets predicted by the model under current market conditions matches that observed in regulatory balance sheet data.

Chart 3 shows how the representative with-profit insurer's holdings of risky assets – as predicted by the model – varies with both the assumed level of the regulatory capital requirement (that is, the barrier below which assets cannot fall without the insurer being placed into run-off) and the assumed horizon over which equity holders value their claim on the insurer's assets.

Chart 3: Calibration of the representative with-profit insurer's optimal weight in the risky asset by adjusting the regulatory capital requirement and the equity holders' valuation horizon



We make three observations:

- First, a higher regulatory capital requirement results in a lower optimal holding of the risky asset. This is because, as the barrier level increases, so too does the probability of the insurer's assets breaching this level, which incentivises the insurer to hold less of the more volatile, risky asset.

- This effect is strongest when the horizon of the equity hold is shorter. This is because during the early part of the equity holders' claim, the insurer's capital requirement is more likely to be breached, and therefore the initial level of the capital requirement has a strong bearing on the insurer's asset allocation. In contrast, were equity holders to value payoffs over an infinitely long horizon, the insurer's optimal holding of the risky asset in this framework would be equal for all levels of the regulatory barrier.

- Second, the impact of the equity holders' horizon depends on the level of the regulatory capital requirement. For low levels of the regulatory requirement, the insurer's optimal holding of the risky asset *decreases* as the equity holder's horizon increases. This is because, when the initial difference between the insurer's assets and the regulatory barrier is high (i.e. when the capital requirement is low) increasing the horizon of the equity holder's claim increases the probability that a given mix of assets will fall beneath that barrier at some point over that horizon. Hence, the insurer finds it optimal to hold less of the risky asset.

- On the other hand, for high levels of the regulatory capital requirement, the insurer's optimal holding of the risky asset *increases* with the equity holder's investment horizon. This is because, when the initial difference between the insurers' assets and the regulatory barrier is low (i.e. where the capital requirement is high), the probability of default is already very high for low equity holder's horizons. Hence, whilst increasing the equity holder's horizon increases the probability of default only modestly, a higher weight in the risky asset gives insurers a greater likelihood of capturing the upside of its potential future growth.

- Third, for very short equity holder investment horizons, the optimal weight in the risky asset tends towards one for all possible levels of the initial barrier level. This results from the fact that the value of the insurer's assets is assumed to follow a smooth diffusion function, where there are no 'jumps' in asset prices over time. Hence, over an infinitely short horizon there is a close-to-zero probability of default for an insurer that starts with a level of capital above its capital target. This means that, faced with a very short horizon, equity holders are incentivised to hold the maximum possible weight in the risky asset, which offers a higher expected return.

We use the above intuition around our three unobserved 'free parameters' to calibrate our model to real-world data. In particular, we simultaneously tweak their values until the two representative insurers' optimal holdings of risky and safe assets predicted by the model under prevailing market conditions matches observed behaviour based on regulatory balance sheet data. But to solve for the unobserved values of the three 'free' parameters in our calibration model of two equations (i.e. two insurers) and three unknowns (i.e. three 'free parameters'), we introduce constraints guiding the plausible ranges of values that these parameters could obtain.

The plausible ranges of values of two of the free parameters – the equity holder horizon and the exogenous balance sheet volatility – are estimated using observed financial market and regulatory data, and intuition provided from consultative interviews with colleagues in the Prudential Regulation Authority (PRA). In contrast, the plausible range of values for the third free parameter – the level of the regulatory barrier – is determined under Solvency II regulations. In particular, there exists a 'supervisory ladder of intervention' based around two regulatory capital requirement levels, which differ in their levels of prudence:

