Actuarial Valuation and Risk Management Under P and Q

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How should pension liabilities be valued?
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Overview

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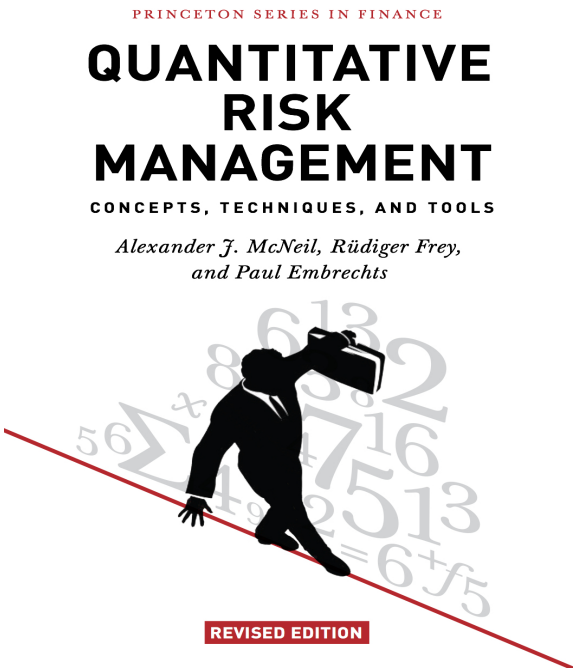
Background

- There has been some convergence in the valuation and capital-adequacy principles applied to insurers and banks.
- This has been prompted by the development of the respective regulatory frameworks: Solvency II and Basel III.
- Common concepts like market-consistent valuation, 3-pillar systems, risk-based capital requirements and risk disclosure.
- There are differences too; more scope to build fully internal models under Solvency II while Basel treats risk in silos.
- In this talk we look at the extent to which these ideas relate to the valuation and funding of DB pension schemes.



Regulation: IORP II to superfunds

- In 2010 the European Commission produced a green paper on the future of pensions (European Commission, 2010).
- Context was the consultation on a new Directive for Institutions for Occupational Retirement Provision (IORP II).
- Should a Solvency II-style, market-consistent, holistic-balance-sheet approach be applied to defined-benefit (DB) pension schemes?
- Proposal dropped from IORP II in 2013 after strong pushback from member countries (European Commission, 2013).
- The European Insurance and Occupational Pensions Authority (EIOPA) has continued to consult on holistic balance sheet (HBS) and solvency rules (EIOPA, 2014).
- The Department of Work & Pensions has recently asked whether the financial adequacy of consolidated pension vehicles ("superfunds") "should be regulated . . . through an insurance based approach using a Solvency II type balance sheet?" (DWP, 2018)

The CBI view

"We are particularly disapointed by misguided proposals to apply insurance-style funding rules to pensions. These could force British companies to put about £500bn of extra money into their final-salary pension schemes. The Commission is seeking to treat pensions in the same way that it deals with insurance schemes – as if they could suddenly face large, unexpected demands on their capital. In fact, pensions pay out over time in fairly predictable ways."

John Cridland, deputy director-general, CBI, 2010

Overview

Balance sheet of an insurer

Insurer XYZ (31st December 2010)			
Assets		Liabilities	
Investments		Reserves for policies written (technical provisions)	£80M
- bonds	£50M		
- stocks	£5M	Bonds issued	£10M
- property	£5M		
Investments for unit-linked contracts	£30M	Debt (sum of above)	£90M
Other assets	£10M		
- property			
		Equity	£10M
Total	£100M	Total	£100M

The Solvency II Directive (2009/138/EC)

How should values be assigned to assets and liabilities?

Article 75(1a) Assets shall be valued at the amount for which they could be exchanged between two knowledgeable willing parties in an arm's length transaction.

Article 75(1b) Liabilities shall be valued at the amount for which they could be transferred, or settled, between two knowledgeable willing parties in an arm's length transaction'.

Article 76(3) The calculation of technical provisions shall make use of and be consistent with information provided by the financial markets [...] (market consistency).

Article 77(1) The value of technical provisions shall be equal to the sum of a best estimate and a risk margin.

(European Parliament and Council, 2014)

On best estimate and risk margin

Article 77(2) The best estimate shall correspond to the probability-weighted average of future cash-flows, taking account of the time value of money (expected present value of future cash flows), using the relevant risk-free interest rate term structure.

Article 77(3) The risk margin shall be such as to ensure that the value of the technical provisions is equivalent to the amount that insurance and reinsurance undertakings would be expected to require in order to take over and meet the obligations.

