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Market Consistent ALM for Life Insurers—Steps toward Solvency II*

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We investigate the impact of the upcoming Solvency II guidelines on the risk/return trade-off for life insurance companies. Using the Dutch (FTK) regulatory framework (Financieel ToetsingsKader or Financial Assessment Framework) as an example, we demonstrate the huge impact of the elements of Solvency II (balance sheet approach, market valuation, etc.) on capital requirements. Much attention is also paid to the impact of the investment policy on the required capital. It is shown that by reducing the short-term risk (as measured by the required capital) the long-term expected returns may also decrease. Insurers should therefore (still) perform additional multi-period calculations for different stochastic scenarios in order to truly optimize their risk/return trade-off.
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Introduction

Solvency II

New European regulations for insurance companies, known as the Solvency II guidelines, are (currently) expected to be in place around 2011. Solvency II is based on important components such as:

- total balance sheet approach (i.e. assets and liabilities);
- economic or market value;
- Value at Risk approach to determine the required capital;
- wide range of risks (market, insurance, operational, …);
- capital requirements based on a confidence level on a one year basis; and
- standard vs. internal models.

Solvency II should solve a number of serious shortcomings of the current (Solvency I) regulations. Under Solvency I, only liability-driven risk is taken into account (and also in a rather simplified way). Investment risk is completely ignored: the required capital for an 80 per cent equities and 20 per cent bonds asset allocation is the same as for a 20 per cent equities and 80 per cent bonds asset allocation, while the corresponding balance sheet risks are obviously completely different. Due to

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these shortcomings, local regulators tend to emphasize the importance of matching the insurance liabilities with proper financial instruments. For example, in the Netherlands, the Dutch Central Bank (DNB) imposes additional solvency requirements in case insurance risks are not matched adequately.

The Solvency II framework is built on the ideas of Basel II.[1] Similar to Basel II, this regulatory framework consists of three different pillars. Pillar I concerns the measurement of assets, liabilities and the required capital. This pillar thus focuses on the more quantitative regulatory aspects. Pillar II concerns the supervisory review process and therefore focuses on the more qualitative aspects. Pillar III addresses disclosure requirements: transparency, open information, etc. In this paper, we focus on the first pillar.

The development of the Solvency II framework should be ready in 2008, when the fourth Quantitative Impact Study (QIS-4) is completed. The adoption by councils and parliaments should subsequently be completed in 2009. The implementation of the framework should then be finished by the end of 2010, so around 2011–2012 Solvency II will constitute the new regulatory framework. Anticipating these developments, many insurers have already started to use economic capital (EC) frameworks to manage their capital. The EC approach is comparable to Solvency II capital requirements but typically a confidence level in line with the target rating is used. Larger insurers disclose these EC calculations in their IFRS 7 risk disclosures (International Financial Reporting Standards).

As a predecessor of Solvency II, the Dutch regulating authority (DNB) has developed the FTK solvency testing framework.[2] In DNB,[3] the Dutch regulating authority positions this framework as follows: *The contours of Solvency II correspond to the foundations of the FTK*. FTK is officially in place (by law) for pension funds as of 1 January 2007. FTK is postponed for an indefinite time for insurance companies, awaiting Solvency II and the second phase of IFRS 4 (valuation of insurance contracts). Nevertheless, in the meantime, the regulator can ask (and asks!) for FTK results in case additional information about the true financial and risk position of insurance companies is needed.[4]

Outline of this paper

In this paper, the impact of Solvency II types of guidelines is studied by using the (Dutch) FTK framework for life insurance companies as a representative predecessor

[1] See the introductory guide to Solvency II by Towers Perrin (2006) and Steffen (2008) for more information. Amenc *et al.* (2006) explore the effects of Solvency II and IFRS on ALM and asset management in the insurance industry.

[2] In Dutch, FTK stands for "Financieel ToetsingsKader" (Financial Assessment Framework).

[3] DNB (2005).

[4] There are significant differences between the FTK and Solvency II/QIS-4 guidelines. Solvency II accounts for operational and concentration risks and uses a markedly different approach to quantify insurance risks. Another important difference between the original FTK guidelines and Solvency II is the so-called "double trigger". In this case two capital requirements are used. When the first solvency capital requirement (SCR) is violated the insurer should file a recovery plan. When the second (minimum) solvency capital requirement is violated the insurer loses its license.

of the actual Solvency II guidelines. We start by describing the valuation of insurance liabilities under the new solvency rules and the setup of the standard solvency test. This test is then applied to a life insurance company. The required capital under the FTK rules is compared to the required capital under Solvency I in this section. Next, the standard solvency test is applied to the same insurance company, but for different investment policies (asset allocation × duration). This way, we are able to examine the influence of the investment policy on the required capital. An important observation in this section is that in such a one-period setting, the risk reducing effects of reducing the equity exposure or matching the duration of the assets with that of the liabilities may be identical and therefore in itself give no indication on which of these two policy measures is to be preferred.

We then evaluate the effect of different investment policies within the settings of a multi-period stochastic scenario model (with a horizon of 10 years). As a suitable risk criterion we use the probability that the insurer fails to meet the required solvency margin at any point in time. The return criterion is the expected funding ratio at the end of the simulation period. Using this risk criterion, we implicitly assume that the shareholder would like to optimize its return on total capital by tying more capital to more risky assets. A life insurer could, of course, also apply the capital available in excess of required capital to new business, new insurance ventures or return the excess capital to the shareholders. These alternatives are relevant, but a detailed analysis of them is outside the scope of this paper. An important observation in this section is that duration matching appears to be a much more efficient (higher return/lower risk) solution than a reduction of the equity exposure. This is due to complex effects consisting of:

- a higher expected return for an asset allocation with equities and a longer duration; and
- a higher correlation with the required capital in case of long-duration investments.