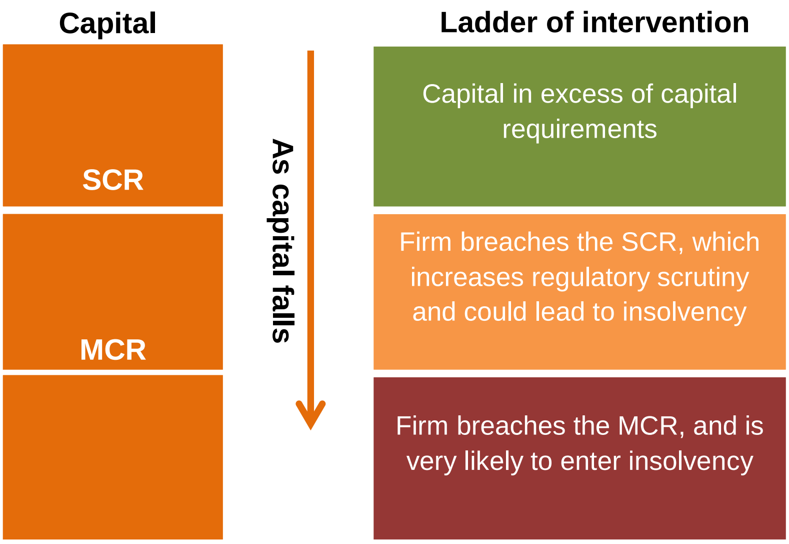
1. The Solvency Capital Requirement (SCR) is the quantity of capital that is intended to provide protection against unexpected losses over a one year period that results from '1 in 200-year events'. Breach of the SCR results in increased regulatory scrutiny, but not necessarily run-off.

2. The Minimum Capital Requirement (MCR) is a more prudent capital threshold, representing the *absolute minimum* amount of capital that insurers must hold at all periods of time. Under the

regulations, the MCR lies between 25-45% of the level of the SCR. Breach of the MCR is highly likely to lead to insolvency.

The ‘supervisory ladder of intervention’ is demonstrated, in a stylised way, in **Figure 4**. Under it, there exists a positive probability that insurers will enter insolvency once they breach the SCR but before they breach the MCR. Hence, we define the plausible range of values of the regulatory barrier level as the MCR-SCR corridor.

Figure 4: Supervisory ladder of intervention under Solvency II



Source: Bank of England (2015).

The plausible ranges of values for the three ‘free parameters’, together with the chosen values that we use to calibrate our models, are outlined in **Table 6**.

Table 6: Calibration results for our ‘free parameters’

Free parameters	Plausible range of values	Chosen values based on calibrating model to real-world data
Equity holder horizon	10 to 20 years	14 years
Regulatory barrier level	Between an insurer’s ‘Solvency Capital Requirement’ (SCR) and its ‘Minimum Capital Requirement’ (MCR)	90% of the Solvency Capital Requirement (SCR)
Exogenous balance sheet volatility (driven by non-market factors)	0% to 5% additional balance sheet volatility	1%

6 Results

There are *two* key outputs from our model. The first output is an estimate of how the two representative insurers' allocations between the risky and safe assets vary in response to changes in asset prices; that is, we estimate insurers' *propensity to act procyclically.* The second output is to assess insurers' willingness to invest in long-term, risky assets.

Procyclicality

To estimate insurers' propensity to invest procyclically, we:

i. Introduce exogenous market shocks, which impact insurers' solvency positions;

ii. Following the introduction of exogenous market shocks and changes in insurers' solvency positions, we re-run the model to estimate the insurers' new optimal holdings of risky and safe assets.

iii. We use the change in the insurers' holdings of different assets to estimate their propensity to act procyclically.

We focus on insurers' investment behaviours following three different types of market shocks, which are described in **Table 7**.

Table 7: How different combinations of changes in interest rates and risky asset prices are assumed to correspond to different macroeconomic scenarios

Scenario	Assumed direction of change in the…		
	Risk-free interest rates	Risky asset…	
		Overall price	Credit rating
(a) Increase in liquidity premia	Unchanged	Decreases	Unchanged
(b) Deterioration in credit fundamentals	Unchanged	Decreases	Decreases
(c) Change in monetary policy expectations	Decrease	Unchanged	

We focus first on a scenario where risky asset prices are assumed to fall due to an increase in liquidity premia – that is, the compensation investors require to bear the liquidity risk associated with holding risky assets – and risk-free interest rates are assumed to remain unchanged (see shock (a) in **Table 7**). Following this shock, both non-profit and with-profit insurers are estimated to act *mildly procyclically* under Solvency II. In particular, in response to a 12% fall in risky asset prices, which corresponds to the estimated fall in the value of a sample of large UK insurers' asset portfolios over the months following Lehman's default in September 2008, non-profit and with-profit insurers find it optimal to switch £9 billion and £4 billion of their asset portfolios from risky to safe assets, respectively (solid lines in **Charts 4 and 5**).

