Measuring Pension Plan Risk from an Economic Capital Perspective

Steve Bonnar, Aniketh Pittea and Pradip Tapadar

University of Waterloo and University of Kent

May 15, 2019

Acknowledgements

- Funding for this project has come from a variety of sources:
    - Canadian Institute of Actuaries
    - Institute and Faculty of Actuaries
    - International Congress of Actuaries
    - Social Sciences and Humanities Research Council (SSHRC)
    - Society of Actuaries

Contents

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

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

Contents

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

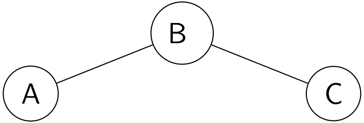
- Select a representative pension plan
  - Universities Superannuation Scheme (UK) 2014 Actuarial Valuation
  - Stylized US pension plan
  - Canadaian pension plan
- Select an economic model
  - Graphical Model [see Oberoi, et al. (2019)]
- Select a mortality model
  - M7 from Cairns, et al. (2007)
- Quantify pension risk [see Porteous, et al. (2012)]

Contents

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

Methodology - forecasting



- Assume 3 economic variables A,B and C.
- The individual economic random variables, Z_{it}s, are modelled as:

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

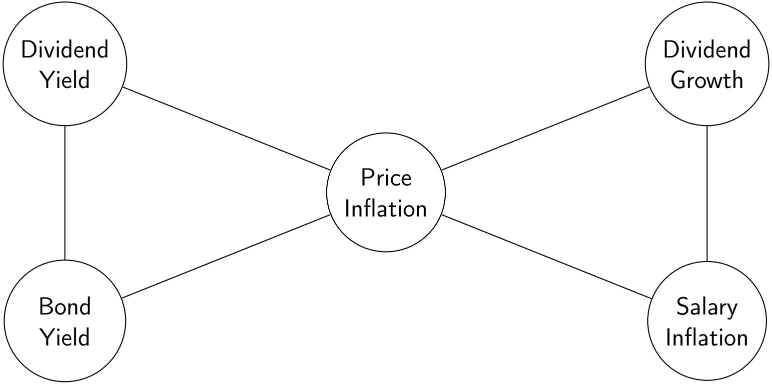
- Correlation of the **error terms** is represented by a graphical model.
- The error terms:
  - are assumed to be independently distributed across time t;
  - which are directly connected to each other are dependent;
  - which are indirectly connected are still dependent, but more weakly so.

Methodology - selecting a correlation structure

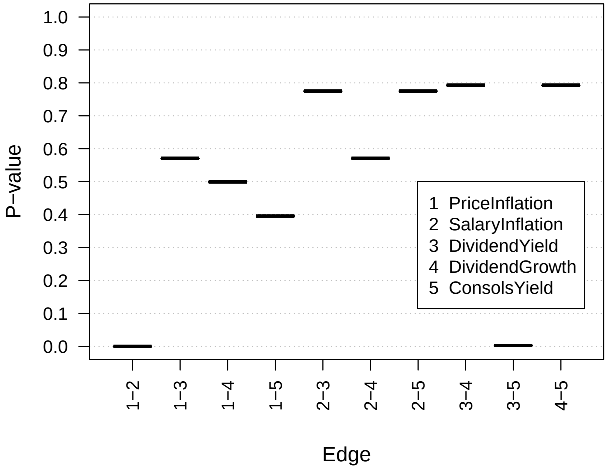
- We use simultaneous p-values to select a graphical structure.
- Hojsgaard et al. (2012). provide guidance on the use of packages written in R to estimate graphical models.
- We use the following UK and US economic time series data:
  - Price Inflation
  - Salary Inflation
  - Dividend Yield
  - Dividend Growth
  - Consols Yield

Economic Model – Graphical Model for UK

Model UK: Graphical model with 6 edges.