Article 77(4) Insurance and reinsurance undertakings shall value the best estimate and the risk margin separately. However, where future cash flows associated with [...] obligations can be replicated reliably using financial instruments for which a reliable market value is observable the value of technical provisions [...] shall be determined on the basis of the market value of those instruments. In this case, separate calculations [...] shall not be required.

Fair-value accounting

Market-consistent value has a similar motivation to fair value in accounting - desire for objectivity in valuation of financial assets and instruments.

The international fair-value accounting standard (IFRS 7) describes a useful 3-level fair-value hierarchy:

1. mark-to-market valuation at level 1;
2. mark-to-model with fully observed market inputs at level 2;
3. mark-to-model with unobserved inputs at level 3.

Examples:

1. publicly traded equities and bonds;
2. European call and put options;
3. catastrophe bonds; collateralized credit instruments (CDOs).

Valuing life insurance liabilities: two examples

- Annuity portfolio.
  Under deterministic mortality scenario (decrements follow a life table) liability is similar to portfolio of zero-coupon bonds.
  Risk factors affecting current value are:
  1. interest-rate risk;
  3. idiosyncratic/basis/longevity risk with respect to deterministic life table (actuarial risks).
- Variable annuities with market-linked guarantees.
  Example: a product with guaranteed minimum income benefit (GMIB).
  Annuitant purchases fund together with guarantee to receive at maturity the greater of fund value or an annuity with guaranteed income.
  Risk factors:
  1. interest-rate risk;
  2. market risk implicit in selling embedded option;
  3. actuarial risks.

Impact of risk factors

Suppose we add risk factors incrementally:

Under . . . (1) Cash-flows are predictable; transfer value should correspond to the best estimate value.
Liabilities can be marked to market using term-structure of risk-free interest rates.
Level 1 valuation problem.

(1)(2) Embedded option risk can be hedged in complete market (provided horizon not too large).
Option can be valued using pricing model under a risk-neutral measure (Q).
Level 2 valuation problem.

(1)(2)(3) Actuarial risks are not market observables.
Since actuarial risk is not hedgeable, a risk margin is required to compute a transfer value.
Level 3 valuation problem.

The problem of the risk margin

- Let the financial market risk-factors be denoted by

$$(\boldsymbol{Z}_s), \quad \boldsymbol{Z}_s = (Z_{s,1}, \ldots, Z_{s,d}),$$

  e.g. interest rates for different maturities, equity prices and volatilities.
- Let the actuarial risk be described by survival indicator processes

$$(\boldsymbol{Y}_s), \quad \boldsymbol{Y}_s = (Y_{s,1}, \ldots, Y_{s,n}), \quad Y_{s,i} = \mathbb{1}_{\{\tau_i > s\}},$$

  depending on the lifetimes $\tau_1, \ldots, \tau_n$ of the annuitants.
- Fix time t and let $\mathcal{F}_t$ denote filtration generated by $(\boldsymbol{Z}_s)_{s \leq t}$, and $(\boldsymbol{Y}_s)_{s \leq t}$.
- Let $\mathcal{Y}_t = \{(\boldsymbol{Y}_s)_{s>t}\}$ denote a future mortality scenario.
- Given $\mathcal{Y}_t$, a typical market-consistent liability value at t might be

$$B_t(\mathcal{Y}_t) = \mathbb{E}^Q(X_T \mid \mathcal{F}_t, \mathcal{Y}_t)$$

  where X_T denotes some aggregate series of future (discounted) cash flows depending on $\mathcal{Y}_t$ and $(\boldsymbol{Z}_s)_{s>t}$.

The problem of the risk margin (II)

- The best-estimate value of the liability would be

$$\widehat{B}_t = B_t\left(\mathbb{E}^P\left(\mathcal{Y}_t \mid \mathcal{F}_t\right)\right)$$

- Computation of $\mathbb{E}^P\left(\mathcal{Y}_t \mid \mathcal{F}_t\right)$ means replacement of indicators $\mathbb{1}_{\{\tau_i > s\}}$ by

$$\mathbb{E}^P\left(\mathbb{1}_{\{\tau_i > s\}} \mid \mathcal{F}_t\right) = \mathbb{P}\left(\tau_i > s \mid \tau_i > t\right) = {}_{s-t}p_{x(i,t)}$$

  i.e. survival rates from a lifetable where $x(i,t)$ is age of individual i at t.
- Randomness in $\mathcal{Y}_t$ means transfer value B_t should be higher.
- The risk margin is essentially equal to the cost of accessing additional capital to cover the scenario where $B_t(\mathcal{Y}_t)$ is at the 99.5% quantile of its distribution under P.
- This necessitates analysing values given by Q-expectations under actuarial scenarios given by P-probabilities.
- Can lead to a nested Monte Carlo problem if Q-expectation is difficult to evaluate: see Pelsser, Salahnejhad, and van den Akker (2016).

