Institute and Faculty of Actuaries

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Impact of changing population demographics on pension plans

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Agenda

1. Introduction
2. Economic demographic model
3. Asset pricing model
4. Mortality model
5. Pension model
6. Conclusions

Agenda

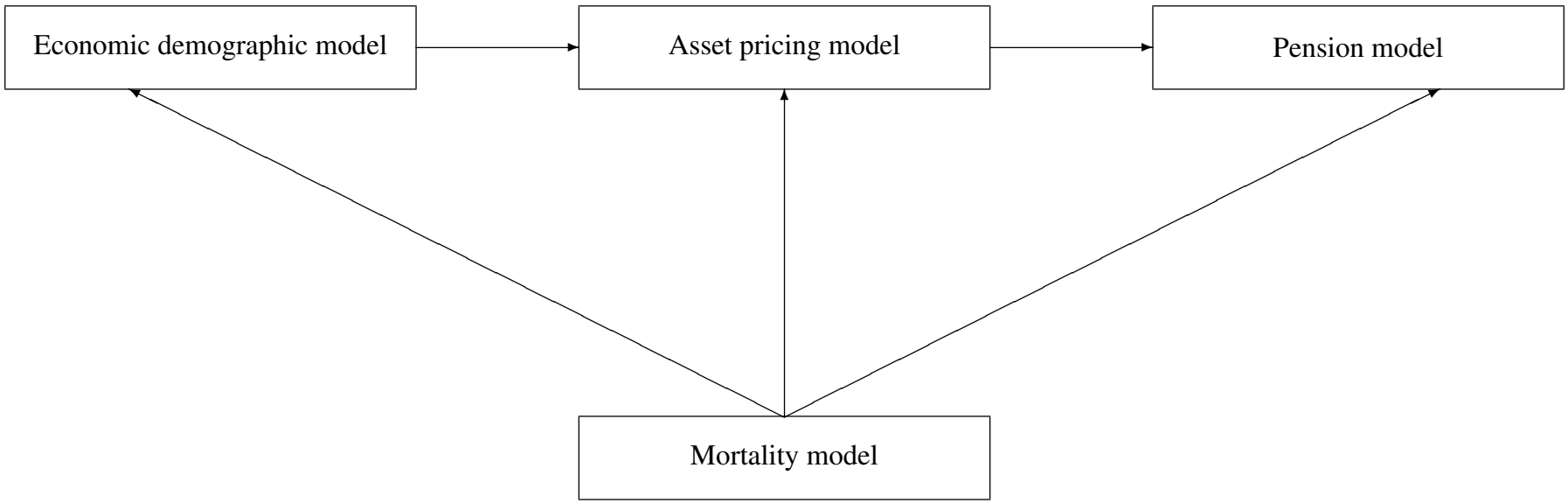
Background

- The end of the 2^{nd} 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 assessement 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
Asset pricing model
Pension model
Mortality model