The standard solvency test

Valuation of insurance liabilities

All assets and liabilities should be market valued consistently under the FTK guidelines. For insurance liabilities, the market (consistent) value is defined as the best estimate value plus a market value margin (MVM). The idea behind the calculation of the MVM is to assess how much a (risk-averse) investor would demand in excess of the liabilities' best-estimate value in order to be compensated for all risks that cannot be hedged. Risks which can be hedged or diversified away should have no impact on the MVM. In the current FTK guidelines, the MVM is approximated (marked-to-model) by using a simplified approach.[5,6]

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[5] This is done by linking the MVM to future mortality uncertainty and adverse stochastic deviations.

[6] There are significant differences between the FTK and Solvency II guidelines with respect to the determination of the MVM. In the current Solvency II (QIS-4) guidelines, the MVM is determined using a cost-of-capital (CoC) approach (see CHEIOPS (2007) for more information). In line with this

Table 1 Types of risks in standard FTK solvency test

S1	Interest rate risk	(maturity-dependent) shift up and down in interest rates and inflation, plus a 25 per cent shift up and down in the implied volatility for (embedded) interest rate options
S2	Equity risk	40 per cent shift down in the value of equities, plus a 25 per cent shift up and down in the implied volatility of stock options
S3	Currency risk	25 per cent shift down in foreign currencies
S4	Commodity risk	40 per cent shift down in commodity prices
S5	Credit risk	60 per cent increase in credit spreads
S6	Insurance risk	$\alpha\%/\sqrt{n}$, depending on type of insurance

The standard solvency test

The standard solvency test of the FTK determines the amount of capital that should be sufficient, with a certainty of 99.5 per cent, to ensure that after one year, the market value of the assets exceeds the market value of the liabilities. In the standard test, six types of risks are distinguished (usually labelled from S1 to S6) as described in Table 1.

The required capital then becomes:

$$\sqrt{S_1^2 + S_2^2 + 2 \cdot 0.80 \cdot S_1 \cdot S_2 + S_3^2 + S_4^2 + S_5^2 + S_6^2}.$$

Note that this formula assumes a 0.80 correlation between interest rate and equity risk and 0 correlations between all other types of risk. So, when the market value of the assets is at least equal to the market value of the liabilities plus the required capital according to this formula, then, with a 99.5 per cent probability, one year later the market value of the assets should still be larger than the market value of the liabilities. Note that operational risk is not explicitly considered as leading to a capital requirement in the FTK framework. Furthermore, the Dutch regulatory authority urges insurers to further develop their own (internal) models for ALM and EC calculations. These models, when approved, can also be applied to determine the required (FTK) capital.

approach, the CRO Forum has recently released a paper concerning the determination of the market value of insurance liabilities and the MVM. The CRO Forum's position is that all cash flows should be separated into hedgeable and non-hedgeable components and valued using either mark-to-market or mark-to-model approaches. Components of the cash flow for which hedging instruments are available in the financial markets should be valued with reference to the prices of those instruments or using the same option pricing techniques and parameters that are used in valuing the hedge portfolio in the financial markets. For components of the cash flow that are subject to non-hedgeable risks (both financial and non-financial) a mark-to-model adjustment (the MVM) should be added to the best estimate value of the cash flow. The CRO Forum position is that the CoC approach to calculate risk margins provides a theoretically sound approach for valuing such cash flows.

ASSETS				LIABILITIES		
Investments (market value)		1,160,000,000	Surplus			160,000,000
Equities	232,000,000	20%				
Fixed Income	812,000,000	70%	Technical reserve (book value)			1,000,000,000
Real Estate	116,000,000	10%	product with profit sharing	750,000,000	75%	
			product without profit sharing	250,000,000	25%	
Total		1,160,000,000	**Total**			1,160,000,000

Figure 1. Traditional balance sheet.

Applying the standard solvency test

In this section, we apply the standard FTK solvency test to a stylized insurance company with two types of liabilities: with and without profit sharing.[7] The liabilities of this insurer consist of the payment of funeral costs. All policies are regular premium paying policies.

For this insurer, the profit sharing mechanism works as follows:

- The insured amount (funeral costs) increases every year with profit sharing.
- Profit sharing=max(10-year moving average u-rate $-/-3\%$,0) $\times$ technical reserve.

Here, the underlying interest rate for profit sharing, the "u-rate", is a benchmark interest rate in the Netherlands which is more or less derived from the yields on several government bonds.

This insurer only invests in three asset classes: fixed income, (unlisted) real estate and equities (developed markets). The (modified) duration of the fixed income portfolio is equal to four. With fixed income representing 70 per cent of all assets, the overall duration is equal to $70\% \times 4 \approx 3$. The duration of equities and real estate is assumed to be zero.

Traditional balance sheet

Figure 1 shows the traditional balance sheet of this insurance company at the end of 2005. The assets are valued at market value, while the liabilities are valued by means of traditional actuarial methods based on fixed discount rates (book value). The so-called "funding ratio" (value of assets/technical reserve) at the end of 2005 is 116 per cent. Under Solvency I, the required capital is 4 per cent of the (book value) technical reserve. Therefore, the surplus amounts to 400 per cent of the legally required capital.

