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# Measuring Pension Plan Risk from an Economic Capital Perspective

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University of Waterloo and University of Kent

May 15, 2019

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  - Canadian Institute of Actuaries
  - Institute and Faculty of Actuaries
  - International Congress of Actuaries
  - Social Sciences and Humanities Research Council (SSHRC)
  - Society of Actuaries

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- Overall Project
- Introduction to Pension Model
- Assumptions and Methodology
- UK's Universities Superannuation Scheme (USS)
- Stylized US Pension Plan
- Canadian Pension Plan
- 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

# 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)]

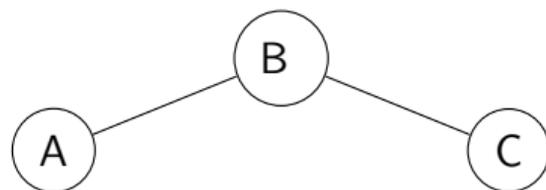
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# Graphical Model - Background

- 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

# Methodology - forecasting



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

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

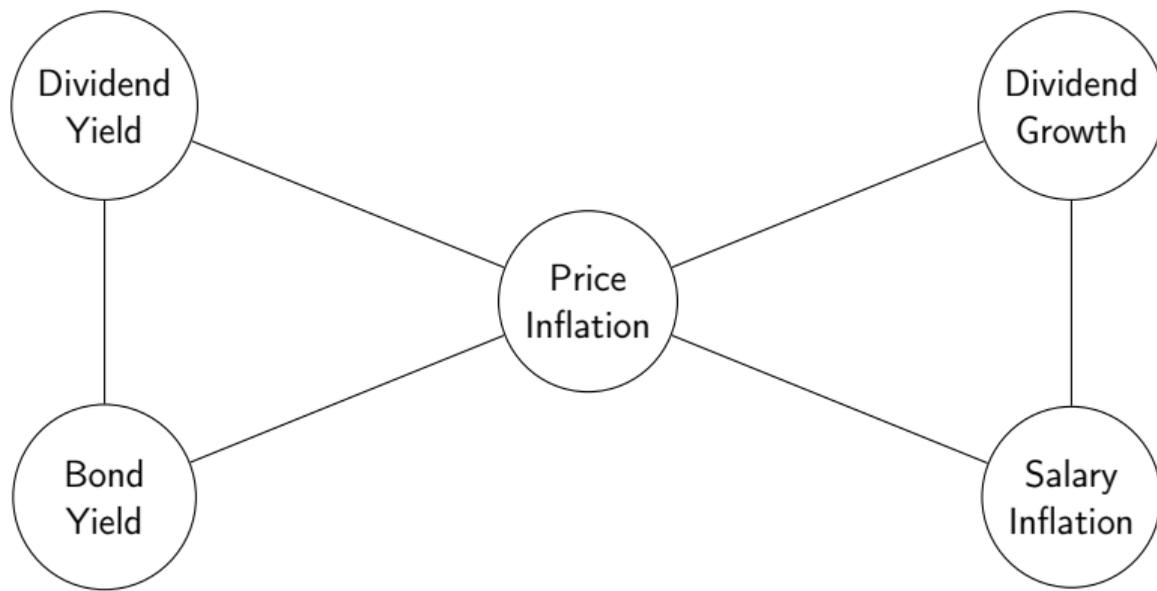
- Correlation of the **error terms** is represented by a graphical model.
- The error terms:
  - are assumed to be independently distributed across time  $t$ ;
  - which are directly connected to each other are dependent;
  - which are indirectly connected are still dependent, but more weakly so.

## Methodology - selecting a correlation structure

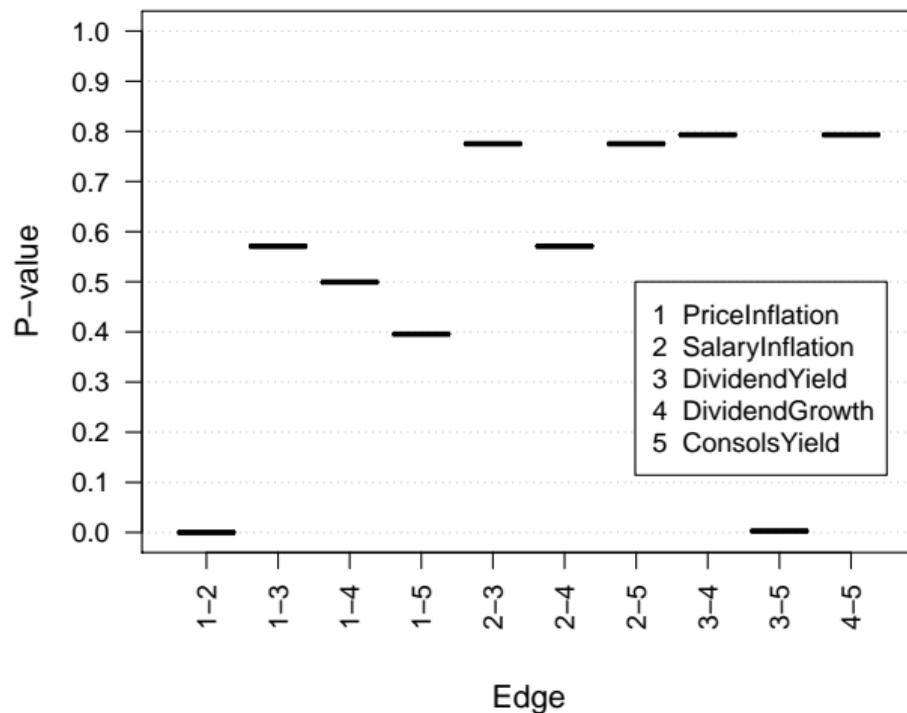
- We use simultaneous p-values to select a graphical structure.
- Hojsgaard et al. (2012). provide guidance on the use of packages written in R to estimate graphical models.
- We use the following UK and US economic time series data:
  - Price Inflation
  - Salary Inflation
  - Dividend Yield
  - Dividend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