Agenda

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

Agenda

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) + γ(Demography) + ε

Agenda

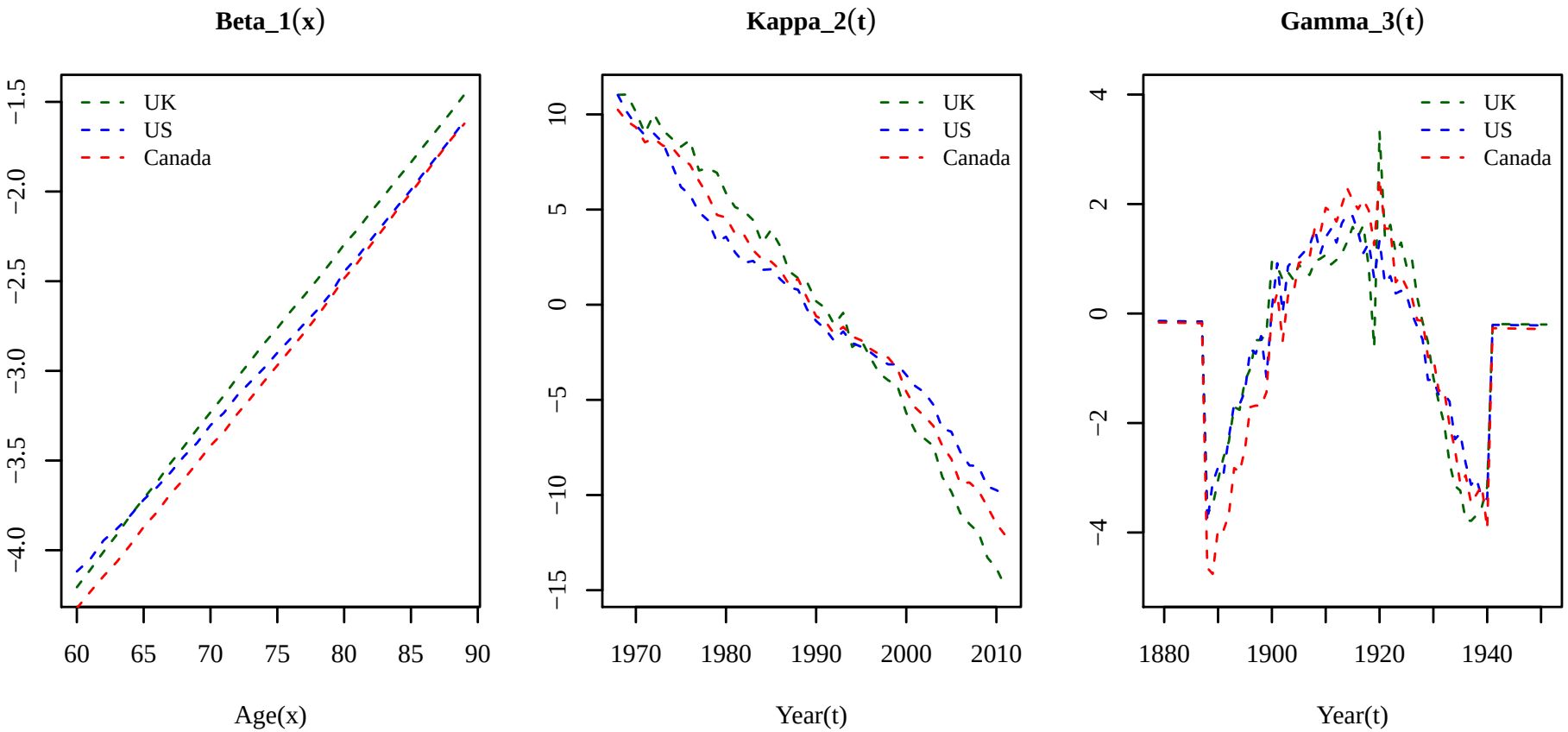
Formulation

Table: Age-Period-Cohort models

Model	Name	Formula
M1	Lee and Carter	$\log m(t,x) = \beta_x^{(1)} + \beta_x^{(2)}\kappa_t^{(2)}$
M3	Currie	$\log m(t,x) = \beta_x^{(1)} + \kappa_t^{(2)} + \gamma_{t-x}^{(3)}$
M5	CBD	$\text{logit}\, q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)}(x-\bar{x})$
M6	CBD(1)	$\text{logit}\, q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)}(x-\bar{x}) + \gamma_{t-x}^{(3)}$
M7	CBD(2)	$\text{logit}\, q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)}(x-\bar{x}) + \kappa_t^{(3)}((x-\bar{x})^2 - \hat{\sigma}_x^2) + \gamma_{t-x}^{(4)}$
M8	CBD(3)	$\text{logit}\, q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)}(x-\bar{x}) + \gamma_{t-x}^{(3)}(x_c - x)$

