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A Tale of Two Pension Plans
Measuring Pension Plan Risk from an Economic Capital Perspective

Pradip Tapadar


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Agenda

- Introduction
- Stochastic models
- Model assumptions
- Results
- Conclusions

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A tale of two pension plans
Longevity 15 2/28
Years of high inflation and good investment returns during the 1970s and 1980s created the illusion that DB pension plans are easily affordable. Over the past decade or more, increasing life expectancy and steady fall in interest rates have meant that pension costs have increased. Regulatory developments: Basel 2/3, Solvency 2, Pensions Regulations.

Objective:
Quantify pension plan risk from an economic capital perspective for:
1. a UK pension plan: Universities Superannuation Scheme (USS); and
2. a stylised US plan, with the same membership profile as USS but with plan provisions modified to reflect a typical US DB plan.
Risk Measurement Framework: Economic Capital

Economic Capital

The economic capital of a pension plan is the proportion by which its existing assets would need to be augmented in order to meet net benefit obligations (in respect of current plan members) with a prescribed degree of confidence.

Notations:

- $A_t$: Value of pension plan assets at time $t$;
- $L_t$: Value of pension plan liabilities at time $t$;
- $X_t$: Net cash flow at time $t$ (excluding investment returns);
- $I_{(s,t)}$: Accumulated value at time $t$ of $1$ invested at time $s$;
- $D_{(s,t)}$: Discount factor, i.e. $D_{(s,t)} = I_{(s,t)}^{-1}$.
Risk Measurement Framework: Formulation

Assuming annual cashflows and valuations, any surplus or deficit is given by:

Profit Vector: \( P_t = L_{t-1} I_{(t-1,t)} - X_t - L_t \), with \( P_0 = A_0 - X_0 - L_0 \).

Over a time horizon of \( T \) years, the present value of future profits (PVFP):

\[
V_0 = \sum_{t=0}^{T} P_t D(0,t).
\]

Given the long-term nature of pension plan risks, we propose a run-off approach (i.e. until the last of the current plan members dies), so that \( L_T = 0 \). Under this assumption:

\[
V_0 = A_0 - \sum_{t=0}^{T} X_t D(0,t).
\]
Risk Measurement Framework: Risk Measures

Standardisation to account for currency and scale:

\[ V_0^* = \frac{V_0}{A_0}, \]

\( \downarrow \) interpreted as the proportional increase in assets required to meet all future benefit obligations.

Based on \( V_0^* \), economic capital can be quantified as either:

- **Value-at-Risk (VaR)** defined as \( P[V_0^* \leq \text{VaR}] = p \); or
- **Expected shortfall (ES)** defined as \( E[V_0^* | V_0^* \leq \text{VaR}] \);

for a given probability \( p \).

\( \downarrow \) In our results, we will show entire distributions of \( V_0^* \),

\( \downarrow \) highlighting the following percentiles: 50\(^{th}\) (median), 10\(^{th}\) and 0.5\(^{th}\).
Stochastic models

Economic Scenario Generator: Wilkie Model (UK only)

- Salary Inflation
- Price Inflation
- Dividend Yield
- Dividend Growth
- Long Bond Yield
- Real Yield
- Short Bond Yield

Economic Scenario Generator: Graphical Model (both UK and US)

The individual economic random variables, $Z_{it}$s, are modelled as:

$$Z_{it} = \mu_i + Y_{it}, \text{ where } Y_{it} = \beta_i Y_{i(t-1)} + \varepsilon_{it} \text{ and } \varepsilon_{it} \sim N(0, \sigma^2_i).$$

The error terms

- which are directly connected to each other are dependent;
- which are indirectly connected are still dependent, but more weakly so. (Oberoi et al. (2019))
Stochastic Mortality Model

We use model M7 of Cairns et al. (2009):

\[
\text{logit } q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \kappa_t^{(3)} [(x - \bar{x})^2 - \sigma_x^2] + \gamma_{t-x},
\]

where

- \( q(t, x) \) is the probability that an individual aged \( x \) at time \( t \) will die within a year;
- \( \kappa_t^{(i)} \) is period effect;
- \( \gamma_{t-x}^{(i)} \) is cohort effect.

The model is parameterised using

- data from Human Mortality Database;
- for both UK and US;
- for both males and females;
- for years 1961 – 2014;
- for ages 30 – 100.
Introduction

Stochastic models

Model assumptions

Results

Conclusions
### Membership Profile: Model Points

Table: USS membership profile as at March 31, 2014 (USS 2014 valuation report).