The problem of solvency capital

- Consider a portfolio of liabilities backed by assets with net asset value

$$V_t = A_t - B_t.$$

- To ensure solvency in 1 year's time with high probability α, company may require extra capital x_0 for this portfolio determined by

$$x_0 = \inf\{x : P(V_{t+1} + x(1+i) \geq 0) = \alpha\},$$

  where i is one-year risk-free interest rate.
- If x_0 is negative the portfolio is already supported by sufficient capital.
- The sum $V_t + x_0$ gives the solvency capital requirement (SCR), namely the available capital corrected by the amount x_0, and is the α-quantile of the distribution of

$$L_{t+1} = V_t - V_{t+1}/(1+i).$$

- This corresponds to value-at-risk concept.

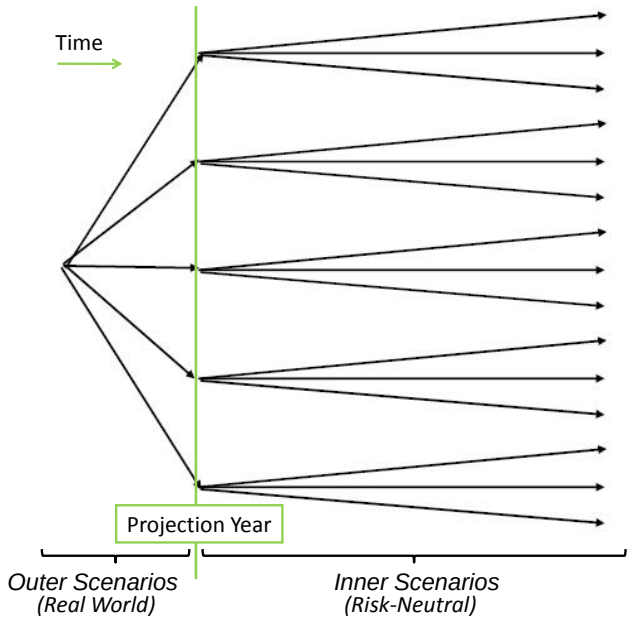
The problem of solvency capital (II)

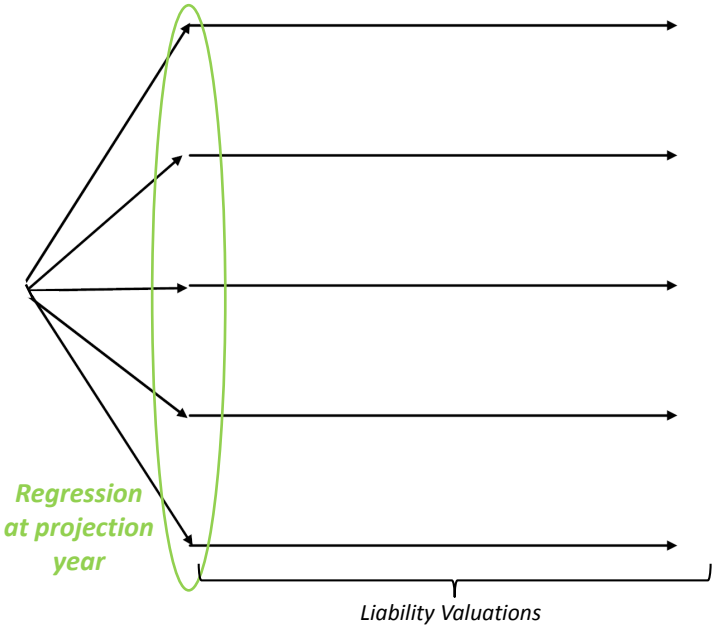
- Evaluation of V_{t+1} involves projecting the risk factors $\boldsymbol{Z}_t$ forward to $\boldsymbol{Z}_{t+1}$.
- For simplicity consider a best-estimate liability taking form

$$\widehat{B}_t = \mathbb{E}^Q(X_T \mid \mathcal{F}_t) = f(t, \boldsymbol{Z}_t)$$

- The mapping f is thus a risk-neutral expectation of (discounted) pay-offs under a best estimate for the non-hedgeable, actuarial risks.
- We need to find the distribution of future values of $\widehat{B}_{t+1} = f(t+1, \boldsymbol{Z}_{t+1})$ under the real-world (P) distribution of $\boldsymbol{Z}_{t+1}$.
- For a complex liability f is typically not given by a simple formula but must be determined by approximating the risk-neutral (Q) expectation.
- This can be done by Monte Carlo integration but this again leads to Q simulations within P simulations.