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



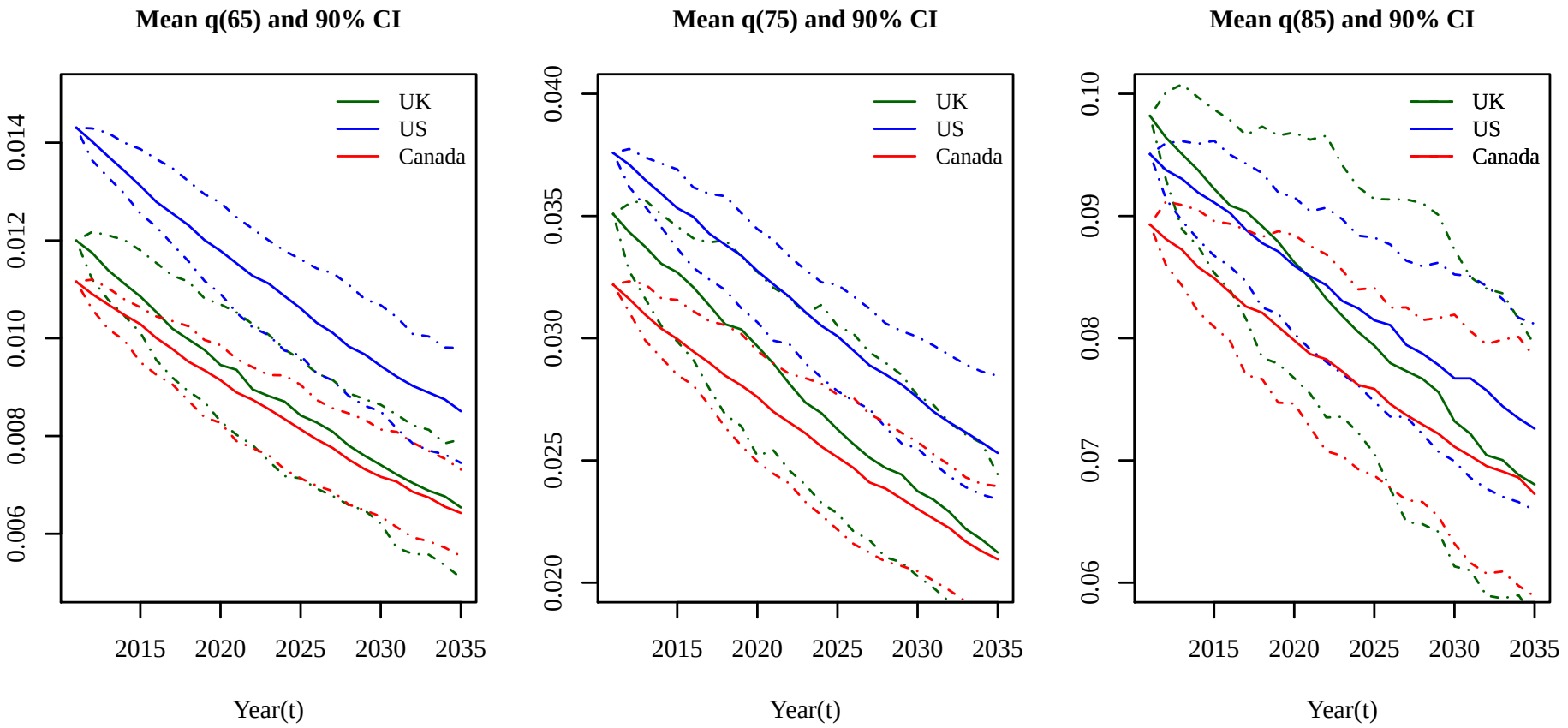
Ranking of models

Table: Models' BIC and rank

Model	UK	US	Canada
M1	-10925 **(4)**	-17362 **(4)**	-8299 **(5)**
M3	-14153 **(6)**	-28115 **(5)**	-9698 **(6)**
M5	-11876 **(5)**	-30134 **(6)**	-8216 **(4)**
M6	-8607 **(3)**	-13459 **(3)**	-7634 **(1)**
M7	-8488 **(1)**	-12781 **(1)**	-7698 **(3)**
M8	-8503 **(2)**	-13161 **(2)**	-7672 **(2)**

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.

