Measuring Pension Plan Risk from an Economic Capital Perspective

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- Overall Project
- Introduction to Pension Model
- Assumptions and Methodology
- UK’s Universities Superannuation Scheme (USS)
- Stylized US Pension Plan
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- Summary
Motivation for Overall Project

- Baby boomers entering retirement
  - concerns of diminished returns, compromised pensions

- Higher old-age dependency ratio may lead to
  - less saving (dissaving) and investment
  - shift in asset allocation toward low risk / low return assets
  - reduced labour force growth

- With implications for asset returns and retirement outcomes
Overall Project

Model Framework / Results – Economic Demographic Model

- Overlapping Generations Model (OLG) with:
  - aggregate uncertainty
  - two asset classes (risky and risk-free)
  - multi-pillar pension systems (saving, pay-go, earnings based)
  - endogenous labour supply

- Generates standard age-specific labour, consumption, asset holdings and portfolio allocation qualitatively consistent with data

- Older population results in moderately lower asset returns
  - Increasing survival probability for age 65+ (20% increase at oldest ages) reduces returns by approximately 4%

- Higher pension replacement ratio results in lower asset accumulations
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Motivation

- Typical pension plan valuation compares assets to liabilities

- This comparison looks at expected values (perhaps including some margin)

- One approach to pension plan risk assessment is Economic Capital [see Porteous, et al. (2012)]
  - Used for banking and insurance sectors under Basel 2, 3 and Solvency 2
  - Sufficient to cover 99.5th percentile outcome
Methodology

- Select a representative pension plan
  - Universities Superannuation Scheme (UK) 2014 Actuarial Valuation
  - Stylized US pension plan
  - Canadian pension plan

- Select an economic model
  - Graphical Model [see Oberoi, et al. (2019)]

- Select a mortality model
  - M7 from Cairns, et al. (2007)

- Quantify pension risk [see Porteous, et al. (2012)]
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Graphical Model - Background

- Graphical models are probabilistic models for which a graph expresses the conditional dependence structure between random variables.

- We use graphical models to simulate economic variables over long time horizons.

- The approach we use is:
  - transparent
  - flexible
  - easy to implement
Assumptions and Methodology

Methodology - forecasting

- Assume 3 economic variables A, B and C.
- The individual economic random variables, $Z_{it}$s, are modelled as:
  \[ Z_{it} = \mu_i + Y_{it}, \text{ where } Y_{it} = \beta_i Y_{i(t-1)} + \varepsilon_{it} \text{ and } \varepsilon_{it} \sim N(0, \sigma_i^2). \]

- Correlation of the **error terms** is represented by a graphical model.
- The error terms:
  - are assumed to be independently distributed across time $t$;
  - which are directly connected to each other are dependent;
  - which are indirectly connected are still dependent, but more weakly so.
Methodology - selecting a correlation structure

- We use simultaneous p-values to select a graphical structure.

- Hojsgaard et al. (2012). provide guidance on the use of packages written in R to estimate graphical models.

- We use the following UK and US economic time series data:
  - Price Inflation
  - Salary Inflation
  - Dividend Yield
  - Dividend Growth
  - Consols Yield
Model UK: Graphical model with 6 edges.
Corresponding P-Values

<table>
<thead>
<tr>
<th>Edge</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1−2</td>
<td>0.0</td>
</tr>
<tr>
<td>1−3</td>
<td>0.1</td>
</tr>
<tr>
<td>1−4</td>
<td>0.2</td>
</tr>
<tr>
<td>1−5</td>
<td>0.3</td>
</tr>
<tr>
<td>2−3</td>
<td>0.4</td>
</tr>
<tr>
<td>2−4</td>
<td>0.5</td>
</tr>
<tr>
<td>2−5</td>
<td>0.6</td>
</tr>
<tr>
<td>3−4</td>
<td>0.7</td>
</tr>
<tr>
<td>3−5</td>
<td>0.8</td>
</tr>
<tr>
<td>4−5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

1  PriceInflation
2  SalaryInflation
3  DividendYield
4  DividendGrowth
5  ConsolsYield
Model US: Graphical model with 6 edges.
Marginal distribution – Price Inflation

UK Price Inflation

US Price Inflation
Marginal distribution – Dividend Yield

**UK Dividend Yield**

- Year: 1924, 1964, 2004, 2044, 2084, 2124
- Values: 0.00, 0.02, 0.04, 0.06, 0.08, 0.10

**US Dividend Yield**

- Year: 1914, 1956, 1998, 2040, 2082, 2124
- Values: 0.00, 0.02, 0.04, 0.06, 0.08, 0.10
Marginal distribution – Long Bond Yield

UK Long Bond Yield (Consols Yield)

US Long Bond Yield
Joint distribution (1)

Figure: Plots of simulated price and salary inflation for UK and US.
Figure: Plots of simulated share and bond returns for UK and US.
Mortality Model – M7 from Cairns, et al. (2007)

\[
\logit q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)}(x - \bar{x}) + \kappa_t^{(3)}((x - \bar{x})^2 - \hat{\sigma}_x^2) + \gamma_t^{(4)}
\]