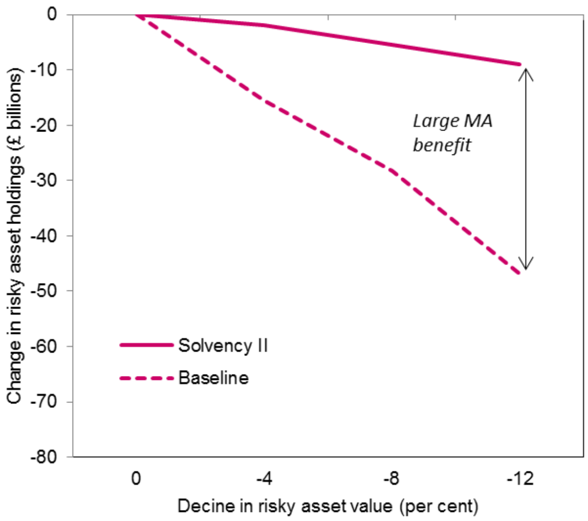
The intuition here is that falls in risky asset prices worsen insurers' solvency positions and increase the probability of future insolvency. In response, insurers find it optimal to reduce the variance of their asset portfolios, which they do by disposing of risky assets and investing in safer assets.

Comparing the Solvency II results to those under the 'Baseline' ICAS model (dotted lines in **Charts 4 and 5**), we find that Solvency II's introduction has a differing impact on the two types of insurers:

- On the one hand, non-profit insurers are estimated to invest less procyclically under Solvency II than ICAS (**Chart 4**). This result is, in large part, driven by the matching adjustment – a more countercyclical solvency measure introduced under Solvency II – which cushions insurers' solvency positions against short term fluctuations in the value of their risky assets.

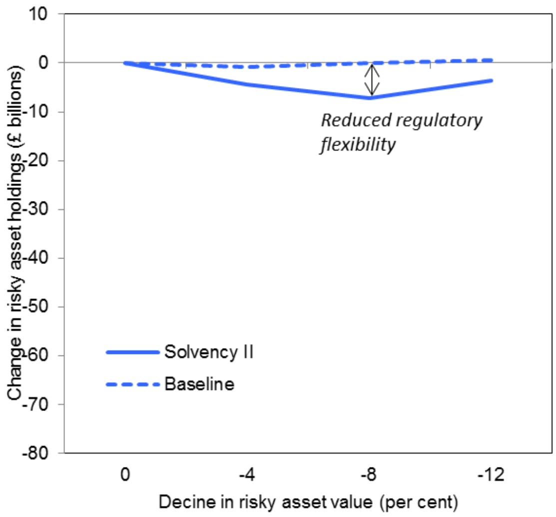
- On the other hand, with-profit insurers are estimated to behave more procyclically under Solvency II than under ICAS (**Chart 5**). This is due, in part, to the increased market transparency under Solvency II, which incentivise insurers to sell risky assets to improve their solvency positions.

Chart 4: Change in risky asset holdings for non-profit insurers under Solvency II vs. ICAS as a function of percentage falls in risky asset prices driven by an increase in liquidity premia



Source: Model outputs.

Chart 5: Change in risky asset holdings for with-profit insurers under Solvency II vs. ICAS as a function of percentage falls in risky asset prices driven by an increase in liquidity premia



Source: Model outputs.

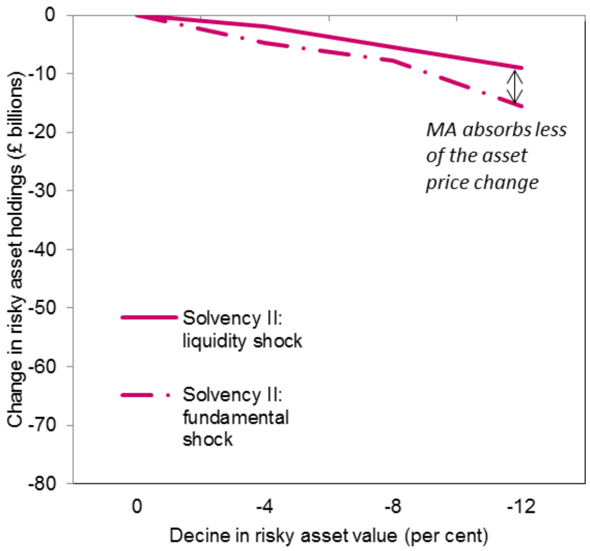
Following the scenario where risky asset prices are assumed to fall due to a deterioration in credit fundamentals (see shock (b) in **Table 7**), under ICAS, insurers are estimated to respond exactly the same as to when prices fall because of increases in liquidity premia. That is, they are expected to act *mildly procyclically* (as shown in **Charts 4 and 5**).