The first step is now to "convert" this traditional balance sheet into a market value balance sheet in order to determine the market value of the surplus. After calculating the required capital we can then compare this capital with the (market value of the) surplus. When the surplus is larger than the required capital, the insurer satisfies the solvency requirements.

[7] Policies with profit sharing dominate the liabilities (75 per cent of all liabilities).

Table 2 Value of the embedded option (in millions) for different scenarios

	Intrinsic value	*Time value*	*Total*
Base curve (31 December 2005)	190.7	30.6	221.3
Interest rates up	272.0	8.2	280.2
Interest rates down	93.0	76.9	169.9
Volatility up	190.7	47.8	238.5
Volatility down	190.7	15.4	206.1

Market value balance sheet

The assets are already valued at market value. We therefore only have to calculate the market value of the liabilities. An important component of the market value of the liabilities is the present value of future profit sharing. These "embedded options" are valued with a risk neutral Monte Carlo approach based on a sufficiently large number of scenarios generated with a one-factor Hull-White interest rate model.[8] The parameters of the Hull-White model have been calibrated based on end of 2005 market prices of options on seven year swap rates[9] with different maturities. A Monte Carlo valuation method is preferred over an analytical approach in this case for two reasons. The first reason is the complexity of the options involved. All profit sharing is accumulated into the final capital payment of the policies which implies that past profit sharing also forms a basis for current and future profit sharing. The second reason is that detailed valuations instead of less accurate analytical approximations are required for reporting and solvency testing purposes. At the same time, the longer calculation time required for a Monte Carlo approach is less of an issue here than in the case of the dynamic stochastic solvency testing described later on in this paper.

Table 2 shows the value of the embedded options. We here decomposed the total option value into the intrinsic value and the additional time (or "volatility") value. The intrinsic value is the value of the option when the volatility is equal to zero (and all future interest rates correspond to the forward rates implied by the yield curve at the moment of valuation). The remaining component of the option value is thus due to the inherent volatility of the interest rates. The table also shows the option value in case of a shifted yield curve and a shifted implied volatility. The shifts applied are in accordance with the rules of the standard solvency test as described in Table 2 and the resulting values can therefore be used when calculating the required capital as we will do later on. Notice that the option value increases/decreases when the interest rates increase/decrease. This is so because the profit sharing option "pays out" more when interest rates are higher. As expected, the option value also increases when the volatility increases. Since the cost of this embedded option is very significant (especially in the case of high interest rates or high interest rate volatilities) this aspect needs to be taken into account in the pricing of the product.

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[8] See Hull (2005) for a description of this model.

[9] Because the underlying interest rate (the u-rate) can be approximated quite well by a swap rate of this maturity.

ASSETS			LIABILITIES		
Investments (market value)		1,160,000,000	Surplus		263,742,153
Equities	232,000,000	20%			
Fixed Income	812,000,000	70%	Market value liabilities		896,257,847
Real Estate	116,000,000	10%	product with profit sharing	687,073,771	77%
			product without profit sharing	183,078,387	20%
			MVM	26,105,690	3%
Total		1,160,000,000	Total		1,160,000,000

Figure 2. Market value balance sheet.

Figure 2 shows the resulting market value balance sheet. This balance sheet is identical to the traditional balance sheet from Figure 1, but the technical reserve is replaced by the market value of the liabilities. The market value of the liabilities consists of the discounted value of the (best estimate) guaranteed benefit payments minus the discounted value of the (best estimate) remaining premium payments plus the value of the profit sharing option as calculated in Table 2. Finally, the market value of the liabilities is increased with the MVM as prescribed by the FTK. The funding ratio increases from 116 per cent on the traditional balance sheet to 129 per cent because the market value of the liabilities (896,257,847) is in this case lower than the traditional value of the liabilities (1,000,000,000). This difference can be explained by the following factors:

- lower mortality rates for the best estimate projection;
- market interest rates which are above the technical rate of interest;
- additional profits for the insurer in case of surrender.

Interest rate sensitivity

Before we proceed with the calculation of the required capital, we first make a more detailed analysis of the interest rate sensitivity of the assets and liabilities and thereby also of the funding ratio (or surplus, if preferred) of the insurer. We do this in order to gain a good understanding of what causes the outcomes of the interest rate risk component (S1) of the standard test. Figure 3 shows how the value of the various components of the market value of the liabilities changes as the level of interest rates changes.

The horizontal axis represents the level of flat yield curves, ranging from 1 to 10 per cent. The vertical axis represents the market value of the liabilities (with and without profit sharing). Note that even for low interest rates (below 3 per cent) the impact of profit sharing is significant. This is due to the fact that profit sharing is determined by the 10-year moving average of the u-rate. High historical interest rates therefore still contribute to high-profit sharing levels in the near future. Also the volatility or time value of the options contributes to the significant option value at low interest rates. Note also that the additional MVM is quite small. In total, the market value of the liabilities shows the, nowadays familiar, convex (curved) pattern in which the value of the liabilities rises sharply as the interest rates go down because the (implicit) guaranteed interest rate at which the policies were sold kicks in.