# Economic Model – Graphical Model for UK

**Model UK:** Graphical model with 6 edges.

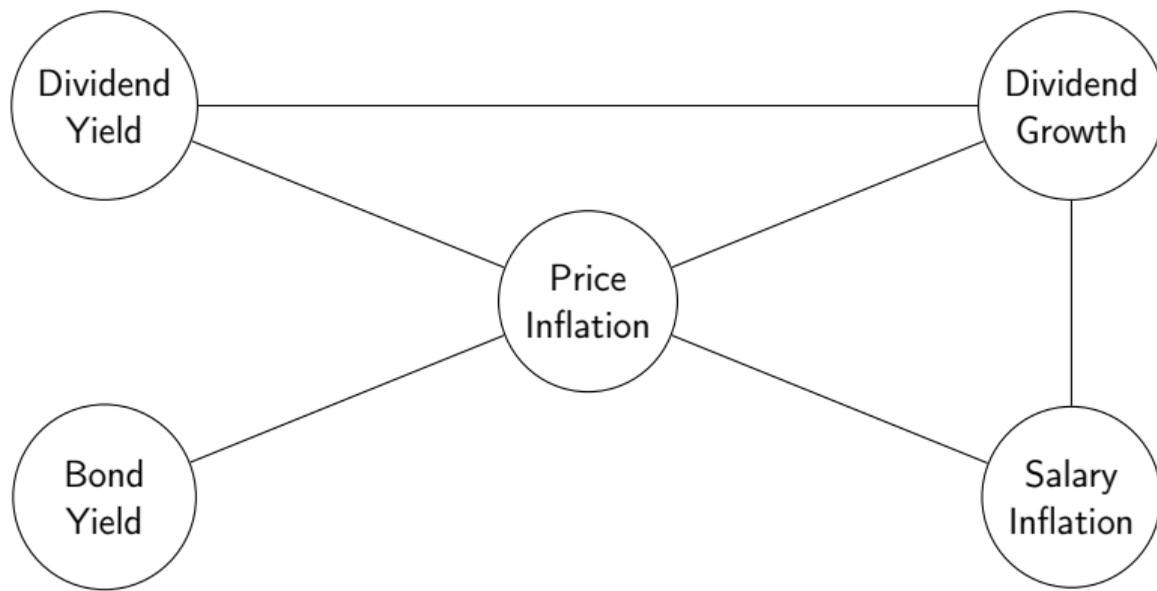


# Corresponding P-Values

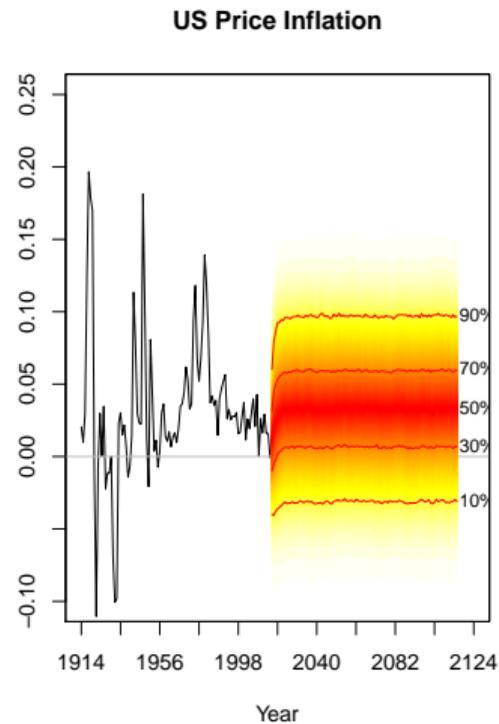
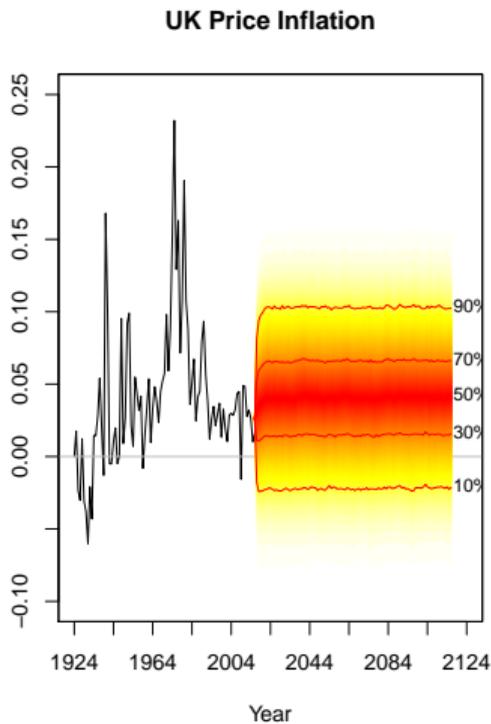