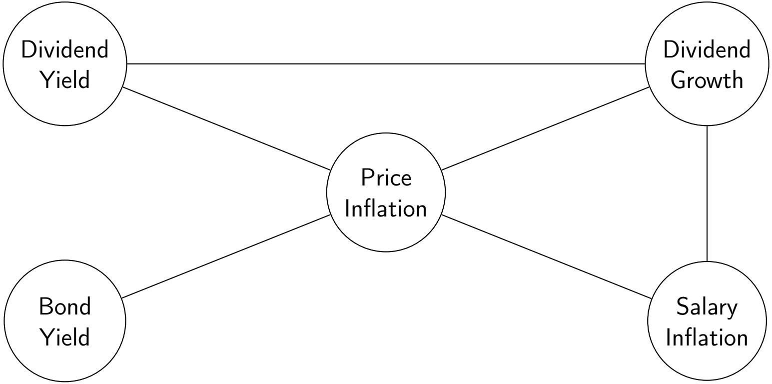


Corresponding P-Values

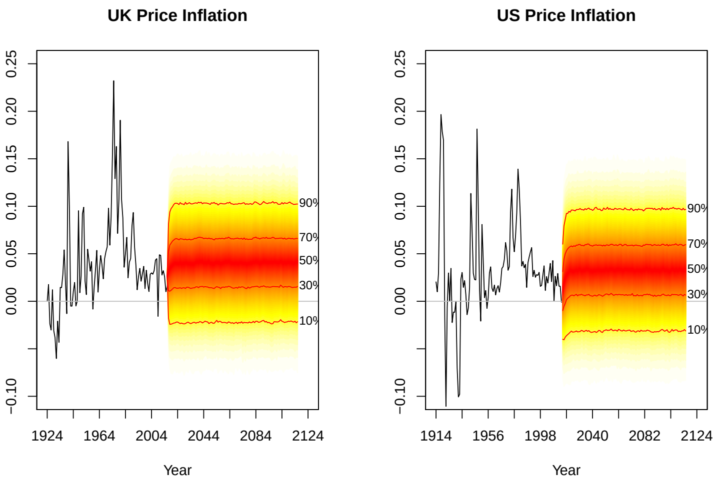


Economic Model – Graphical Model for US

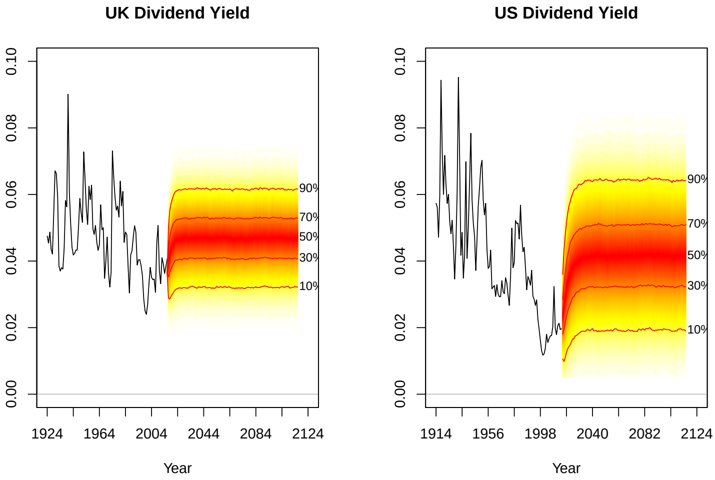
Model US: Graphical model with 6 edges.



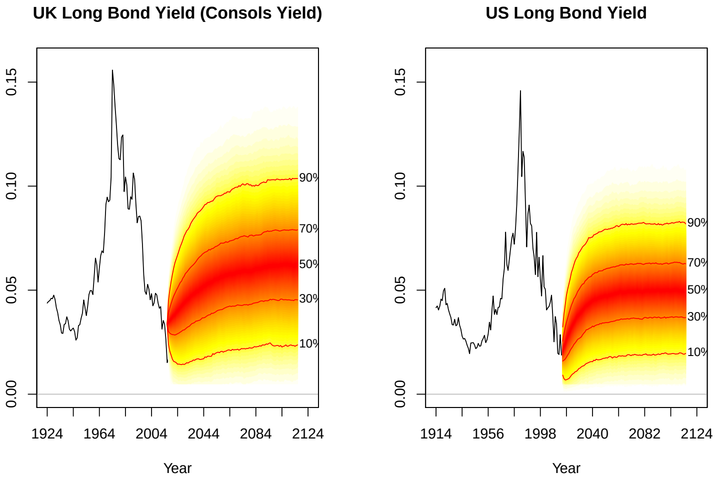
Marginal distribution – Price Inflation



Marginal distribution – Dividend Yield



Marginal distribution – Long Bond Yield



Joint distribution (1)