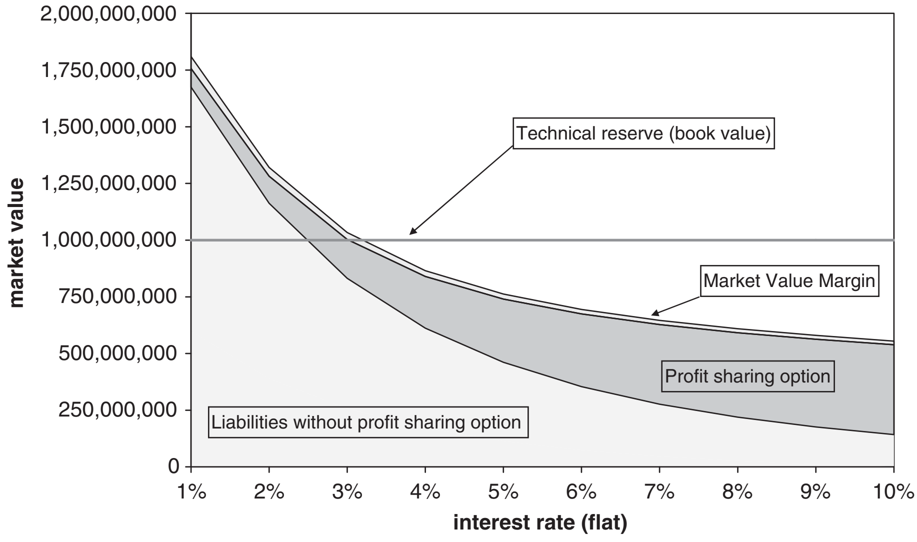

Figure 3. Interest rate sensitivity of the liabilities.

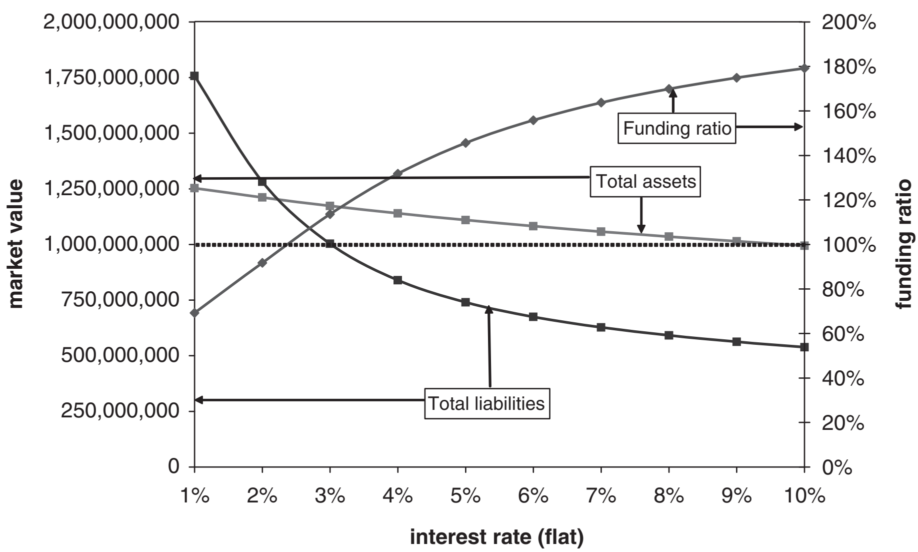

Figure 4. Interest rate sensitivity of the funding ratio.

In Figure 4, we also show the interest rate sensitivity of the funding ratio (on the right vertical axis). The term structure at the end of 2005 is best approximated by a 4 per cent flat curve. It is seen from this figure that when the term structure drops approximately by 1.5 per cent, the market value funding ratio becomes lower than 100 per cent because, in that case, the value of the liabilities increases much more than

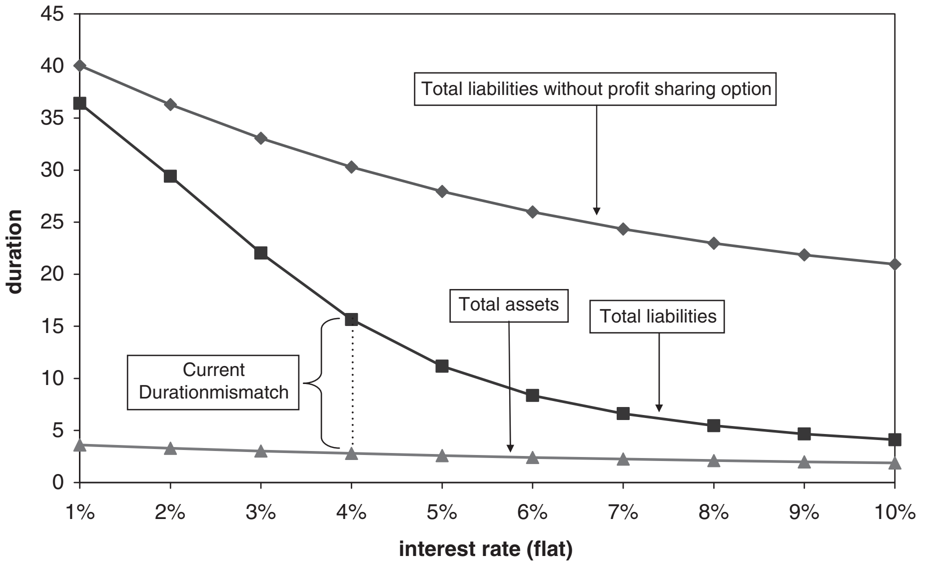

Figure 5. Duration of liabilities and assets.

the value of the assets. So, we see that although the current market value funding ratio of 129 per cent may seem rather comfortable, the current surplus completely vaporizes in case of a drop in interest rates of 1.5 per cent or more.