# Economic Model – Graphical Model for US

**Model US:** Graphical model with 6 edges.

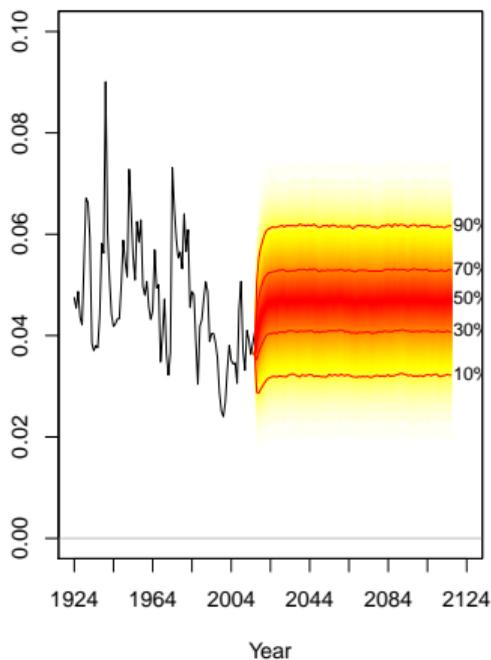


# Marginal distribution – Price Inflation

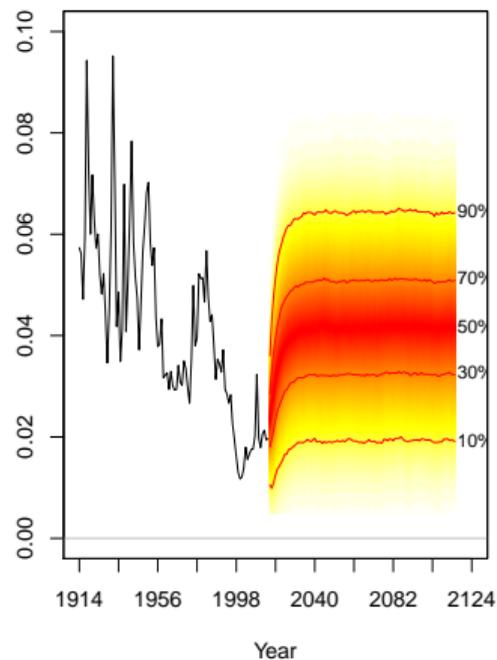


# Marginal distribution – Dividend Yield

### UK Dividend Yield

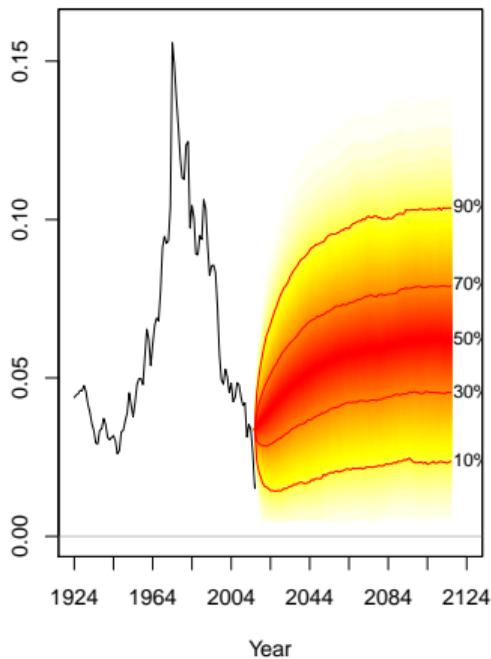


### US Dividend Yield

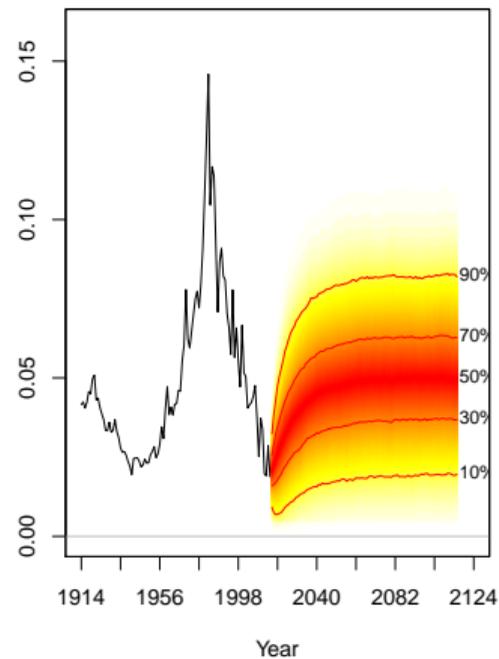


# Marginal distribution – Long Bond Yield

### UK Long Bond Yield (Consols Yield)



### US Long Bond Yield



## Joint distribution (1)

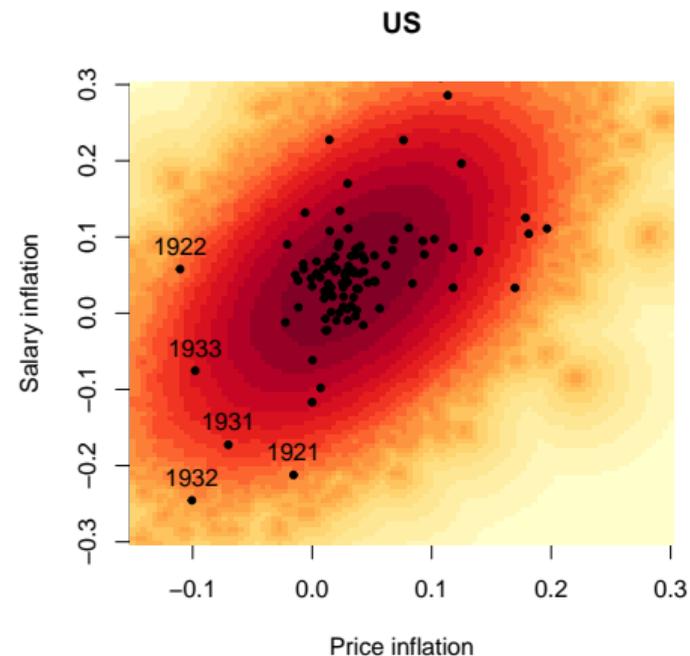
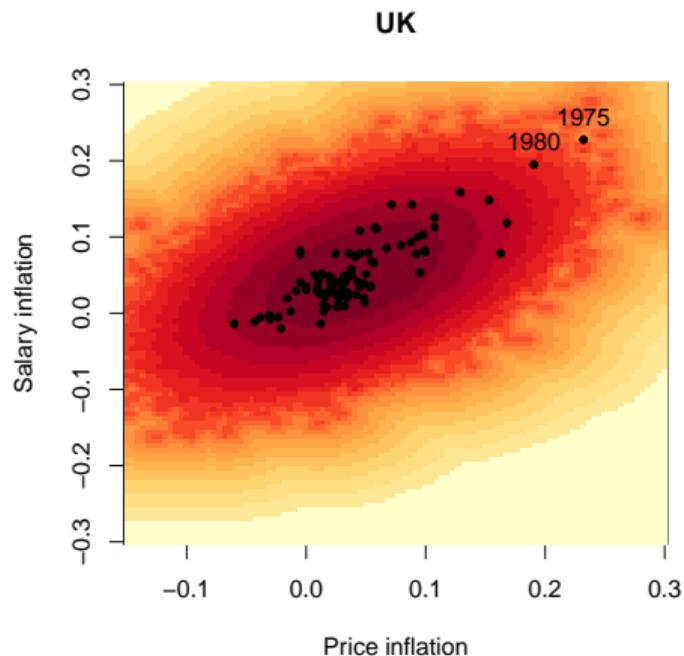


Figure: Plots of simulated price and salary inflation for UK and US.

