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### A Tale of Two Pension Plans

Measuring Pension Plan Risk from an Economic Capital Perspective

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Co-authors: Douglas Andrews, Stephen Bonnar, Lori J. Curtis, Jaideep S. Oberoi, Aniketh Pittea.

#### Longevity 15 Conference, September 2019

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This research is part of a larger project funded by the CIA, IFoA, SoA, SSHRC, University of Kent and University of Waterloo.

- Introduction
- Stochastic models
- Model assumptions
- Results
- Conclusions

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### Background

- Years of high inflation and good investment returns during the 1970s and 1980s created the illusion that DB pension plans are easily affordable.
- Over the past decade or more, increasing life expectancy and steady fall in interest rates have meant that pension costs have increased.
- Regulatory developments: Basel 2/3, Solvency 2, Pensions Regulations.

#### **Objective:**

Quantify pension plan risk from an economic capital perspective for:

- a UK pension plan: Universities Superannuation Scheme (USS); and
- a stylised US plan, with the same membership profile as USS but with plan provisions modified to reflect a typical US DB plan.

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# Risk Measurement Framework: Economic Capital

#### **Economic Capital**

The economic capital of a pension plan is the proportion by which its existing assets would need to be augmented in order to meet net benefit obligations (in respect of current plan members) with a prescribed degree of confidence.

Notations:

- $A_t$ : Value of pension plan assets at time t;
- $L_t$ : Value of pension plan liabilities at time t;
- $X_t$ : Net cash flow at time t (excluding investment returns);
- $I_{(s,t)}$ : Accumulated value at time t of \$1 invested at time s;

 $D_{(s,t)}$ : Discount factor, i.e.  $D_{(s,t)} = I_{(s,t)}^{-1}$ .

Introduction

### Risk Measurement Framework: Formulation

Assuming annual cashflows and valuations, any surplus or deficit is given by:

Profit Vector:  $P_t = L_{t-1}I_{(t-1,t)} - X_t - L_t$ , with  $P_0 = A_0 - X_0 - L_0$ .

Over a time horizon of *T* years, the present value of future profits (PVFP):

$$V_0 = \sum_{t=0}^{I} P_t D_{(0,t)}.$$

Given the long-term nature of pension plan risks, we propose a run-off approach (i.e. until the last of the current plan members dies), so that  $L_T = 0$ . Under this assumption:

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

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Longevity 15 5/28

### Risk Measurement Framework: Risk Measures

Standardisation to account for currency and scale:

$$V_0^\star = \frac{V_0}{A_0},$$

4 interpreted as the proportional increase in assets required to meet all future benefit obligations.

Based on  $V_0^*$ , economic capital can be quantified as either:

- Value-at-Risk (VaR) defined as  $P[V_0^* \le VaR] = p$ ; or
- Expected shortfall (ES) defined as  $E[V_0^* | V_0^* \le VaR];$

for a given probability *p*.

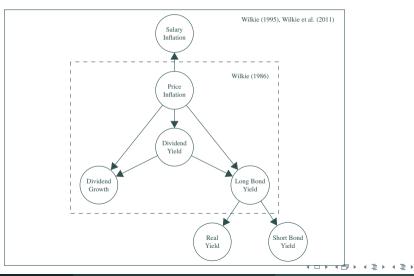
 $\downarrow$  In our results, we will show entire distributions of  $V_0^{\star}$ ,

4 highlighting the following percentiles:  $50^{th}$  (median),  $10^{th}$  and  $0.5^{th}$ .