This high interest rate sensitivity of the funding ratio is due to the duration (and convexity) mismatch between the assets and liabilities. To illustrate this, Figure 5 shows the duration (on the vertical axis) of the liabilities, with and without profit sharing, for different flat yield curves. The duration of the liabilities is much higher than that of the assets, 15 versus three at the "current" 4 per cent, interest rate, which is caused by the long maturities of the liabilities and the relatively short maturities of the bond portfolio. As a result, as an approximation a 1 per cent drop in interest rates causes the liabilities to increase by 15 per cent, while the assets increase by only 3 per cent and thereby reduce the funding ratio by as much as 12 per cent.

Figure 5 also shows that profit sharing reduces the duration of the liabilities because the amount of profit sharing increases (instead of decreases) when interest rates go up and this effect more than compensates the value reducing effect of a higher discount rate for future cash flows. The duration of the liabilities strongly increases as interest rates go down, which is another way of showing the high degree of convexity (curvature) of the liabilities. The assets, on the other hand, have a low convexity (their duration is relatively constant) and also the level of the duration is much lower than that of the liabilities. As a result, the duration mismatch between the assets and liabilities changes heavily as interest rates go up and down. The duration mismatch is approximately one at an interest rate of 10 per cent while it is more than 30 (!) at an interest rate of one per cent.

Table 3 Results of the standard solvency test for the current investment policy

Solvency II	*Current policy (%)*
S1. Interest rate risk	13.7
Volatility risk	2.0
S2. Equity risk	12.9
S3. Currency risk	0.0
S4. Commodity risk	0.0
S5. Credit risk	0.0
S6. Insurance risk	0.03
Diversification benefit	−1.5
Required capital	27.2
Available capital	29.4
Solvency ratio	108.2

Results of the standard solvency test

After having calculated the market value of the liabilities, constructed the market value balance sheet and investigated the large interest rate risk inherent in the balance sheet, we are now ready to calculate the results of the (standard solvency) test.

Table 3 shows the results. The required capital amounts to 27.2 per cent of the liabilities, which is more than six times the current legally required (Solvency I) capital of 4 per cent. Note that, in practice, we have also encountered situations in which the "Solvency II" required capital is actually (much) lower than the Solvency I required capital. Here, the required capital is dominated by the interest rate risk (due to the duration and convexity mismatch) and equity risk (due to the significant equity exposure) in approximately equal proportions. Because of the assumed 0.8 correlation between interest rate and equity risk, the diversification effect is relatively limited in this case. Also note the minor contribution of insurance technical risk in this case. This is due to the large number of policy-holders for this insurer, which suppresses stochastic deviations from the best-estimate projection.[10]

The available surplus amounts to 29.4 per cent of the liabilities and therefore the available capital only just exceeds the required capital. This indicates what we have already seen before, namely that the available surplus may seem high in itself, but is in fact very much needed to cover the large amount of interest rate and equity risk present in the balance sheet. The (Solvency I) solvency ratio of 400 per cent on the traditional balance sheet therefore gives a wrong picture of the actual solvency position of the insurance company. The (Solvency II) solvency ratio drops dramatically to a level of only 108 per cent and thereby gives a better picture of the actual risk position.

[10] This insurer does not invest in commodities and credits and is not exposed to foreign currency risk. For this reason these risk components are equal to zero in Table 3.

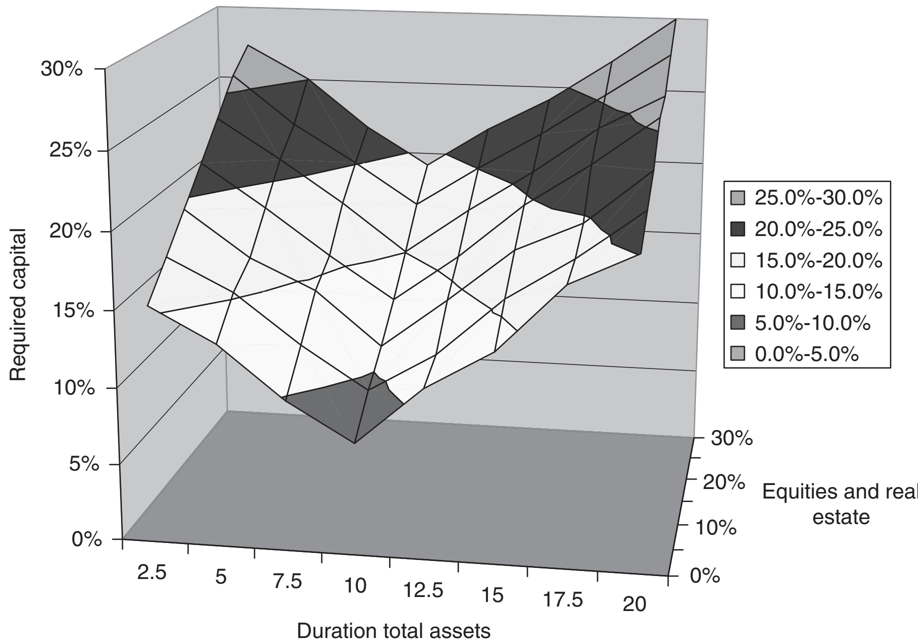

Figure 6. Required capital for different investment policies.

The impact of different investment strategies

We now investigate the impact of the investment policy on the required capital. Because of the importance of the interest rate and equity risk, we look at various combinations of changing both the asset allocation and the duration of the assets. We assume that the insurer only invests in equities, real estate and fixed income and vary the asset allocation between 0 and 30 per cent for equities and real estate, for which we maintain constant proportions, versus 100 and 70 per cent for fixed income. We vary the total duration of the assets between 2.5 and 20.[11] For each of the resulting combinations of asset allocation and asset duration, we repeat the calculations of the standard solvency test and determine the required capital.