## Joint distribution (2)

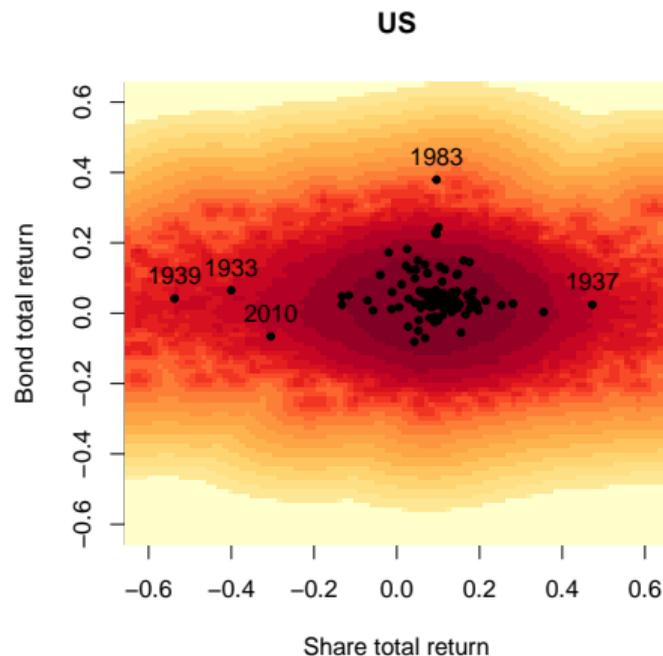
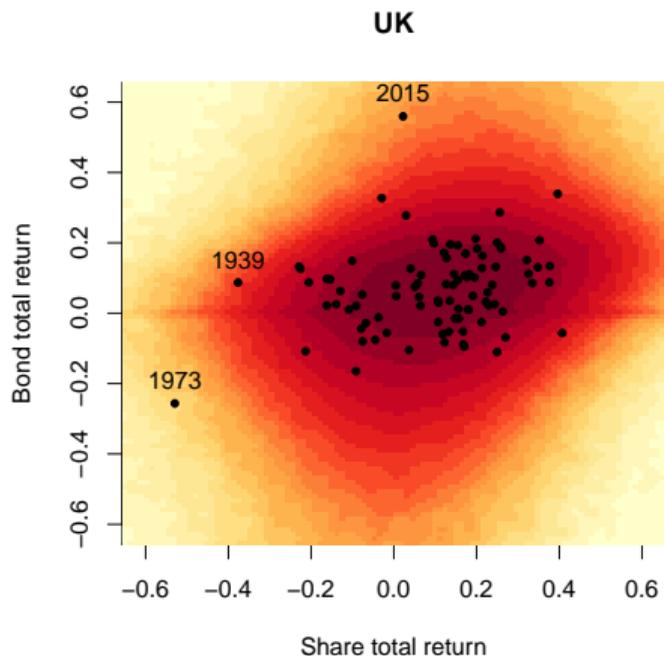


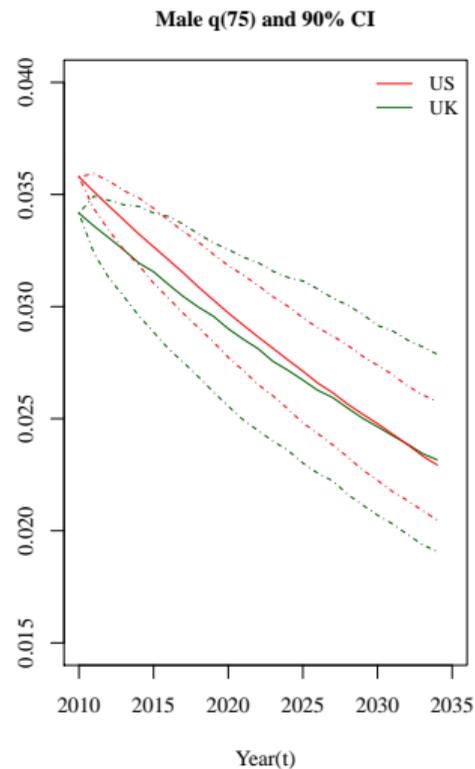
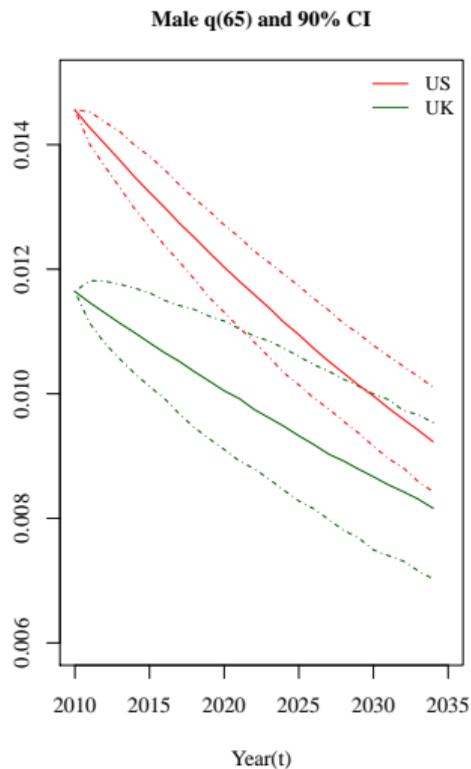
Figure: Plots of simulated share and bond returns for UK and US.