<table>
<thead>
<tr>
<th>Membership types</th>
<th>Age</th>
<th>Number</th>
<th>Accrued service/benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>30</td>
<td>50,264</td>
<td>7 years past service</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>50,264</td>
<td>11 years past service</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>33,509</td>
<td>15 years past service</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>33,509</td>
<td>19 years past service</td>
</tr>
<tr>
<td>Deferred</td>
<td>45</td>
<td>110,430</td>
<td>Accrued pension of £2,373 per year</td>
</tr>
<tr>
<td>Pensioner</td>
<td>71</td>
<td>70,380</td>
<td>Accrued pension of £17,079 per year</td>
</tr>
</tbody>
</table>

Other assumptions:
- 50:50 gender split.
- Promotional salary scale, withdrawal rates and proportion married assumptions are as provided in the valuation report.
Model assumptions

Retirement Benefits

**USS**

Annual Pension = Pensionable salary × Pensionable service × Accrual rate;
Cash lump sum = 3 × Annual pension.

Simplified modelling approach:
- Until 2014, accrual rate of 1.25% on a final salary basis.
- Post 2014, accrual rate of 1.33% on a career revalued benefits basis.
- Annual pension increase in line with inflation.

**Stylised US plan**

- Accrual rate of 1.5% on a final salary basis.
- No cash lump sum on retirement.
- No indexation of pension during the payment period.
Withdrawal Benefits

**USS**
- Deferred inflation-linked pension benefits are provided based on accrued service on withdrawal.
- Inflation indexation of salaries between the date of leaving and retirement is provided.

**Stylised US plan**
- A deferred pension, without any indexation, is provided based on accrued service on withdrawal.
- There is no indexation during the payment period.
Death Benefits

**USS**

On death of an active member

- Lump sum payment of 3 times the annual salary is paid on death.
- A spouse’s pension of half the amount of pension the member would have received if survived till retirement.

On death of a pensioner, a spouse’s pension of half the member’s pension is payable.

**Stylised US plan**

On death of an active member

- Lump sum equal to the present value of the pension the member would have received if survived till retirement.

On death of a pensioner, a spouse’s pension of half the member’s pension is payable.
### Contributions, Assets and Liabilities

<table>
<thead>
<tr>
<th></th>
<th>USS</th>
<th>Stylised US plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contributions</td>
<td>22.5% of salary</td>
<td>10.8% of salary</td>
</tr>
<tr>
<td>Assets</td>
<td>£41.6b</td>
<td>$26.1b</td>
</tr>
<tr>
<td>Liabilities</td>
<td>£46.9b</td>
<td>$32.6b</td>
</tr>
</tbody>
</table>

**Asset allocation:**

- **USS:** 70% equities and 30% bonds.
- **Stylised US plan:** 50% equities and 50% bonds.
Agenda

- Introduction
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- Results
  - UK’s USS
  - Stylised US plan
- Conclusions
USS: Base Case Graphical Model

Density

Percentiles
- 50th (median)
- 10th
- 0.5th

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Longevity 15
USS: Base Case Wilkie Model

Graphical Model
Wilkie Model

Percentiles
50th (median)
10th
0.5th

Density

$V_0^*$

Percentiles

$-300$ $-250$ $-200$ $-150$ $-100$ $-50$ $0$ $50$ $100$
USS: Sensitivity to Asset Allocation (Graphical Model)

- Equity 70 / Bond 30 (Base case)
- Equity 30 / Bond 70

Density

Percentiles

50th (median)
10th
0.5th

Equity 70 / Bond 30 (Base case)
Equity 30 / Bond 70

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Longevity 15
USS: Sensitivity to Contribution Rates (Graphical Model)

Contribution Rates
- 25%
- 22.5% (Base case)
- 20%

Density
- -300
- -250
- -200
- -150
- -100
- -50
- 0
- 50
- 100

Percentiles
- 50th (median)
- 10th
- 0.5th

V_0

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Agenda

- Introduction
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  - UK’s USS
  - Stylised US plan
- Conclusions
Stylised US Plan: Base Case Graphical Model (With Amortisation)

Density

Percentiles
- 50th (median)
- 10th
- 0.5th

V0

0

-400 -350 -300 -250 -200 -150 -100 -50 0 50 100

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Longevity 15
Stylised US Plan: Sensitivity to Asset Allocation (Graphical Model)

- Density
- Percentiles
  - 50th (median)
  - 10th
  - 0.5th

Equity 75 / Bond 25
Equity 50 / Bond 50 (Base case)
Equity 25 / Bond 75

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Results

Stylised US Plan

Styled US Plan: Sensitivity to Contribution Rates (Graphical Model)

Contribution Rates
- 13.3%
- 10.8% (Base case)
- 8.3%

Percentiles
- 50th (median)
- 10th
- 0.5th

Density

Contribution Rates

V₀

0

−400 −350 −300 −250 −200 −150 −100 −50 0 50 100

V₀

0

−400 −350 −300 −250 −200 −150 −100 −50 0 50 100
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Conclusions

- Range of results is very wide – this is a function of using the long run-off approach.
- Impact of changes in asset allocation is much larger than for changes to plan contributions.
- As a percentage of starting assets, stylised US plan is more volatile than the USS plan.
- Benefits of greater bond investment is greater for the stylised US plan than for USS.
References