Figure 6 shows the required capital (as a percentage of the market value of the liabilities) for these different investment policies. The vertical axis represents the required capital, while the other two axes represent on the one hand the percentages invested in equities and real estate and on the other hand the total duration of the assets. The figure clearly shows that the required capital decreases when the percentage invested in equities and real estate decreases. This is simply due to the diminishing effect of adverse equity and real estate shocks when the allocation to these categories

[11] Recall that we assume that the duration of equity and real estate is equal to zero.

decreases. The figure also clearly shows that the required capital is minimized in case of a total asset duration of around 10.[12] By reducing the equity and real estate investments to zero and at the same time increasing the duration to 10, the required capital can be reduced from 27.2 to 7.3 per cent, which would mean an increase of the solvency ratio from 108.2 per cent (back) to more than 400 per cent.[13]

One of the crucial differences between the Solvency II type of approaches with the Solvency I approach for determining the required capital is that the first is a risk-based approach that includes "all" risk types while the second excludes, for example, investment risk. As a result, in the new setting, changes in the investment policy (asset allocation, duration, derivatives, etc.) have a direct impact on the required capital. For future solvency requirements, even product design on the liability side of the balance sheet has a direct influence on the required capital. In our example, we are at a solvency ratio of 108.2 per cent and can even bring the solvency ratio back to more than 400 per cent by selling all equities and increasing the duration of the assets. Does this mean everything is in order and settled now for our example insurance company? The answer is a firm no.

First of all, the fact that the current solvency position is sufficient does not mean this will continue to be so in the future as market conditions and asset and liability characteristics are bound to change. In the next section, we will see that in fact there is a very large probability of capital shortages in the next 10 years.

Second, the results in Figure 6 do not give us sufficient information on which policy measures are optimal. For example, changing the duration to 2.5 and investing 0 per cent in equities and real estate on the one hand and changing the duration to 10 and investing for 30 per cent in equities and real estate on the other hand lead to very similar levels of required capital (15.4 versus 19.2 per cent of the liabilities). The solvency risks of these two policies, measured in terms of the required capital, are thus similar. This, however, says nothing about the expected returns of these policies. We are therefore not able to make an optimal risk/return trade-off based on the required capital alone. Similarly, opting for the minimum risk combination (duration 10 and 0 per cent equities and real estate) is not by definition the best choice because low risk typically also means low expected returns.

Third, the one year horizon of the solvency tests is very short compared to the long-term nature of a life insurance company while at the same time it becomes more and more well known that long-term properties (volatilities, correlations, etc.) of interest rates and asset returns are very different from the corresponding short-term properties.

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[12] Given that the current duration of the liabilities is approximately equal to 15 (see Figure 5) this may come as a surprise. There are several reasons, however, why the "optimal" asset duration is lower than 15. The main reason is that the funding ratio is higher than 100 per cent (129 per cent). As a consequence the duration of the assets has a relatively large impact on the interest rate sensitivity of the surplus. Convexity issues and non-parallel shifts of the interest rate curve also influence the "optimal" asset duration.

[13] To reduce the required capital below 7.3 per cent we should also match the second-order interest-rate sensitivity (convexity) and apply duration matching for different segments of the interest-rate curve (to reduce the sensitivity to non-parallel interest-rate shifts).

For more information on this issue, see for example, Campbell and Viceira, Steehouwer and Hoevenaars.[14]

From these three issues, it follows that what is required for the insurance company is an optimization of the long-term risk/return trade-off. For this, various (long-term) return measures could be used (return on equity, risk-adjusted return on equity, return on risk-based capital, etc.). For the (short-term) risk measures it seems the most logical to look (at least) at the probability and the extent to which the available capital of the company is insufficient to meet the legally required capital. The bottom line here is that determining the required capital of insurance companies according to a Solvency II type of approach does not change anything about the need for companies to optimize their investment policy in terms of the corresponding short and long-term risk and returns as ALM models are designed to do. What does change, and complicates matters considerably, is that the criteria for the optimization become more complex. As an illustration, in the next section we extend our example by performing additional multi-period stochastic simulations.

A dynamic solvency testing framework

Introduction

In this section, we evaluate the effects of different investment policies in a dynamic stochastic sense with a horizon of 10 years. First of all, we do this for the current investment policy in order to assess the future solvency position of our example insurance company. In the next section, we then repeat the calculations for the same asset allocations and asset durations as analysed in the impact of different investment strategies sections in order to optimize the risk/return profile. In all calculations, we use a going concern perspective by taking aspects into account such as new business, taxes, dividends, etc.

The stochastic scenarios of equity and real estate returns and yield curves are generated with a Vector AutoRegressive (VAR) model estimated on annual time series data for the period 1970–2005. This means that volatilities, correlations and dynamics (i.e. auto- and cross-correlations) are in accordance with the historical statistics. The expected values for the different variables are overruled, based on current market and forward-looking information. As a suitable risk criterion we use the probability that the insurer does not satisfy the required (FTK) solvency margin (i.e. that the available capital is smaller than the required capital according to the standard test in any year of any scenario). As a return criterion, we use the average or expected market value funding ratio at the end of the 10-year simulation period.

Current investment policy

In Figure 7, for the current investment policy, Panel A shows the scenarios of the (long) interest rate scenarios as resulting from the VAR model, Panel B the

[14] Campbell and Viceira (2005); Steehouwer (2005) and Hoevenaars (2008).