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

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

- 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

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

## USS Pension Scheme – Data

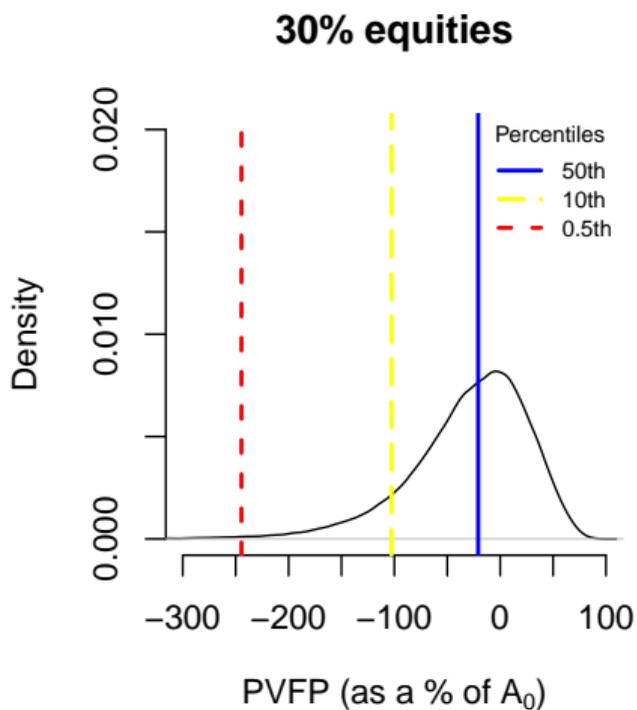
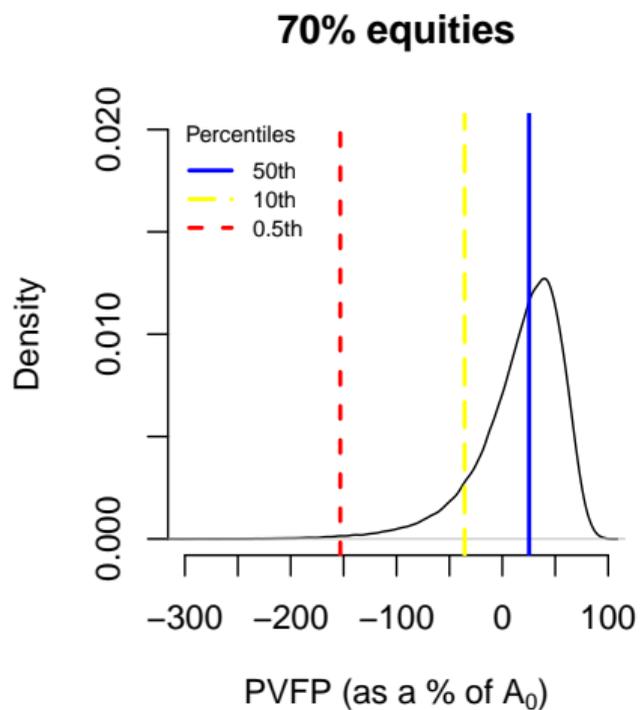
Active Members	Number	167,545
	Average pensionable salary	£42,729
	Average age	43.8
	Average past service	12.5
Deferred Members	Number	110,430
	Average deferred pension	£2,373
	Average age	45.1
Pensioners (including dependents)	Number	70,380
	Average pension	£17,079
	Average Age	71.1

## USS Pension Scheme – Assets

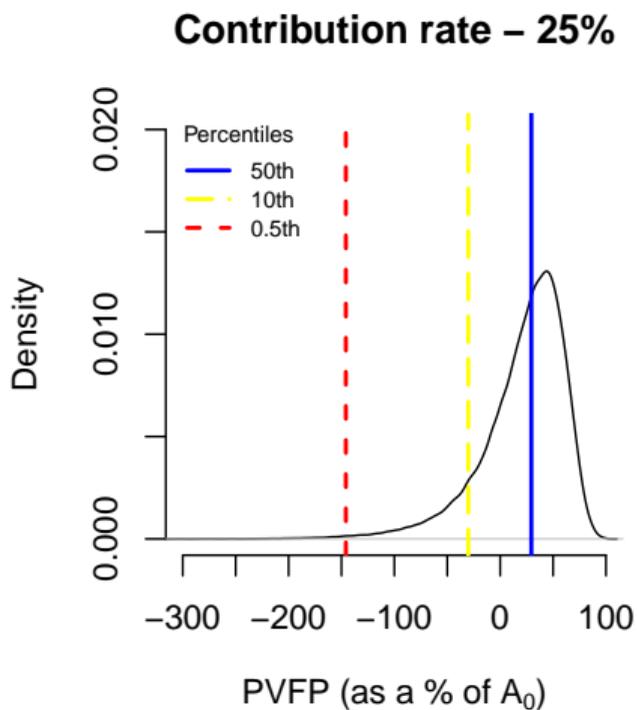
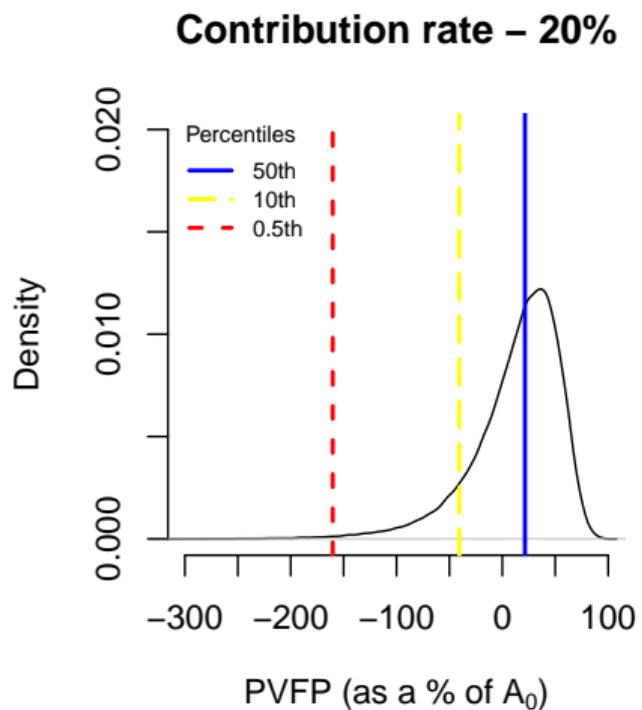
Assets	Benchmark Allocation
UK equities	16%
Overseas equities	31
Alternative assets	19
Property	7
Total real	73%
Fixed interest	27
Cash	0
Total fixed	27%