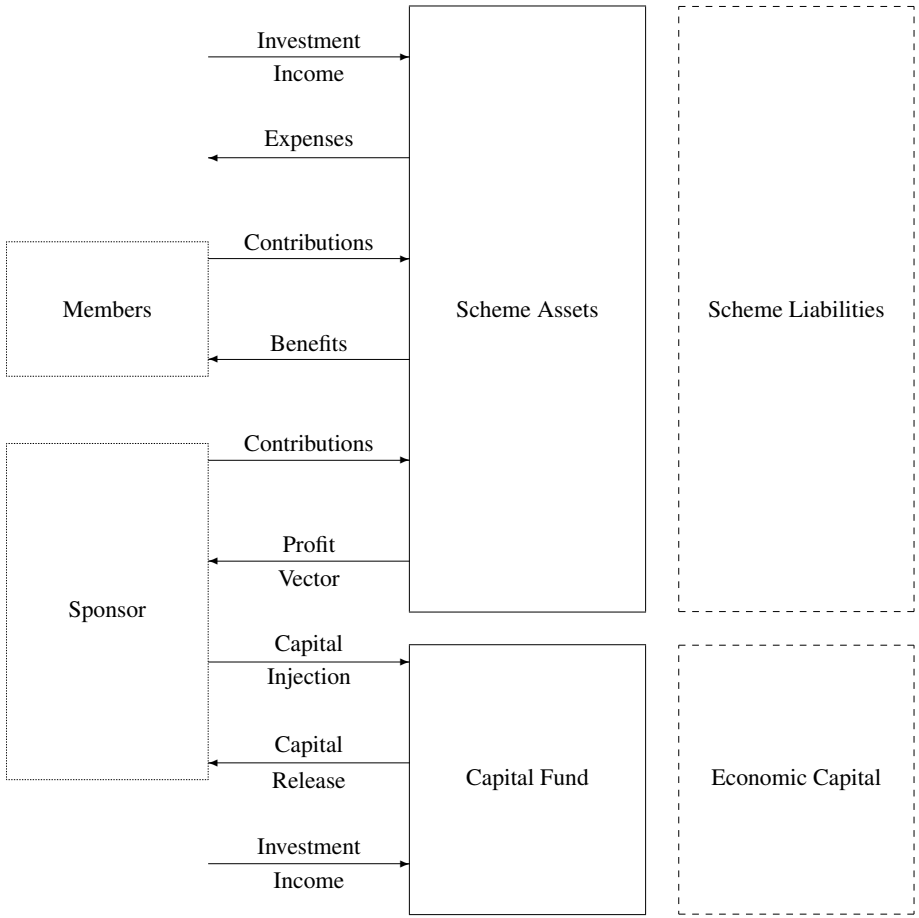
Building blocks

$P_t = L_{t-1}I_{(t-1,t)} - X_t - L_t$: 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.