- Model assumes a functional relationship between ages (and hence smoothness).
- One of the better fit models to England and Wales data (Cairns et al. (2007)).
Mortality Model – M7 from Cairns, et al. (2007)
Economic Capital Approach

- Use asset yield at time $t$, discount future benefits/expenses to obtain best estimate asset requirement

- Surplus/deficit at time $t$ (profit vector) given by

$$P_t = L_{t-1}l_{t-1,t} - X_t - L_t$$

- Present value of future profits given by:

$$V_0 = \sum_{t=1}^{T} P_t D_{(0,t)}$$
Present value of future profits, $V_0$, can also be expressed as follows:

$$V_0 = A_0 - \sum_{t=0}^{T} X_t D(0,t)$$

Repeat previous steps 10,000 times to obtain a distribution of $V_0$. The required economic capital is the 0.5th percentile of the $V_0$ distribution.
UK’s Universities Superannuation Scheme (USS)

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USS Pension Scheme – Benefits

- 1/80th final salary benefit for service to April 1, 2016
- 1/75th career revalued benefit for service from April 1, 2016
- Lump sum at retirement = 3 × annual pension
- Pension increases based on min [CPI, 5%]
- Contribution rate: 24% of salary (8% employee + 16% employer)
### UK’s Universities Superannuation Scheme (USS)

#### USS Pension Scheme – Data

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Average pensionable salary</th>
<th>Average age</th>
<th>Average past service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Members</td>
<td>167,545</td>
<td>£42,729</td>
<td>43.8</td>
<td>12.5</td>
</tr>
<tr>
<td>Deferred Members</td>
<td>110,430</td>
<td>£2,373</td>
<td>45.1</td>
<td></td>
</tr>
<tr>
<td>Pensioners (including dependents)</td>
<td>70,380</td>
<td>£17,079</td>
<td>71.1</td>
<td></td>
</tr>
<tr>
<td>Assets</td>
<td>Benchmark Allocation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK equities</td>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overseas equities</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative assets</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total real</td>
<td>73%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed interest</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fixed</td>
<td>27%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Modelled as 70% Equities and 30% Bonds
UK’s Universities Superannuation Scheme (USS)

USS Economic Capital – Sensitivity to Asset Allocation Strategy

**70% equities**

- Density
- Percentiles
  - 50th
  - 10th
  - 0.5th

**30% equities**

- Density
- Percentiles
  - 50th
  - 10th
  - 0.5th

PVFP (as a % of $A_0$)
UK’s Universities Superannuation Scheme (USS)

USS Economic Capital – Sensitivity to Contribution Rates

Contribution rate – 20%

Contribution rate – 25%

PVFP (as a % of $A_0$)

Density

Percentiles

50th

10th

0.5th

0.000

0.010

0.020

−300 −200 −100 0 100

−300 −200 −100 0 100
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Sylized US Pension Plan – Benefits

- Benefits based on USS pension scheme, except for the following
- 1.5% final average salary for all pension service
- No lump sum payment on retirement
- No pension increases
- Contribution rate: 10.8% of salary
US Stylized Plan Economic Capital – Sensitivity to Asset Allocation Strategy

75% equities

PVFP (as a % of A₀)

25% equities

PVFP (as a % of A₀)
US Stylized Plan Economic Capital – Sensitivity to Contribution Rate

**Contribution rate – 13.3%**

**Contribution rate – 8.3%**

PVFP (as a % of $A_0$)
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Pension payment: 1.7% of 5-year average salary benefit

Pension increases based on CPI

No lump sum payment

Contribution rate: 20.8% of salary up to YMPE and 24% for earnings exceeding YMPE.
## OTPP – Data

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Average pensionable salary</th>
<th>Average age</th>
<th>Average past service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>144,325</td>
<td>$90,468</td>
<td>44.4</td>
<td>14.6</td>
</tr>
<tr>
<td>Deferred Members</td>
<td>71,205</td>
<td>$1,965</td>
<td>45.1</td>
<td></td>
</tr>
<tr>
<td>Pensioners</td>
<td>129,785</td>
<td>$41,154</td>
<td>71.1</td>
<td></td>
</tr>
</tbody>
</table>
Model Canada: Graphical model with 6 edges.
OTPP Economic Capital

55% Equity

Percentiles
- 50th
- 10th
- 0.5th

Density

PVFP (as a % of $A_0$)
OTPP Economic Capital – Sensitivity to Asset Allocation Strategy

75% Equity

25% Equity

PVFP (as a % of A₀)

Percentiles
- 50th
- 10th
- 0.5th

Density

0.000 0.010 0.020

-400 −200 0 100

-400 −200 0 100
OTPP Economic Capital – Sensitivity to Contribution Rate

Contribution rate – 18.3%

Contribution rate – 23.3%
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- There is a very large range of potential results.

- The stylized US plan is more volatile than the USS:
  - Economic capital twice as large as a percentage of starting assets.
  - Economic capital also larger in absolute terms.

- The beneficial effect on economic capital of increasing the allocation to long bonds is greater in the stylized US plan:
  - Larger proportion of nominal (rather than inflation protected) benefits.

- Continuing to analyze Canadian plan results:
  - Initial results look similar to USS.
  - Will consider implications of reduced inflation protection and differing levels of plan maturity.
References