Note: Modelled as 70% Equities and 30% Bonds

## USS Economic Capital – Sensitivity to Asset Allocation Strategy



## USS Economic Capital – Sensitivity to Contribution Rates



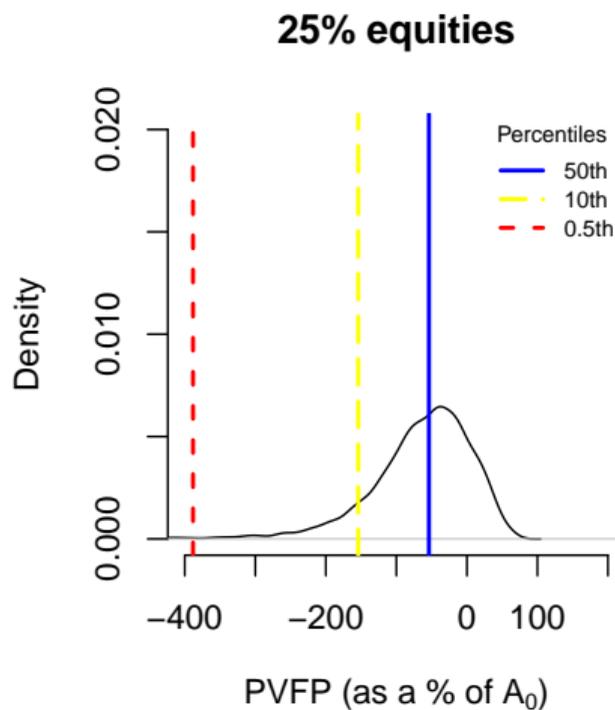
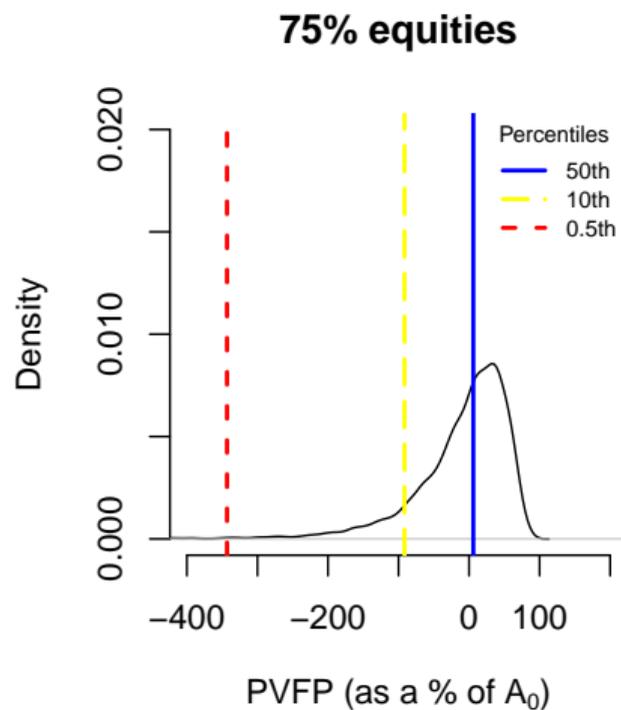
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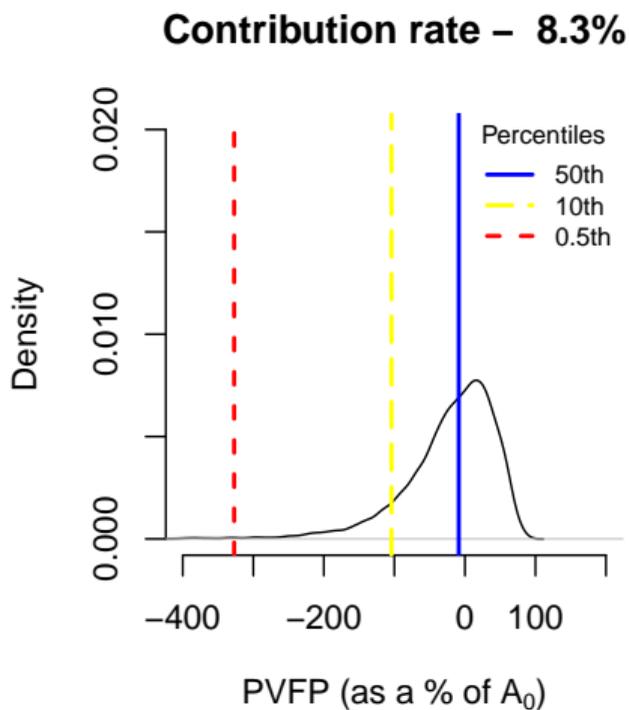
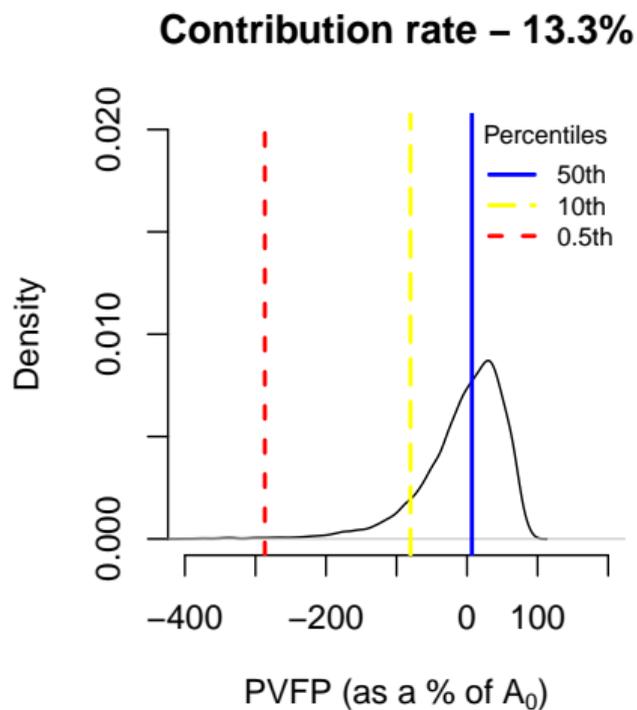
## Stylized US Pension Plan – Benefits