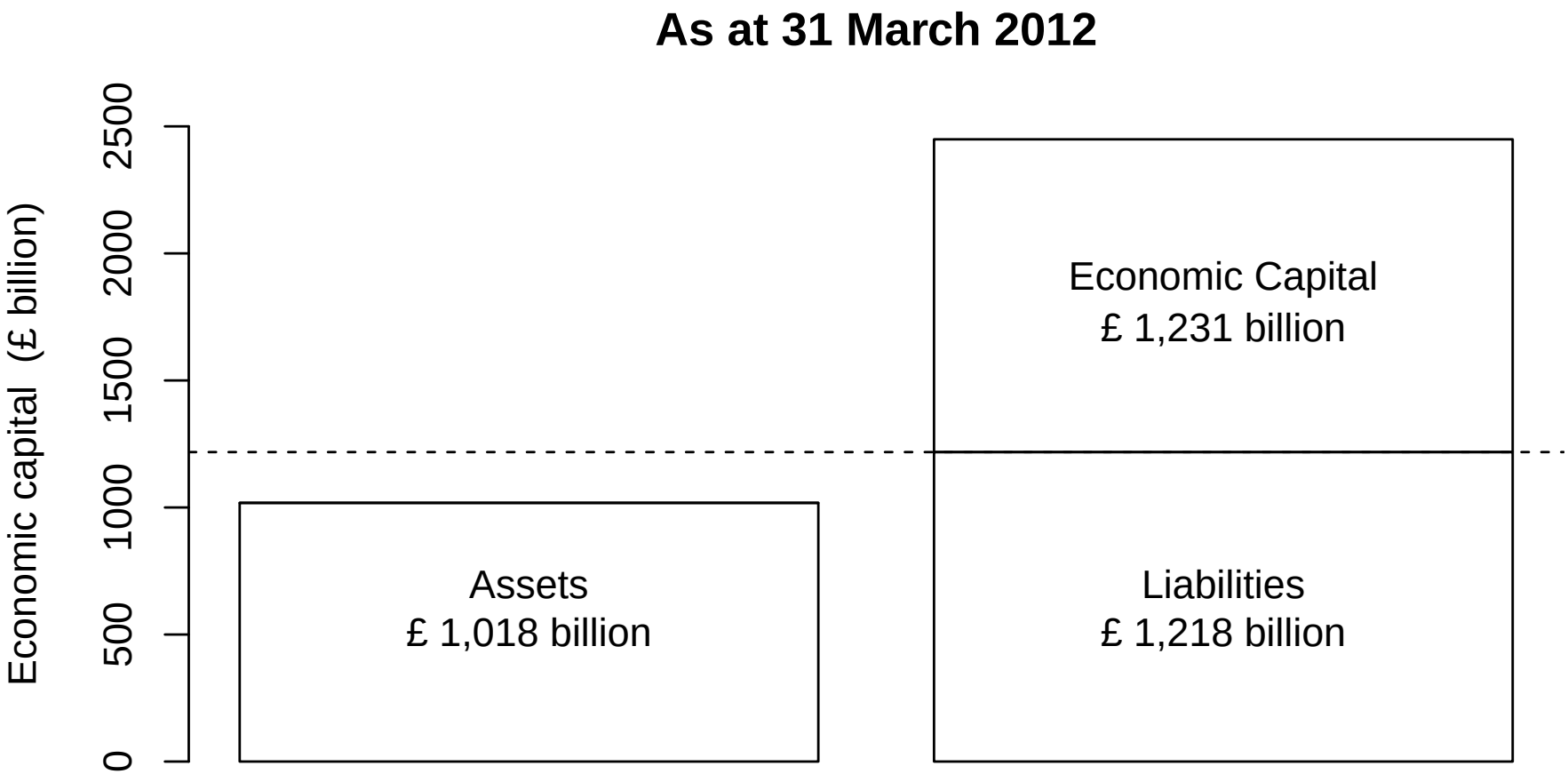
Eligible Scheme Cashflow and Capital Requirement



