Impact of changing population demographics on pension plans

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Introduction

Economic demographic model

Asset pricing model

Mortality model

Pension model

Conclusions
Agenda

1. Introduction
2. Economic demographic model
3. Asset pricing model
4. Mortality model
5. Pension model
6. Conclusions
The end of the 2nd World War brought a baby boom to many countries including the UK, US and Canada.

The retirement of this boomer generation brings several questions such as:

▶ Will assets backing pension schemes deflate in value?
▶ Will this change in population demographics bring down asset returns below expected levels?
▶ To what extent will increasing longevity of pensioners put further pressure on pension schemes?

The project aims at carrying a risk assessment of pension schemes to answer these questions.
Background

- Multi-year, multi-disciplinary, international project with the following institutions involved:
  - University of Waterloo
  - University of Kent
  - Institute and Faculty of Actuaries (IFoA)
  - Canadian Institute of Actuaries (CIA)
  - Society of Actuaries (SOA)
  - Social Sciences and Humanities Research Council (SSHRC)

- Three modelling stages involved:
  - Economic demographic model
  - Asset pricing model
  - Pension model
Background

- Economic demographic model
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Mortality model
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Overlapping generations (OLG) model

- OLG model provides a framework to study the allocation of resources across generations.
- In a basic two-period OLG model:
  - Agents live for 2 periods (young and old)
  - Population grows at a constant rate
  - The young work and earn an income; income is allocated between consumption and savings
  - The old are retired and live off their savings
  - Firms use capital (savings) and labour to produce consumer goods
Overlapping generations (OLG) model

- Economic demographic modelling team working on an OLG model with:
  - many overlapping generations
  - reproduced demographic structure
  - aggregate productivity shock
  - endogenous labour supply
  - portfolio allocation between two assets

- OLG model to be used to study demographic effects on:
  - return on equities and bonds
  - portfolio allocation
  - generation risk sharing
  - business cycle moments
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Approaches to modelling

- Aim is to model demographic effect on:
  - Stocks
  - Government/Corporate bonds
  - Short/Medium/Long term bonds
  - Housing prices
  - Infrastructure

- Detailed structural approach:
  - Goyal (2004) provides a full OLG framework
  - Creates a theoretical framework to link demographic change to stock market returns and stock market inflows and outflows

- Risk factor approach:
  - Similar approach to Fama and French (1992)
  - Return = $\alpha + \beta(Economy) + \gamma(Demography) + \varepsilon$
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## Formulation

### Table: Age-Period-Cohort models

<table>
<thead>
<tr>
<th>Model</th>
<th>Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Lee and Carter</td>
<td>( \log m(t, x) = \beta_x^{(1)} + \beta_x^{(2)} \kappa_t^{(2)} )</td>
</tr>
<tr>
<td>M3</td>
<td>Currie</td>
<td>( \log m(t, x) = \beta_x^{(1)} + \kappa_t^{(2)} + \gamma_{t-x}^{(3)} )</td>
</tr>
<tr>
<td>M5</td>
<td>CBD</td>
<td>( \logit q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) )</td>
</tr>
<tr>
<td>M6</td>
<td>CBD(1)</td>
<td>( \logit q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \gamma_{t-x}^{(3)} )</td>
</tr>
<tr>
<td>M7</td>
<td>CBD(2)</td>
<td>( \logit q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \kappa_t^{(3)} ((x - \bar{x})^2 - \hat{\sigma}<em>x^2) + \gamma</em>{t-x}^{(4)} )</td>
</tr>
<tr>
<td>M8</td>
<td>CBD(3)</td>
<td>( \logit q(t, x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \gamma_{t-x}^{(3)} (x_c - x) )</td>
</tr>
</tbody>
</table>
Parameter estimates

Figure: Parameter estimates of model M3 for UK, US and Canada fitted using males mortality data ages 60-89 and years 1968-2011
## Ranking of models

### Table: Models’ BIC and rank

<table>
<thead>
<tr>
<th>Model</th>
<th>UK</th>
<th>US</th>
<th>Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>-10925 (4)</td>
<td>-17362 (4)</td>
<td>-8299 (5)</td>
</tr>
<tr>
<td>M3</td>
<td>-14153 (6)</td>
<td>-28115 (5)</td>
<td>-9698 (6)</td>
</tr>
<tr>
<td>M5</td>
<td>-11876 (5)</td>
<td>-30134 (6)</td>
<td>-8216 (4)</td>
</tr>
<tr>
<td>M6</td>
<td>-8607 (3)</td>
<td>-13459 (3)</td>
<td>-7634 (1)</td>
</tr>
<tr>
<td>M7</td>
<td>-8488 (1)</td>
<td>-12781 (1)</td>
<td>-7698 (3)</td>
</tr>
<tr>
<td>M8</td>
<td>-8503 (2)</td>
<td>-13161 (2)</td>
<td>-7672 (2)</td>
</tr>
</tbody>
</table>
Simulated mortality rates

Figure: Simulated mortality rates under model M5 for UK, US and Canada for males age 65, 75 and 85
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Economic Capital Formulation

**Economic capital** is the excess of assets over liabilities in respect of accrued benefits required to ensure that assets exceed liabilities on all future valuation dates over a specified time horizon with a prescribed high probability.

**Notations:**

- $X_t$: Net cash flow of the scheme;
- $L_t$: Value of s179 liability of the scheme;
- $I_{s,t}$: Accumulation factor;
- $D_{s,t}$: Discount factor.

**Building blocks**

- $P_t = L_{t-1}I_{(t-1,t)} - X_t - L_t$: Profit vector, with $P_0 = -X_0 - L_0$.
- $R_t = \sum_{s=0}^{t} P_s I_{s,t}$: Accumulated retained profits until time $t$,
- $V_t = \sum_{s=t+1}^{T} P_s D_{t,s}$: Present value of future profits at time $t$. 
Eligible Scheme Cashflow and Capital Requirement

Capital requirement: \( C_t = \max \left[ - \min_{s=t}^T V_s D_{t,s}, 0 \right] \).

Economic capital requirement: \( \rho(C_t) = \text{VaR}(C_t, p = 0.995) \).
Aggregate Economic Capital for Eligible Schemes

As at 31 March 2012

- Assets: £1,018 billion
- Liabilities: £1,218 billion
- Economic Capital: £1,231 billion
Economic Capital: Eligible Scheme in A

Membership group A

Liability and economic capital (£ million)

\[ \rho_t^{AH}, \rho_t^{AM}, \rho_t^{AL}, L_t^A \]
PPF: Base Case Results

PPF schemes liability and economic capital: Base case

- Liability
- Economic capital

<p>|</p>
<table>
<thead>
<tr>
<th>Year</th>
<th>Liability</th>
<th>Economic capital</th>
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</thead>
<tbody>
<tr>
<td>2020</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2040</td>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>2060</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>2080</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>2100</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

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Summary

- The project aims at looking at the impact of population ageing on asset values and illustrates this impact by applying it to pension plans.
- Three modelling stages involved:
  - Economic demographic model
  - Asset pricing model
  - Pension model

References