By comparison, under Solvency II, the underlying driver of the fall in risky asset prices can have a bearing on insurers' investment responses.

In the case of non-profit insurers, firms are estimated to act only *slightly more procyclically* when prices fall due to deteriorations in credit fundamentals than when prices fall due to increases in liquidity premia (**Chart 6**). This is because the matching adjustment, under its current design, provides slightly less protection for non-profit insurers' solvency positions against falls in risky asset prices that are driven by deteriorations in credit fundamentals.

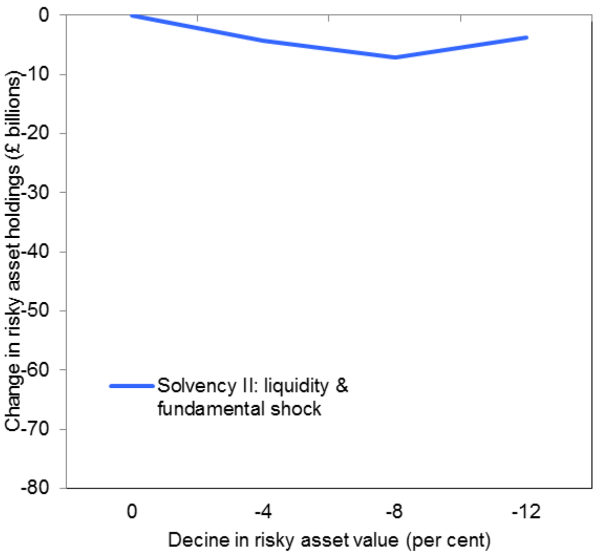
In the case of with-profit insurers, firms' investment responses are identical when risky asset prices fall due to deteriorations in credit fundamentals to when prices fall due to increases in liquidity premia (**Chart 7**). This is because with-profit insurers do not benefit from the matching adjustment, and so all types of risky asset price fall have the same impact on their solvency positions.

Chart 6: Comparison of change in risky asset holdings for non-profit insurers under Solvency II as a function of percentage falls in risky asset prices that are driven by a deterioration in credit fundamentals vs. an increase in liquidity premia



Source: Model outputs.

Chart 7: Comparison of change in risky asset holdings for with-profit insurers under Solvency II as a function of percentage falls in risky asset prices that are driven by a deterioration in credit fundamentals vs. an increase in liquidity premia



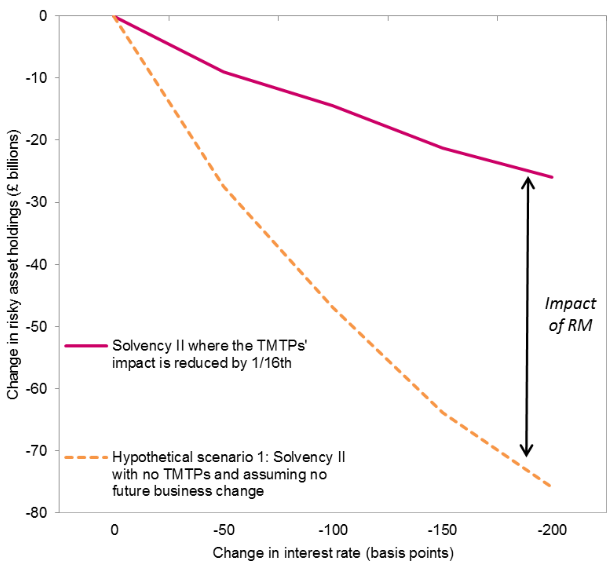
Source: Model outputs.

Last, we look at the scenario where there is a parallel downward shift in the yield curve, which increases the value of the safe asset but – for simplicity – is assumed to have no impact on the risky asset price (see shock (c) in **Table 7**). Following this shock, model results suggest that, under Solvency II, both non-profit and with-profit insurers sell risky assets following falls in interest rates. And to the extent that interest rates tend to fall during market downturns, this can be interpreted as preliminary evidence of procyclical investment behaviour.