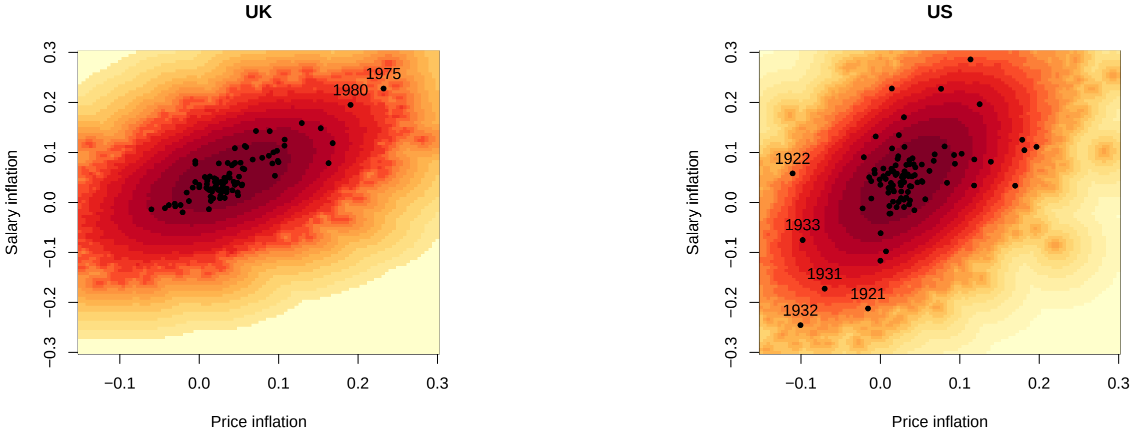


Figure: Plots of simulated price and salary inflation for UK and US.

Joint distribution (2)

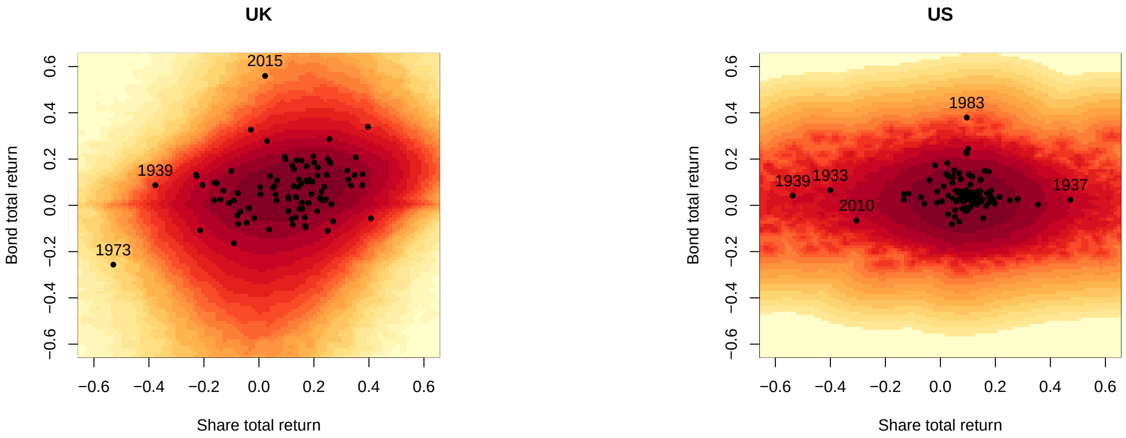


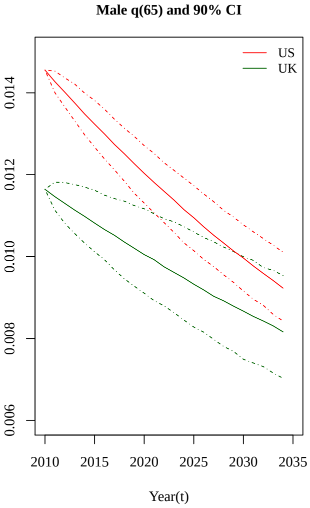
Figure: Plots of simulated share and bond returns for UK and US.