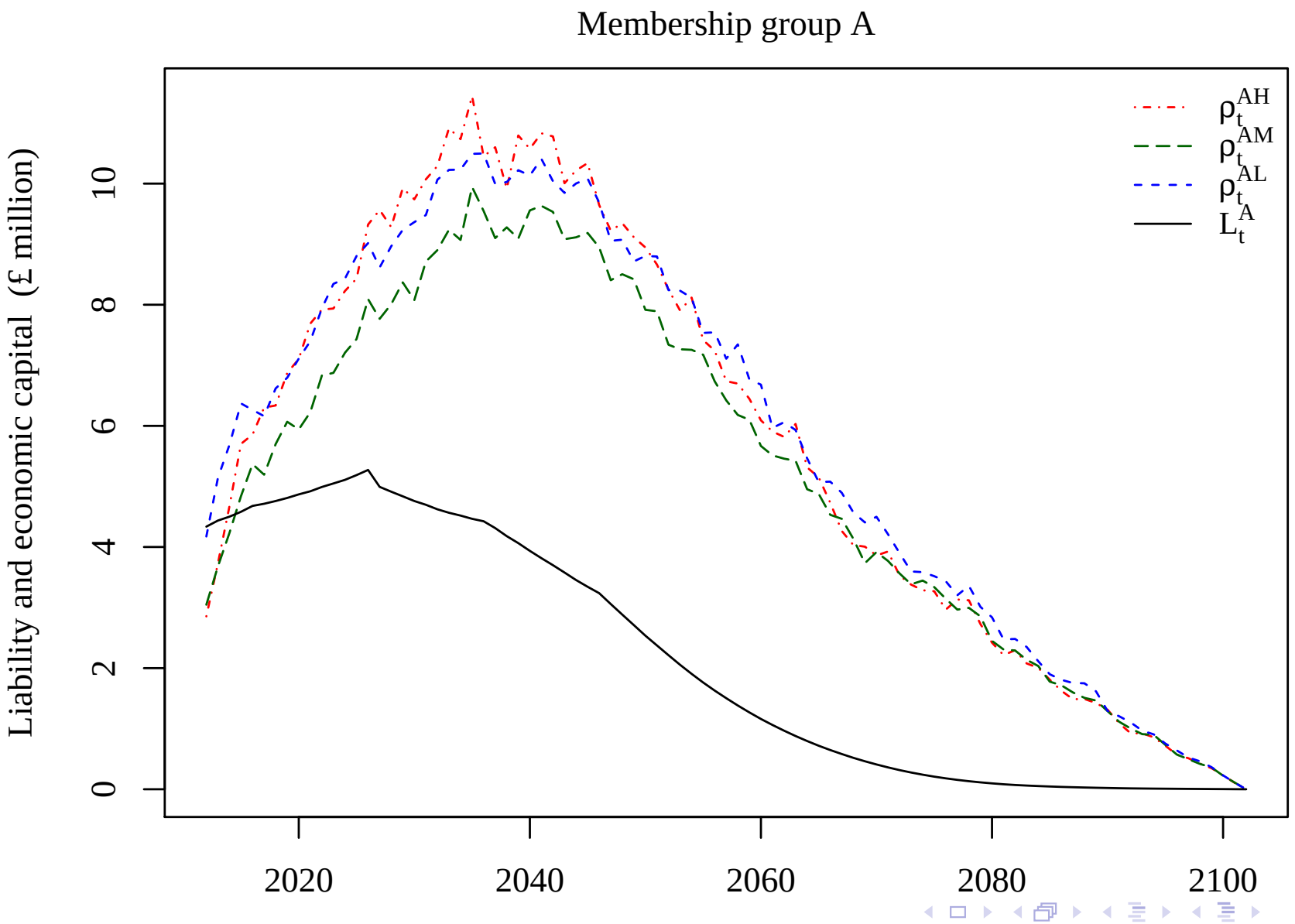
$$\text{Capital requirement: } C_t = \max\left[-\min_{s=t}^{T} V_s D_{t,s}, 0\right].$$