In particular, following a 100bps parallel downwards shift in the yield curve, non-profit and with-profit insurers find it optimal to switch £14 billion and £17 billion of their asset portfolios from risky to safe assets, respectively (block lines of **Charts 8 and 9**). However, by the time transitional measures have run-off completely by 2032, a similar 100bps parallel downwards shift in the yield curve is estimated to cause these insurers to switch £47 billion and £24 billion of their asset portfolios from risky to safe assets, respectively (dotted lines of **Charts 8 and 9**).

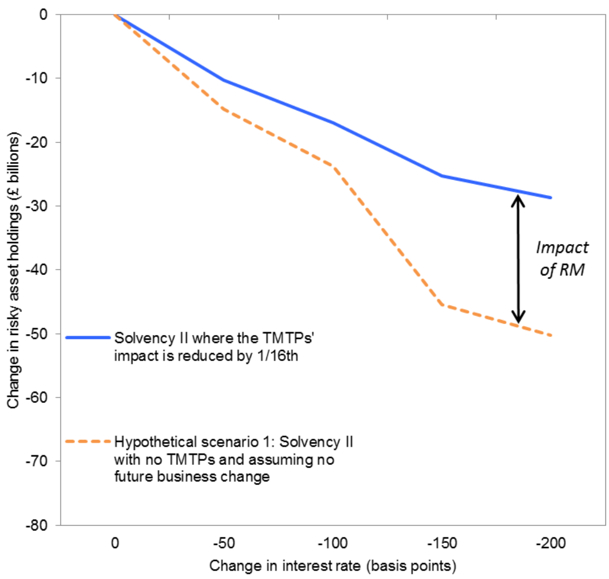
The increased investment response that is estimated by 2032 is driven by the risk margin, which, under its current design and as described in **Section 3**, increases in value considerably as interest rates fall. This has the effect of worsening insurers' solvency positions. Then, faced with a higher probability of regulatory insolvency, insurers find it optimal to reduce the variance of their asset portfolios, which they do by disposing of risky assets.

Chart 8: Change in risky asset holdings for non-profit insurers under Solvency II as a function of falls in risk-free interest rates for differing levels of benefit provided by transitional measures (TMTPs)



Source: Model outputs.

Chart 9: Change in risky asset holdings for with-profit insurers under Solvency II as a function of falls in risk-free interest rates for differing levels of benefit provided by transitional measures (TMTPs)



Source: Model outputs.

Long-term investment

The *second* key output of the model is to assess insurers' willingness to invest in *long-term, risky assets*. To do so, we:

i. Impose historically average market conditions. In particular, we assume that risk-free interest rates and the return and volatility of risky assets move instantaneously towards their long-run average levels.

ii. Following the introduction of historically average market conditions, which change the insurers' trade-off between the risky and safe assets, we re-run the model to estimate insurers' new optimal holdings of risky and safe assets.

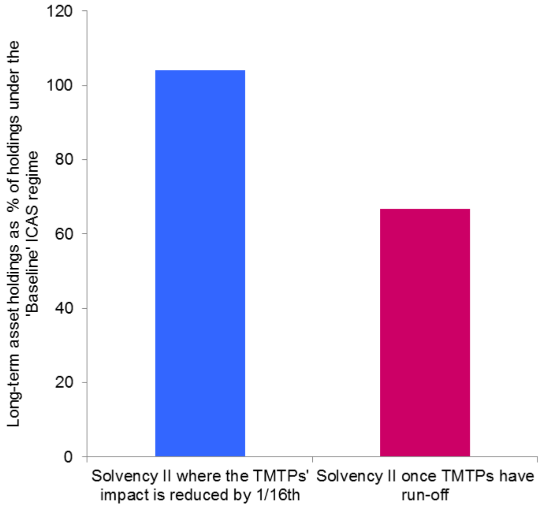
iii. We use the insurers' chosen holding in the risky asset as a proxy for its willingness to hold long-term, risky assets.

As with our results on procyclicality, we examine both non-profit and with-profit insurers' willingness to hold long-term, risky assets.