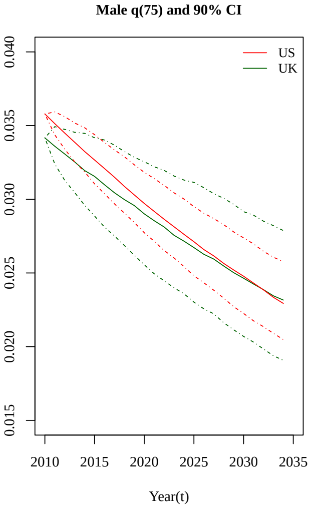
Mortality Model – M7 from Cairns, et al. (2007)

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

- 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

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

- Present value of future profits given by:

$$V_0 = \sum_{t=1}^{T} P_t D_{(0,t)}$$

Economic Capital Approach

- 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

Contents

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 $= 3 \times$ annual pension
- Pension increases based on min [CPI, 5%]
- Contribution rate: 24% of salary (8% employee + 16% employer)

USS Pension Scheme – Data

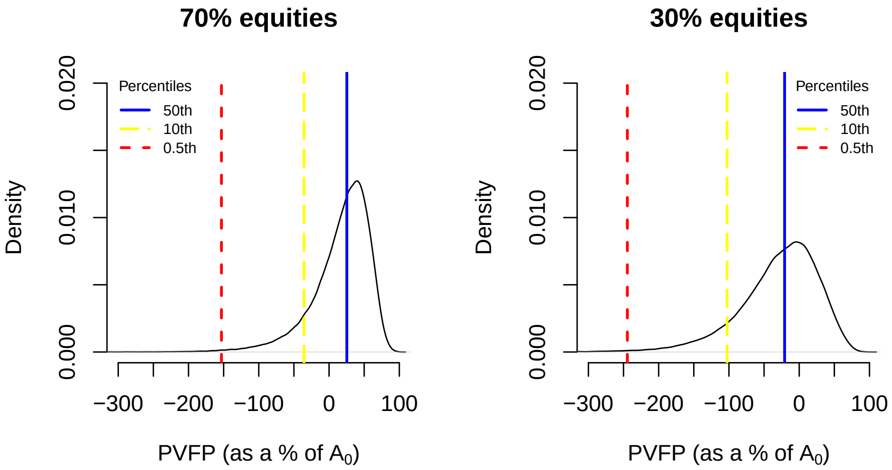
Active Members	Number	167,545
	Average pensionable salary	£42,729
	Average age	43.8
	Average past service	12.5
Deferred Members	Number	110,430
	Average deferred pension	£2,373
	Average age	45.1
Pensioners	Number	70,380
(including dependents)	Average pension	£17,079
	Average Age	71.1

USS Pension Scheme – Assets

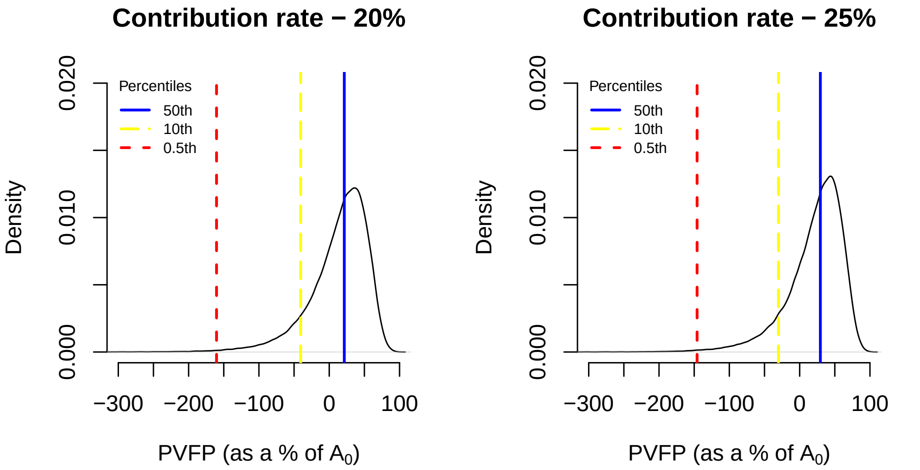
Assets	Benchmark Allocation
UK equities	16%
Overseas equities	31
Alternative assets	19
Property	7
Total real	73%
Fixed interest	27
Cash	0
Total fixed	27%