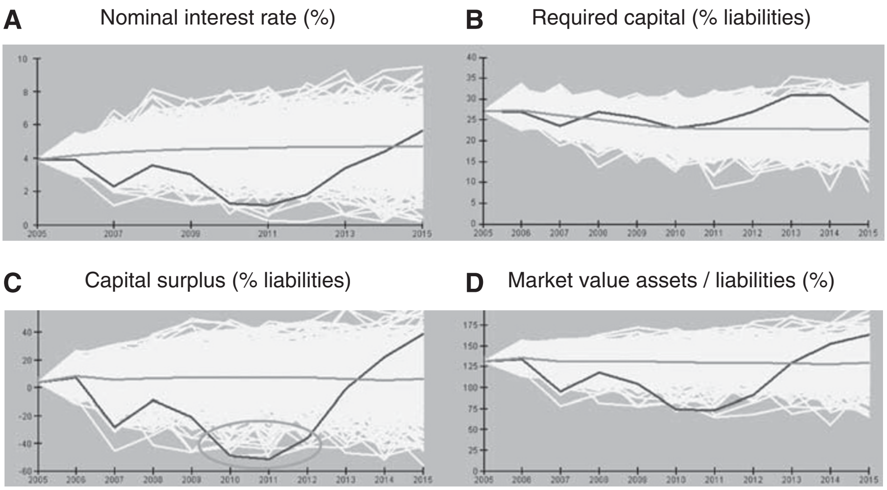

Figure 7. Dynamic going concern analysis of the current policy.

corresponding scenarios of the required (FTK) capital as a percentage of the liabilities (starts at the end of 2005 value of 27.2 per cent), Panel C the scenarios of the difference between the surplus and the required capital as a percentage of the liabilities (i.e. negative means a capital shortage) and finally Panel D the scenarios of the market value funding ratio.

Panel B shows that the required capital varies significantly across different scenarios (between 15 and 35 per cent of the liabilities). By contrast, under the current Solvency I rules, the required capital is a fixed percentage of the book value of the liabilities. As a result of this volatility, Panel C shows that there is a large probability of around 30 per cent that there will be (large) capital shortages in the future. The selected scenario shows that this will be especially the case in case of low interest rates. So the initial solvency ratio (of just above 100 per cent) can deteriorate rapidly into large capital shortages in case interest rates go down. This illustrates that a static solvency test alone is not enough to completely judge the solvency situation. Once extreme adverse movements in market conditions have taken place (possibly together), all existing capital can disappear. There is no guarantee that in the following years the markets will recover while formally the required capital should still be available. From the previous analysis it is of course clear that an important reason for the observed risks is the significant mismatch in terms of interest rate sensitivity between the assets and liabilities.

Panel D shows that the probability that the market value funding ratio drops below 100 per cent is relatively small at around 3 per cent (but larger than 0.5 per cent). This 100 per cent market value funding ratio level (or a negative surplus in economic terms) is exactly what the solvency requirements are designed to prevent to happen. So, that this happens with a much smaller probability than a violation of the required capital is logical and comforting. However, at the same time this observation brings up some difficult methodological and practical questions. If the required capital is designed at a

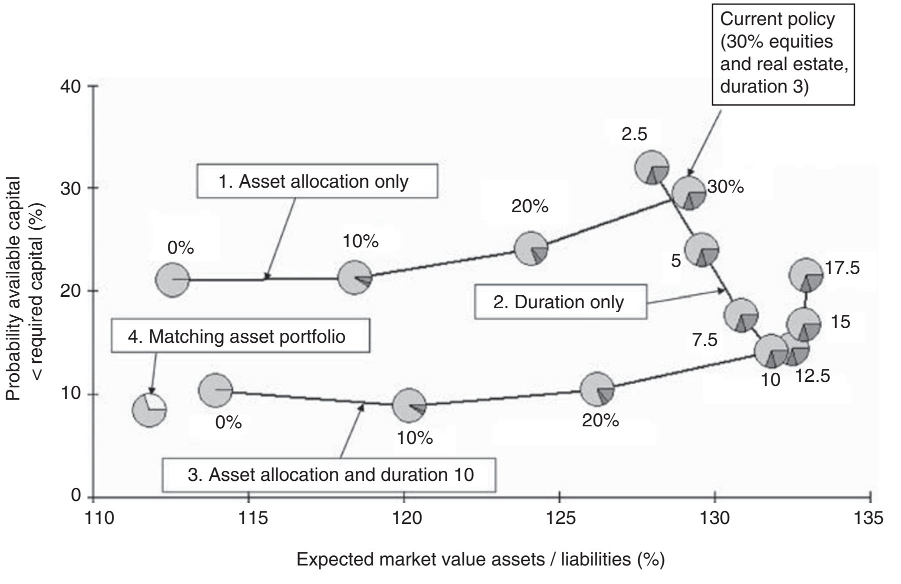

Figure 8. Risk and return for alternative investment policies.

confidence level of 99.5 per cent, with what confidence level should this required capital itself be available in the future? Should this be with an "absolute" certainty or is a small capital shortage probability allowed?[15]

Alternative investment policies

We proceed by studying the impact of the different investment policies on risk and return as defined earlier. Based on the scenario results, for various combinations of asset allocation and asset duration we calculated the expected market value funding ratio and the probability that the available capital is smaller than the (FTK) required capital. The results are shown in Figure 8. The current policy is indicated by a circle and indicates the 30 per cent probability of solvency risk that we mentioned before and an expected funding ratio of a little less than 130 per cent (also see Panel D of