Nested simulations





Proxy balance sheet models: two approaches

1. Least squares Monte Carlo. Regress now
   $f(t+1, \boldsymbol{Z}_{t+1})$ is approximated by a regression model in $\boldsymbol{Z}_{t+1}$

$$f(t+1, \boldsymbol{Z}_{t+1}) \approx \sum_k \alpha_k \psi_k(\boldsymbol{Z}_{t+1})$$

   where the $\psi_k(\boldsymbol{z})$ are basis functions (Longstaff and Schwartz, 2001). There is interest in using machine learning and neural networks.

2. Replicating portfolios. Regress later
   X_T is approximated by a portfolio of simpler pay-offs depending on $\boldsymbol{Z}_T$ and this is valued anaytically at $t+1$.

Literature: Bauer, Bergmann, and Reuss (2010), Cathcart, Lok, Morrison, and McNeil (2015), Pelsser and Schweizer (2016), Ha and Bauer (2018).

Overview

Balance sheet of a DB pension fund

Pension fund LJK (26th March 2019)			
Assets		Liabilities	
Investments		Technical provisions	
- cash	£5M		
- equities	£45M	Active member benefits	£70M
- bonds	£35M	Deferred member benefits	£30M
- other	£15M	Pensioner member benefits	£20M
Total	£100M	Total	£120M

- This scheme is in deficit.
- Form of liabilities similar to annuity liabilities of an insurer.
- Additional uncertainty around, for example, future employment of active members and future inflation.

State of DB pensions (Thurley and Mor, 2018)

- Percentage of employees with DB pension: 34% in 1997 to 9% in 2016
- Scheme members in 2016: 1.3M active; 6.7M deferred; 5.5M pensioner
- Schemes are 68% funded on full buy-out basis; 91% on S179 basis.
- Factors driving deficit:
  - Longevity
  - Discretionary promises that have turned into statutory promises (indexation, gender equality)
  - Equity market bull run of 1980s and 1990s
  - QE since 2008.
- Full buy-out: transfer of promises from scheme to insurance company through purchase of bulk annuities.
- Section 179: value of reduced level of pension provision if 'promises' are transferred to Pension Protection Fund (PPF).

Valuation of DB pension liabilities

While assets are valued at market prices, there are different forms of liability valuation for different purposes (Pensions Policy Institute, 2017):

Accounting valuation: discounting based on yields of high-quality bonds with same duration as liabilities.

3-yearly scheme valuation: liabilities must be valued prudently and with allowance for adverse deviations; scope for discretionary discount rate based on sponsor risk appetite, strength of covenant and investment mix.

Buy-out valuation: transfer value similar to Solvency II valuation; discounting based on government bond yields plus some sort of risk margin demanded by insurer.

Section 179 valuation: value of liabilities under PPF compensation rules.

Going to Solvency II valuation means going to someting closer to buy-out valuation and would increase deficits.

Matching adjustment

- The introduction of market-consistent (MC) liability valuation for insurers under Solvency II also led to concerns that it would pitch perfectly sound companies into apparent “insolvency”.
- “For every £1 increase in assets due to falling gilt yield, there is a corresponding £5 increase in liabilities.” (NAPF, 2012)
- Insurers argued successfully that such an artefact of market fluctuations in interest rates was undesirable.
- They argued that insurers matched many longer-term liabilities with long-term investments that were cheaper than gilts.
- Therefore these liabilities should be valued the same way as backing assets.
- Therefore a higher discount rate should be applied to the liabilities.

Holistic balance sheet of DB pension fund

Pension fund LJK (26th March 2019)			
Assets		Liabilities	
Investments		Technical provisions	
- cash	£5M		
- equities	£45M	Active member benefits	£70M
- bonds	£35M	Deferred member benefits	£30M
- other	£15M	Pensioner member benefits	£20M
Sponsor covenant	£25M		
Total	£125M	Total	£120M

- Critics of SII for pensions also point to the existence of the sponsor's covenant (and PPF protection) as key differences.
- Sponsor's covenant can be added to the holistic balance sheet.

Market-consistent valuation of sponsor covenant?