$$\text{Economic capital requirement: } \rho(C_t) = VaR(C_t, p = 0.995).$$

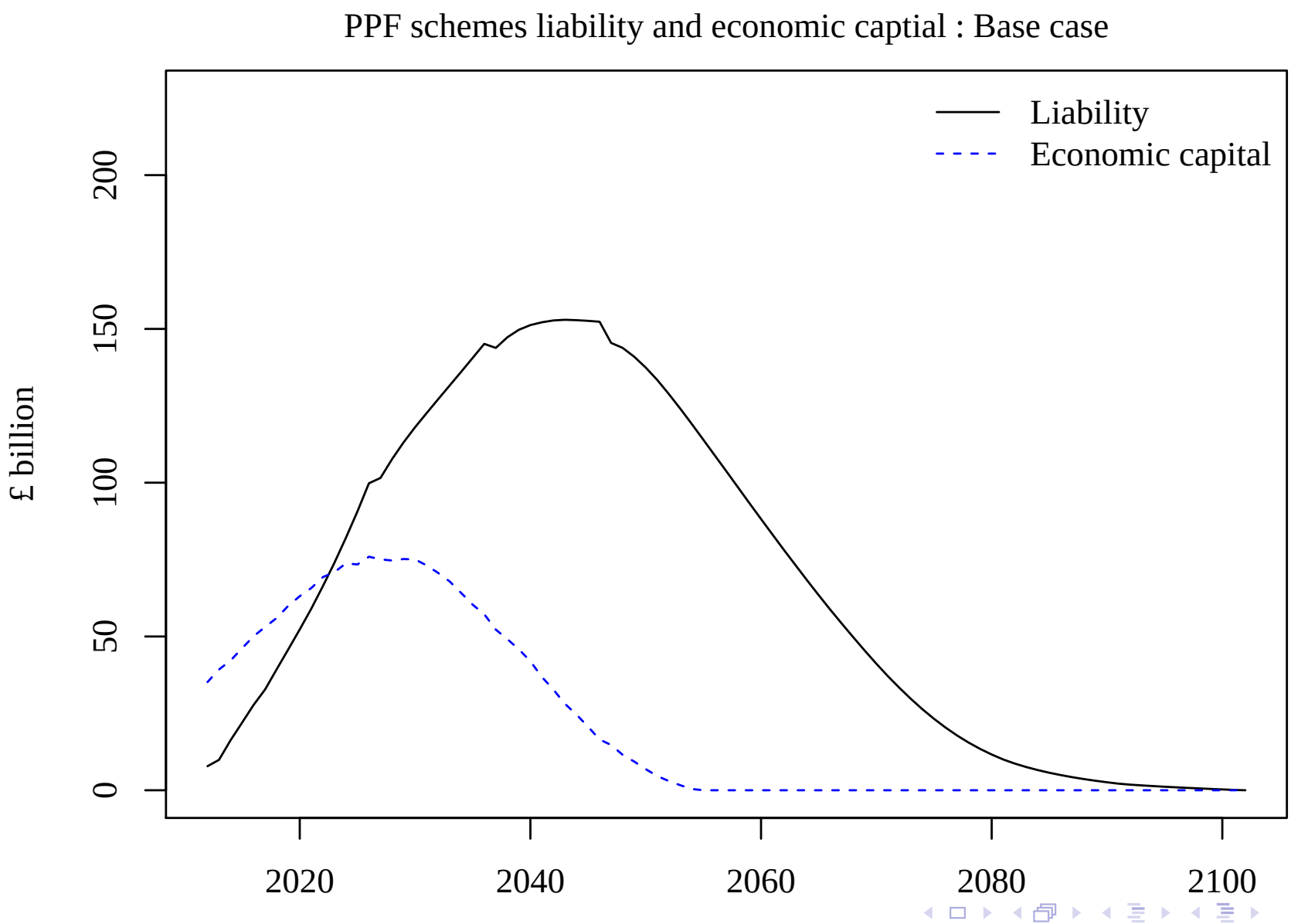
Aggregate Economic Capital for Eligible Schemes



Economic Capital: Eligible Scheme in *A*



PPF: Base Case Results



Agenda

Conclusions

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

- De La Croix, D., & Michel, P. (2002). A theory of economic growth: dynamics and policy in overlapping generations. *Cambridge University Press*.
- Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., Ong, A. & Balevich, I. (2009). A quantitative comparison of stochastic mortality models using data from England and Wales and the United States. *North American Actuarial Journal*, **13**, 1–35.
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