Focusing first on non-profit insurers, the model suggests that Solvency II may have a mixed impact on firms' willingness to hold long-term, risky assets. In the short-term, whilst transitional measures are in place, the matching adjustment, which reduces the sensitivity of insurers' solvency positions to changes in risky asset prices, encourages insurers to hold more long-term, risky assets than under ICAS (**Chart 10**). In contrast, in the long-tem, the risk margin – whose impact is felt in full once transitional measures have run-off completely by 2032 – is estimated to provide a more powerful disincentive. In particular, by 2032 we estimate that Solvency II will encourage non-profit insurers to reduce their holdings of long-term, risky assets by around 35% relative to their holdings under ICAS.

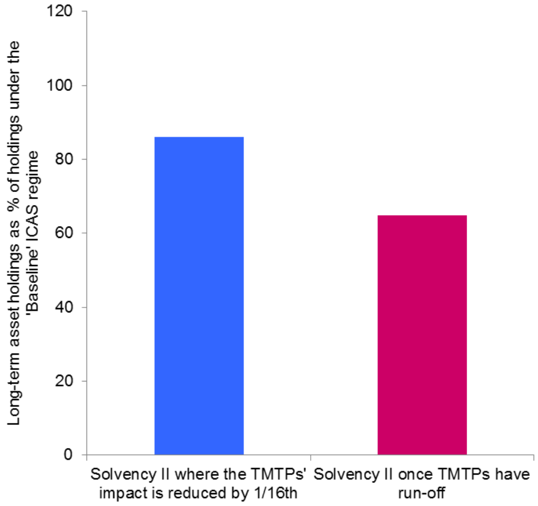
In the long-term, the model results for with-profit insurers are very similar to those for non-profit insurers (**Chart 11**). This is, once again, driven by the risk margin, whose effects are felt in full once transitional measures have run-off completely by 2032. But, unlike for the non-profit insurer, we estimate that Solvency II will reduce with-profit insurers' incentives to hold long-term, risky assets in the short-term too. This is because with-profit insurers do not benefit from the matching adjustment, but are impacted by the reduced regulatory flexibility permitted under Solvency II. This reduced regulatory flexibility increases the probability of insolvency for any breach of the regulatory capital requirement and thereby encourages insurers to reduce their holdings of long-term, risky assets to reduce the variance of their asset portfolio.

Chart 10: Non-profit insurers' holdings of long-term, risky assets under different regulatory regimes



Source: Model outputs.

Chart 11: With-profit insurers' holdings of long-term, risky assets under different regulatory regimes



Source: Model outputs.

Sensitivity testing

The above results could be subject to two main types of estimation errors. First, the estimated values of the various input parameters could be inaccurate. Second, even if the values of the input parameters are estimated accurately, the model outputs could be subject to some degree of simulation error (which could arise, for example, by choosing an insufficiently large number of simulations in our Monte Carlo simulations).

Starting with the first type of estimation error, we have tested the sensitivity of our results to the chosen values of a number of our model inputs. The key finding of this sensitivity testing is that the input values that play the greatest role in driving our results are those that have been estimated using observed regulatory or financial data. That is, the above results depend most on those input parameters whose values can be estimated most accurately. Such input parameters include the Risk Margin and the Matching Adjustment Liabilities, whose values depend on formulaic measures defined under Solvency II regulations.

Moving to the second type of estimation error, the results reported above each use 100,000 simulations. With this number of simulations, the standard error associated with an insurer's chosen weight in the risky asset – that is, the proportion of its assets invested in the risky asset – is under one percentage point.

7 Conclusion

This paper uses a structural model of insurers' balance sheets to understand how the introduction of Solvency II regulations may impact the investment behaviour of two different types of UK life insurers – non-profit and with-profit insurers.

We use this structural model to answer two questions:

First, we use the model to estimate how the two types of UK life insurers' allocations between risky and safe assets vary in response to different types of shocks to market prices. As a result, we estimate their *propensity to act procyclically*. We find that both types of insurers are expected to invest only *marginally* procyclically under Solvency II regulations following an exogenous fall in risky asset prices. In contrast, we find that, once transitional measures have run-off completely by 2032, both types of insurers are expected to dispose of large quantities of risky assets following falls in risk-free interest rates. This latter behaviour is driven by the so-called 'risk margin' – a new liability provision introduced under Solvency II – which reduces insurers' solvency positions following falls in interest rates and thereby encourages them to dispose of risky assets to reduce their probabilities of default.