- 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



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# OTPP – Benefits

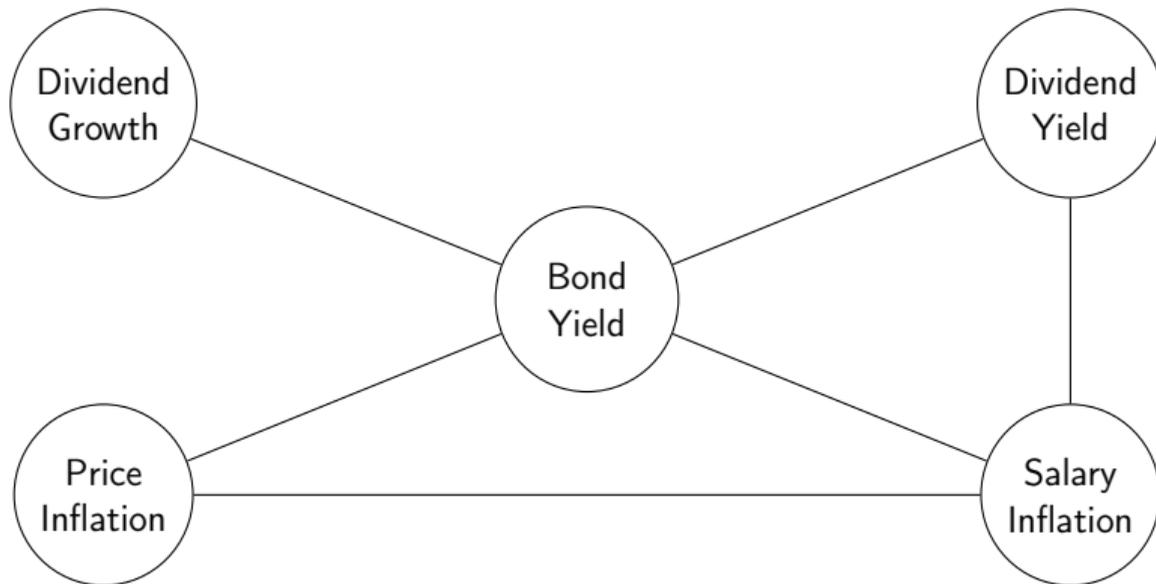
- Pension payment: 1.7% of 5-year average salary benefit
- Pension increases based on CPI
- No lump sum payment
- Contribution rate: 20.8% of salary up to YMPE and 24% for earnings exceeding YMPE.

## OTPP – Data

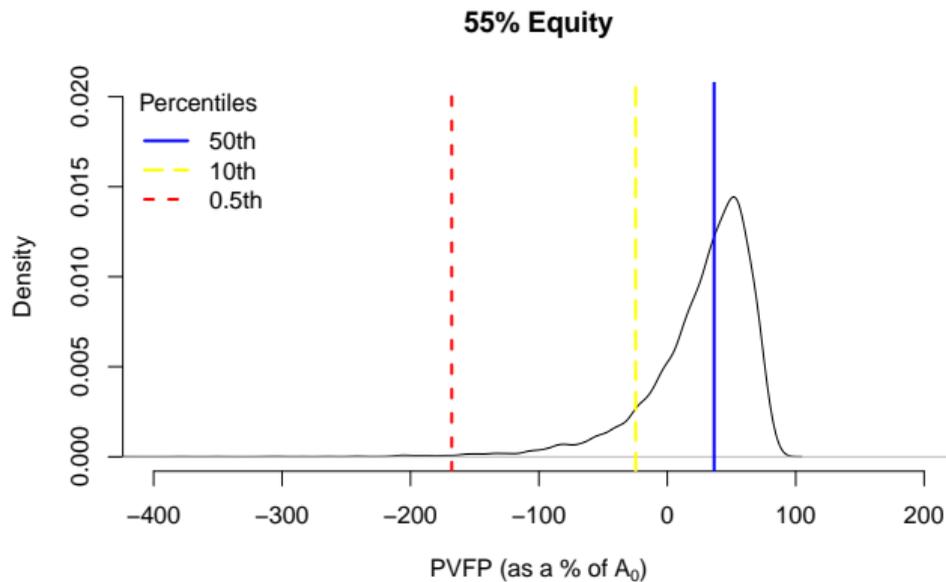
Active	Number	144,325
	Average pensionable salary	\$90,468
	Average age	44.4
	Average past service	14.6
Deferred Members	Number	71,205
	Average deferred pension	\$1,965
	Average age	45.1
Pensioners	Number	129,785
	Average lifetime pension	\$41,154
	Average age	71.1