Note: Modelled as 70% Equities and 30% Bonds

USS Economic Capital – Sensitivity to Asset Allocation Strategy



USS Economic Capital – Sensitivity to Contribution Rates

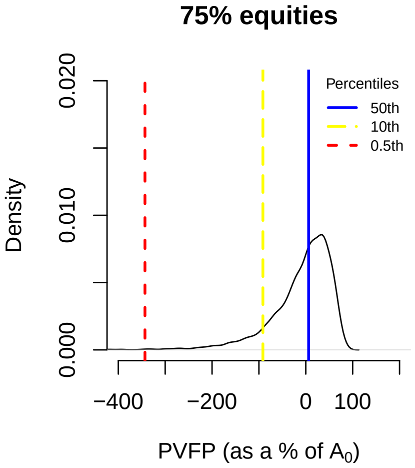


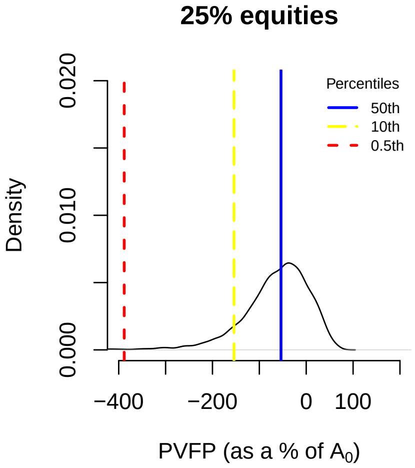
Contents

Sylized US Pension Plan – Benefits

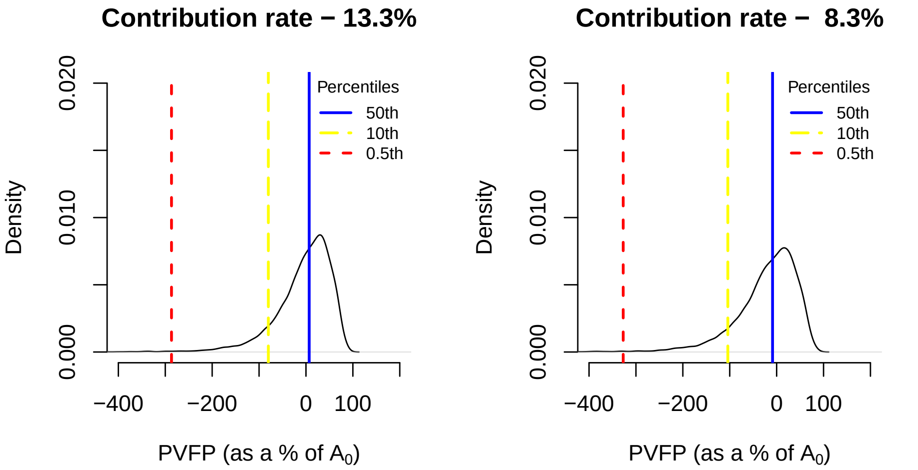
- Benefits based on USS pension scheme, except for the following
- 1.5% final average salary for all pension service
- No lump sum payment on retirement
- No pension increases
- Contribution rate: 10.8% of salary

US Stylized Plan Economic Capital – Sensitivity to Asset Allocation Strategy





US Stylized Plan Economic Capital – Sensitivity to Contribution Rate



Contents

OTPP – Benefits

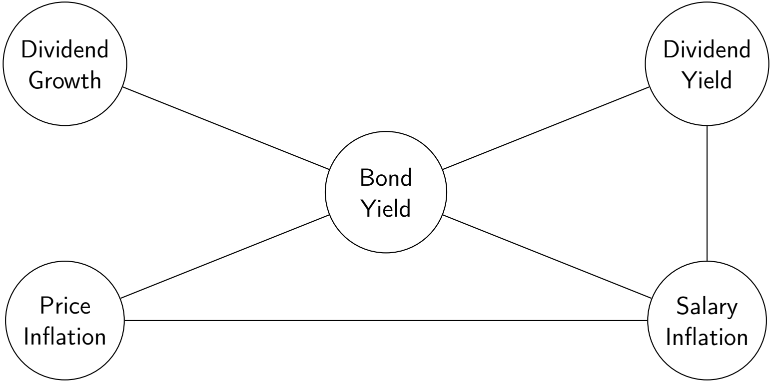
- Pension payment: 1.7% of 5-year average salary benefit
- Pension increases based on CPI
- No lump sum payment
- Contribution rate: 20.8% of salary up to YMPE and 24% for earnings exceeding YMPE.