Second, we use the model to estimate insurers' willingness to invest in long-term, risky assets. We find that, once the effects of Solvency II are felt in full by 2032, both types of insurer are likely to have markedly reduced their holdings of long-term, risky assets. This is also driven by the risk margin, which increases the volatility of insurers' solvency positions and thereby encourages them to de-risk to reduce the variance of their asset portfolios.

As with other papers of this sort, this analysis is not without caveats. Addressing these could represent avenues for future research:

First, structural models, in general, are subject to drawbacks. As noted, for example, by Mele (2014), such models require inputs that are, in many cases, unobservable (e.g. the market value or volatility of assets), and they often predict lower probabilities of default and lower credit spreads at short maturities than observed empirically. That said, these potential drawbacks are less of an issue in the case of UK insurers, which: (1) are required to report frequent mark-to-market accounts containing information that can be directly inputted into a structural model; and (2) have business models that are typically of a long horizon, suggesting that their equity holders' investment horizons are also long-tailed (i.e. at longer maturities where the structural model performs better at valuing contingent liabilities).

Second, we assume that the value of the risky asset follows a Geometric Brownian Motion (GBM), with shocks that follow a standard normal distribution. Empirically however, we observe that the distribution of asset returns tend to have fat tails, particularly on the downside (Pimco (2015)). Hence, one natural extension of this paper would be to introduce price processes that give rise to fat-tailed distributions (e.g. those with stochastic volatility).

Third, this paper has focused its analysis on two stylised insurers: an aggregate UK non-profit insurer and an aggregate UK with-profit insurer. Hence, the balance sheets of these aggregated insurers, and therefore the results from this paper, will be skewed towards the largest insurers in our sample. One way to assess whether the results reported in this paper are representative across the distribution of insurers would be to repeat the same analysis on a firm-by-firm basis.

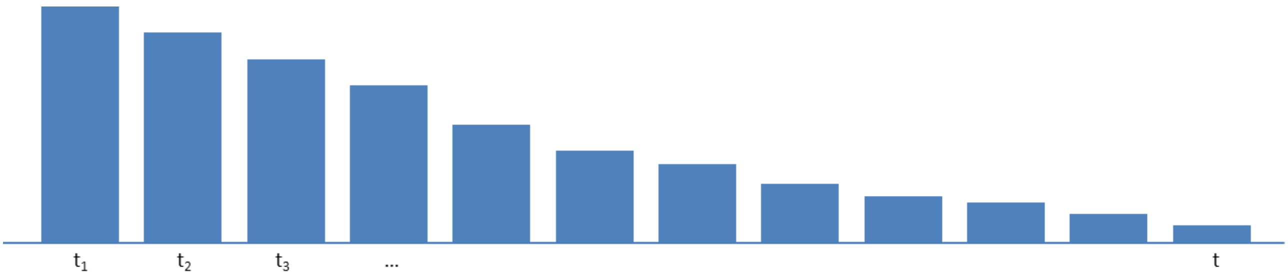
Fourth, this paper focuses on three separate, instantaneous market shocks. Hence, one extension would be to model more comprehensive, dynamic shocks. For example, we could model an economic shock with simultaneous changes to liquidity premia, credit fundamentals and market interest rates. And such shocks could be assumed to unfold incrementally over time, rather than instantaneously, so that the dynamics of insurers' investment behaviour can be better understood.

These caveats aside, the paper provides a framework through which public policymakers – if they so choose – could assess how changes to the current regulatory framework might alter insurers' investment behaviour. One additional future extension of our framework could be to assess the impact of the sort of macroprudential policy tools that have been introduced in other financial sectors to the life insurance sector – for example, countercyclical capital tools that have been introduced to the banking sector (Basel Committee on Banking Supervision (2015)).

Annex 1 –The Risk Margin and potential policy modification

The Risk Margin is a new balance sheet liability introduced under Solvency II that insurers hold to reflect the compensation required by a third party to take on their insurance liabilities in the event of future failure. Under its current formula, the Risk Margin is calculated by:

1) Projecting forward the amount of capital that must be held against risks on the insurers' balance sheets that cannot be hedged away, called the 'Non-hedgeable Solvency Capital Requirements' (NHSCR).



2) Multiplying the projected NHSCRs in each year by a constant cost of capital (6%) to calculate the future cost of capital.

3) Discounting these projected future costs of capital to time zero using the prevailing risk-free rate, and summing them to calculate the value of the Risk Margin.