[15] According to recent EU Solvency II guidelines, insurance companies should inform the supervisory authority as soon as they observe that the SCR is no longer complied with, or where there is a risk of non-compliance in the following three months. Within two months from the observation of the non-compliance with the SCR, the insurance company must then submit a realistic recovery plan for approval by the supervisory authority. The supervisory authority requires the insurance company to take the necessary measures to achieve, within six months from the observation of the non-compliance with the SCR, the re-establishment of the level of eligible own funds covering the SCR or the reduction of its risk profile to ensure compliance with the SCR. The supervisory authority may, if appropriate, extend that period by 3 months. See Article 135 of the Proposal for a Directive of the European Parliament and of the Council on the taking-up and pursuit of the business of Insurance and Reinsurance—Solvency II (SEC(2007) 870/871), 10 July 2007.

Figure 7). Besides the current policy, there are also three other lines visible. On line number one are policies for which we only reduce the percentage invested in equities and real estate and maintain the same original total asset duration. The other way around, on line number two are policies for which we leave the asset allocation unchanged and vary the asset duration between short and long. On line number three are policies for which we combine an asset duration of 10 with different asset allocations.

For comparison, we also show results for a matching asset portfolio. In this case, we first replace all risky assets (equities and real estate) with cash. Next, we hedge the interest rate risk due to the guaranteed cash flows (premiums, benefits and costs) using a layer of swaps with maturities of five, 10, 15, 20, 30 and 50 years. These swaps are bought a pari (i.e. at zero cost) at the start of the ALM simulation. In addition, we buy a basket of swaptions to hedge the embedded profit sharing options. These swaptions have option maturities of five, 10, 15, 20 and 30 years and are written on an underlying swap contract of seven years. All swaptions are forward-at-the-money at the start of the ALM simulation. The optimal swap/swaption hedge is determined by varying the notionals of these instruments. As a suitable optimization criterion, we minimize the sum of squared differences between changes in the market value of the liabilities and changes in the market value of the matching assets.

We argued before that the outcomes of the solvency test in itself are not enough to make a decision between, for example, increasing the duration or reducing the equity and real estate allocation, simply because the required capital is approximately the same for both cases and expected return effects are left out of consideration. The results in Figure 8 show, however, that increasing the asset duration to around 10 is in fact a much more efficient strategy than reducing the equity and real estate allocation to, for example, 10 per cent. The first has a higher expected return and at the same time also a lower risk than the second strategy. The explanation is that besides the *required* capital, it is also the *available* capital that determines the final solvency position. For the long duration case, this available capital behaves much more favourably relative to the required capital for the following two, rather complex, reasons. First, an asset allocation with equities and a longer duration has a higher expected return which causes a higher upward expected trend in the available capital. Second, as we have seen, the longer duration assets imply a better (though not perfect) matching of the assets with the liabilities, which causes the available capital to move much more in line with the required capital (i.e. they have a higher correlation). The most efficient strategies therefore lie on line number three and consist of a total asset duration of 10 and asset allocations consisting of 10 per cent equities and real estate or more. Less than 10 per cent equities and real estate is not efficient because of well known diversification effects between equities, bonds and real estate.

Alternative number four in Figure 8 is the matching asset portfolio. To be expected, this portfolio has a low expected return. Perhaps more surprisingly, the probability that the available capital is lower than the required capital is still significant for this portfolio. This is due to two reasons. First, the interest rate hedge (consisting of swaps and swaptions) is not perfect because we only consider the more liquid swap and swaption maturities. As a result, the required capital is small but not equal to zero. Second, the available capital decreases steadily because all assets with a higher return (equities and real estate) have been replaced by cash.

If the policy alternatives analysed here would constitute the complete range of policies, a choice would thus have to be made for one of the investment policies on line number three, depending on the required or desired level of risk while taking into consideration that reducing the equity and real estate exposure more rapidly reduces the expected return than that it reduces the risk. Note, however, that even at the "minimum risk" policy of 10 per cent equities and real estate and a duration of 10, there is still a significant probability of 8–9 per cent of a capital shortage. Fortunately, in reality further risk reductions and efficiency gains are possible along various directions. Possible improvements could be, for example, a dynamic (state-dependent) asset allocation, the use of equity derivatives (put options) to limit downside risks, hedging currency risk (if present), or investing in other (alternative) asset classes for purposes of diversification or extra return. All these investment decisions can be analysed adequately within a suitable dynamic Solvency II framework as the one described and used in this paper.

Conclusions

The upcoming Solvency II guidelines will have a profound influence on capital budgeting and risk management for insurers. The available capital may decrease under Solvency II because the market value of "embedded" options in insurance contracts (like profit sharing mechanisms or minimum return guarantees) needs to be considered explicitly. This stresses the need to properly account for the (potentially very high) costs of these embedded options when pricing insurance products.

Under Solvency I the investment policy has no impact on the solvency ratio. This picture will change completely under Solvency II. We show in this paper, using a realistic example, that an insurers' solvency ratio can change dramatically: from 400 per cent under Solvency I to only around 100 per cent according to the Dutch solvency test (a predecessor of Solvency II). We also show that the investment policy, in terms of, for example, the asset allocation and asset duration, can have a large impact on the capital requirements. It may, for example, well be the case that by reducing the short-term risk (as measured by the required capital), the long-term expected returns will also decrease. Insurers should therefore perform additional multi-period calculations for different stochastic scenarios to truly optimize their risk/return trade-off in terms of setting the appropriate investment policy.

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