OTPP – Data

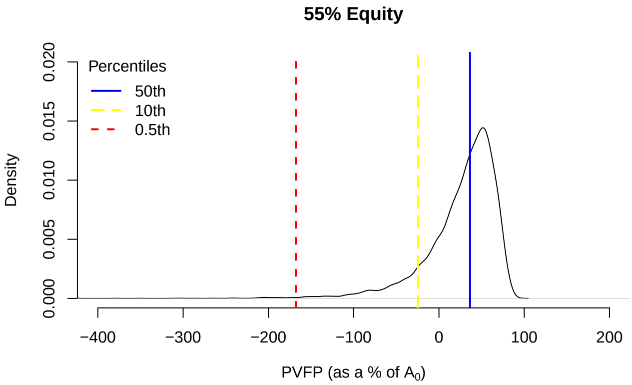
Active	Number	144,325
	Average pensionable salary	$90,468
	Average age	44.4
	Average past service	14.6
Deferred Members	Number	71,205
	Average deferred pension	$1,965
	Average age	45.1
Pensioners	Number	129,785
	Average lifetime pension	$41,154
	Average age	71.1

OTPP – Economic Model

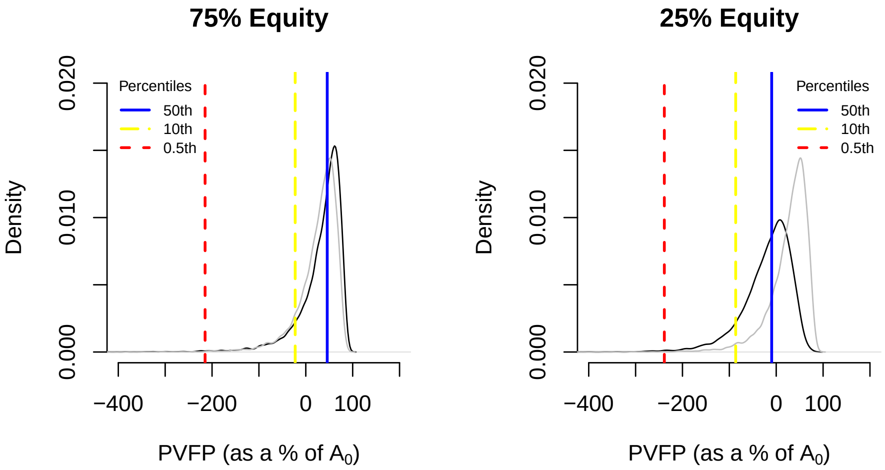
Model Canada: Graphical model with 6 edges.



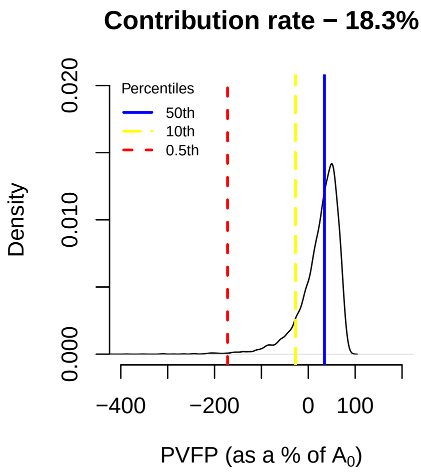
OTPP Economic Capital

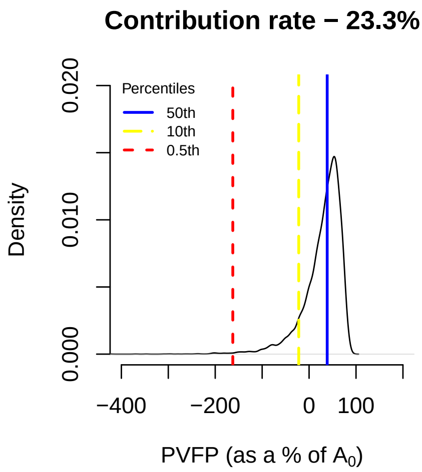


OTPP Economic Capital – Sensitivity to Asset Allocation Strategy



OTPP Economic Capital – Sensitivity to Contribution Rate





Contents

Summary

- 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

- Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., Ong, A., and Balevich, I. A quantitative comparison of stochastic mortality models using data from England and Wales and the United States. *North American Actuarial Journal* 13, no. 1: 1-35, 2009.

- Hojsgaard, S., Edwards, D. and Lauritzen, S. Graphical models with R. *Springer Science & Business Media* 2012.

- Oberoi, J., Pittea, A. and Tapadar, P. *A graphical model approach to simulating economic variables over long horizons*. To appear in Annals of Actuarial Science, 2019.

- Porteous, B.T., Tapadar, P. and Yang, W. Economic capital for defined benefit pension schemes: An application to the UK Universities Superannuation Scheme. *Journal of Pension Economics & Finance*, 11, no. 4: 471-499, 2012.