That is, the risk margin, RM, is given by:

$$RM = \text{CoC} * \sum_{i=1}^{t} \frac{NHSCR_i}{(1 + r_f)i}$$

Where: RM is the Risk Margin; CoC is the cost of capital (currently fixed 6%); $NHSCR_i$ is the projected future 'Non-hedgeable Solvency Capital Requirements'; and r_f is the prevailing interest rate (currently EIOPA swap curve).

Under the current design, as interest rates change, the value of insurers' Risk Margins change for two reasons:

I. ***Channel 1**:* the projected future NHSCRs are a negative function of interest rates (i.e. as interest rates falls, the projected value of future NHSCRs increase).

II. ***Channel 2**:* as market interest rates fall, the present value of future NHSCRs increase, as they are discounted less heavily.

References

Anderson R, Sundaresan S (2000), A Comparative study of structural models of corporate bond yields: An exploratory investigation, Journal of Banking and Finance 24: 255–269.

Bank of England:

a) (November 2016) Financial Stability Report, Issue No. 40.
b) (February 2016) Bank of England Response to European Commission Call for Evidence on EU Regulatory Framework for Financial Services.
c) (December 2015) Financial Stability Report, Issue No. 38.
d) (Q2 2015) The prudential regulation of insurers under Solvency II', Quarterly Bulletin.

Bank of England and the Procyclicality Working Group (2014), Procyclicality and structural trends in investment allocation by insurance companies and pension funds.

Baranova Y, Liu Z, Noss J (2017), The role of collateral in supporting liquidity, Bank of England, Staff Working Paper No. 609.

Basel Committee on Banking Supervision (October 2015), Frequently asked questions on the Basel III Countercyclical Capital Buffer.

Black F, Cox J (1976), Valuing corporate securities: Some effects of bond indenture provisions, Journal of Finance 31: 351–367.

Black F, Scholes M (1973), The pricing of options and corporate liabilities, Journal of Political Economy 81 (3): 637–654.

Blake D, Lehmann B, Timmermann A (2002) Performance clustering and incentives in the UK pension fund industry, Journal of Asset Management 3(2): 173-194.

Collin-Dufresne P, Godlstein R (2001), Do credit spreads reflect stationary leverage ratios?, Journal of Finance 56, 1929-1957.

Episcopos A (2008), Bank capital regulation in a barrier option framework, Journal of Banking & Finance 32: 1677–1686.

BBC News (Wednesday 20th October 2010), Equitable Life: Timeline of key events, http://www.bbc.co.uk/news/business-10725923

Ernst and Young (2015), Infrastructure investments: An attractive option to help deliver a prosperous and sustainable economy, http://www.ey.com/Publication/vwLUAssets/EY-infrastructure-investments-for-insurers/$FILE/EY-infrastructure-investments-for-insurers.pdf

European Commission (November 2009), Directive 2009/138/EC of the European Parliament and of the Council of 25 Movember 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II).

Greenwood R, Vayanos D (2010), Price pressure in the government bond market, American Economic Review, 100(2): 585-590.

Haugh M (2010), Term Structure Models, Columbia University.

Impavido G, Tower I (2009), How the Financial Crisis Affects Pensions and Insurance and Why the Impacts Matter, IMF Working Papers 09/151.

Leland H (1994), Corporate debt value, bond covenants, and optimal capital structure, Journal of Finance 49: 1213–1252.

Lloyd's of London (July 2010), Solvency II: An overview, https://www.lloyds.com/~/media/files/the%20market/operating%20at%20lloyds/solvency%20ii/solvency%20ii%20introduction%20july%202010.pdf

Mele A (December 2014), Lectures on Financial Economics, Swiss Finance Institute, University of Lugano.

Merrill C B, Nadauld T D, Stulz R M, Sherlund S M (2012), Did Capital Requirement and Fair Value Accounting Spark Fire Sales in Distressed Mortgage-Backed Securities?, Working Paper, Ohio State University.

Merton R (1974), On the pricing of corporate debt. The risk structure of interest rates, Journal of Finance 29, 449–470, 1974.

Pimco (2015), 'Understanding tail risk', Education Series.

The Financial Times (Wednesday 4th December 2003), Insurers to promise £25bn for infrastructure, http://www.ft.com/cms/s/0/1f74e176-5c41-11e3-b4f3-00144feabdc0.html#axzz4LRxYPCUY