## OTPP – Economic Model

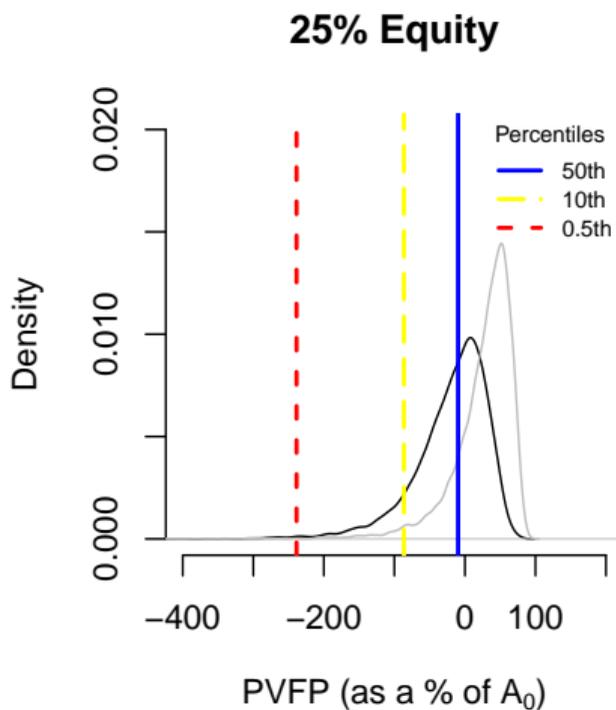
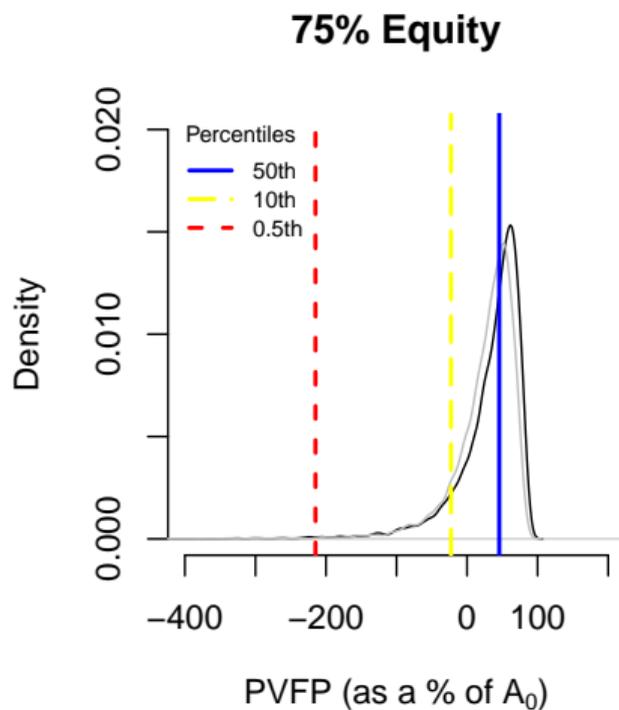
**Model Canada:** Graphical model with 6 edges.



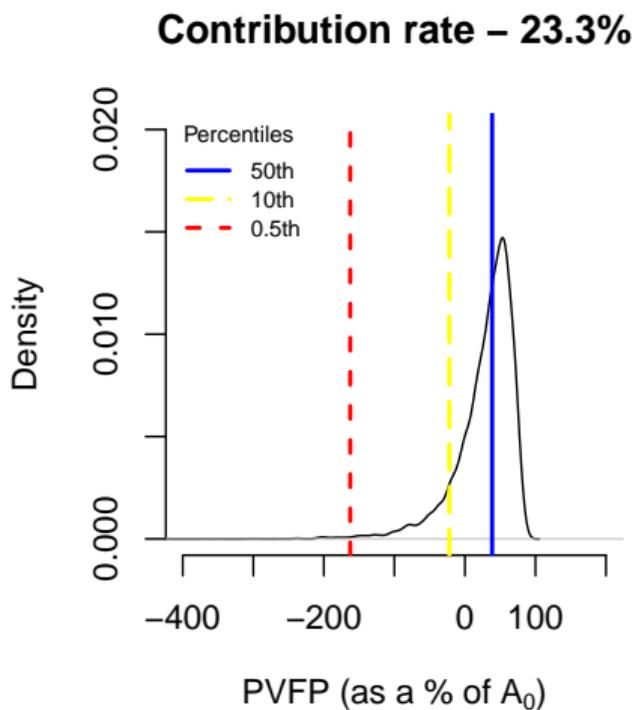
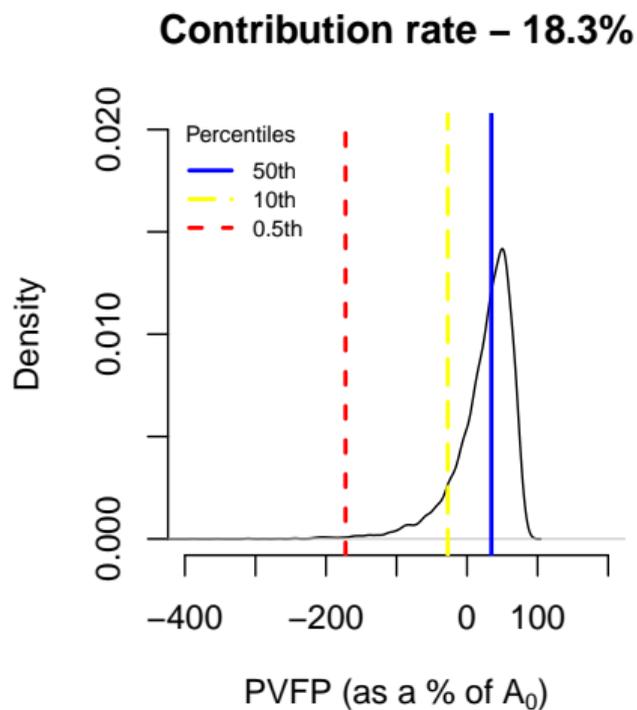
## OTPP Economic Capital



## OTPP Economic Capital – Sensitivity to Asset Allocation Strategy



## OTPP Economic Capital – Sensitivity to Contribution Rate



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# 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

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