- Attempts have been made to value the sponsor covenant (Turnbull, 2014), i.e. the commitment to make deficit funding contributions.
- Features:
  - The pattern of contributions is likely to be dynamic;
  - Contributions can be viewed as claims on the sponsor and are thus subject to the sponsor's credit risk;
  - The credit risk may be greatest in scenarios where deficit is greatest (wrong-way risk).
- The Turnbull (2014) approach:
  - Make assumption about deficit funding policy - annual contribution as percentage of deficit.
  - Model deficit dynamically by MC valuation of pension fund's assets and liabilities.
  - Value sponsor's contributions as credit-risky claims.
  - Link sponsor default risk to other market variables (bonds and equities).
  - Apply stochastic simulation framework to determine MC values.

Solvency capital for a pension fund?

- The holistic balance sheet valuation exercise makes it possible to determine a notional solvency-capital requirement for the fund (perhaps using Q simulations within P simulations).
- This would be the surplus/deficit at time t corrected by the amount required to ensure the holistic balance sheet was in surplus at end of a one-year horizon ($t + 1$) with a given high probability.
- This could give signals for the need to increase assets (e.g. sponsor contributions) or reduce liabilities (e.g. cash settlements with members).

Critics see dangers:

- Pensions schemes might de-risk assets to reduce the solvency capital requirement making long-term situation worse.
- Any kind of decisions taken on basis of fluctuating annual values fundamentally misguided; fluctuations have little to do with whether the cash flows in and out will ultimately prove to have been well matched.

Relevance for consolidation of funds into superfunds

- A superfund would offer DB pension schemes who were not in a position to buy out their liabilities with an insurer a more cost-effective means of transferring liabilities.
- Economies of scale are provided by the consolidation.
- To replace the employer/sponsor convenant a superfund would have a capital buffer provided by investors, who would expect to make a reasonable return.
- This would give a superfund a degree of similarity to an insurer.
- Aim of regulation is to balance interests of (1) protecting members, (2) offering affordability to employers and (3) offering profitability to investors.
- DWP consulting on regulatory regime; range of increasngly stringent approaches considered.
- At minimum end, stochastic modelling to demonstrate a 99% probability of member benefits being paid over lifetime of fund; at maximum end, full Solvency II style system with a solvency capital requirement.
- Potential entrants not impressed by latter (Clara-Pensions, 2019).

For Further Reading

Bauer, Daniel, Daniela Bergmann, and Andreas Reuss, 2010, Solvency II and nested simulations - a least-squares Monte Carlo approach, in *Proceedings of the 2010 ICA congress*.

Cathcart, M., Y.H. Lok, S. Morrison, and A.J. McNeil, 2015, Calculating variable annuity liability 'Greeks' using Monte Carlo simulation, *Astin Bulletin* 45, 239–266.

Clara-Pensions, 2019, Consolidation of defined benefit schemes, Consultation response, Clara-Pensions.

DWP, 2018, Consolidation of defined benefit pension schemes, Public consultation, Department for Work & Pensions.

EIOPA, 2014, Further work on solvency of IORPs, Consultation paper, EIOPA.

European Commission, 2010, towards adequate, sustainable and safe European pension systems, Green paper, European Commission.

European Commission, 2013, Occupational pensions funds IORP: next steps, Memo, European Commission.

For Further Reading (cont.)

European Parliament and Council, 2014, On the taking-up and pursuit of the business of Insurance and Reinsurance (Solvency II) (recast), Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009, European Parliament and Council.

Ha, H., and D. Bauer, 2018, A least-squares Monte Carlo approach to the calculation of capital requirements, Working paper.

Longstaff, F. A., and E. S. Schwartz, 2001, Valuing American options by simulation: A simple least-squares approach, *Review of Financial Studies* 14, 113–147.

NAPF, 2012, Exceptional times, exceptional measures?, Report, National Association of Pension Funds.

Pelsser, A., A. Salahnejhad, and R. van den Akker, 2016, Market-consistent valuation of pension liabilities, Industry paper; vol. design 63, NETSPAR.

Pelsser, A., and J. Schweizer, 2016, The difference between LSMC and replicating portfolio in insurance liability modeling, *European Actuarial Journal* 6, 441–494.

For Further Reading (cont.)

Pensions Policy Institute, 2017, Defined benefits: valuing and managing liabilities, Briefing note, PPI, Number 93.

Thurley, D., and F. Mor, 2018, Defined benefit pension schemes, White paper, House of Commons Library, Number CBP-8219.

Turnbull, C., 2014, Market-consistent valuation of a defined benefit pension fund's employer covenant and its use in risk-based capital assessment, *British Actuarial Journal* 19, 346–403.