- Introduction
- Stochastic models
- Model assumptions
- Results
- Conclusions

Stochastic models

### Economic Scenario Generator: Wilkie Model (UK only)

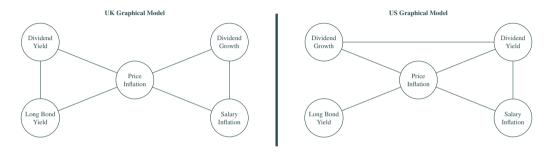


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#### A tale of two pension plans

Stochastic models

# Economic Scenario Generator: Graphical Model (both UK and US)



The individual economic random variables,  $Z_{it}$ s, are modelled as:

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

The error terms

- which are directly connected to each other are dependent;
- which are indirectly connected are still dependent, but more weakly so. (Oberoi et al. (2019))

## Stochastic Mortality Model

We use model M7 of Cairns et al. (2009):

logit 
$$q(t,x) = \kappa_t^{(1)} + \kappa_t^{(2)} (x - \bar{x}) + \kappa_t^{(3)} [(x - \bar{x})^2 - \sigma_x^2] + \gamma_{t-x}^{(4)}$$
, where

- q(t, x) is the probability that an individual aged x at time t will die within a year; •  $r^{(i)}$  is period effect:
- $\kappa_t^{(i)}$  is period effect;
- $\gamma_{t-x}^{(i)}$  is cohort effect.

The model is parameterised using

- data from Human Mortality Database;
- for both UK and US;
- for both males and females;
- for years 1961 2014;
- for ages 30 100.

- Introduction
- Stochastic models
- Model assumptions
- Results
- Conclusions

# Membership Profile: Model Points

Table: USS membership profile as at March 31, 2014 (USS 2014 valuation report).

Age	Number	Accrued service/benefit
30	50,264	7 years past service
40	50,264	11 years past service
50	33,509	15 years past service
60	33,509	19 years past service
45	110,430	Accrued pension of £2,373 per year
71	70,380	Accrued pension of £17,079 per year
	30 40 50 60 45	30     50,264       40     50,264       50     33,509       60     33,509       45     110,430

Other assumptions:

- 50:50 gender split.
- Promotional salary scale, withdrawal rates and proportion married assumptions are as provided in the valuation report.

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### **Retirement Benefits**

#### USS

Annual Pension = Pensionable salary  $\times$  Pensionable service  $\times$  Accrual rate; Cash lump sum = 3  $\times$  Annual pension.

#### Simplified modelling approach:

- Until 2014, accrual rate of 1.25% on a final salary basis.
- Post 2014, accrual rate of 1.33% on a career revalued benefits basis.
- Annual pension increase in line with inflation.

### Stylised US plan

- Accrual rate of 1.5% on a final salary basis.
- No cash lump sum on retirement.
- No indexation of pension during the payment period.

### Withdrawal Benefits

### USS

- Deferred inflation-linked pension benefits are provided based on accrued service on withdrawal.
- Inflation indexation of salaries between the date of leaving and retirement is provided.

### Stylised US plan

- A deferred pension, without any indexation, is provided based on accrued service on withdrawal.
- There is no indexation during the payment period.

### **Death Benefits**

### USS

#### On death of an active member

- Lump sum payment of 3 times the annual salary is paid on death.
- A spouse's pension of half the amount of pension the member would have received if survived till retirement.

On death of a pensioner, a spouse's pension of half the member's pension is payable.

### Stylised US plan

On death of an active member

• Lump sum equal to the present value of the pension the member would have received if survived till retirement.

On death of a pensioner, a spouse's pension of half the member's pension is payable.

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### Contributions, Assets and Liabilities

	USS	Stylised US plan
Contributions	22.5% of salary	10.8% of salary
Assets	£41.6b	\$ 26.1b
Liabilities	£46.9b	\$ 32.6b

Asset allocation:

- USS: 70% equities and 30% bonds.
- Stylised US plan: 50% equities and 50% bonds.

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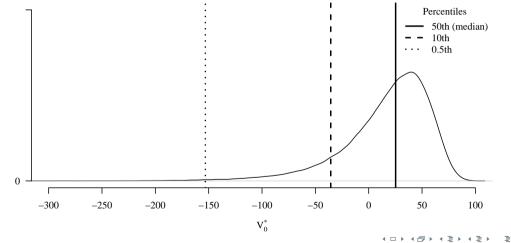
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- Introduction 0
- Stochastic models •
- Model assumptions •
- Results
  - UK's USS
  - Stylised US plan
- Conclusions

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### USS: Base Case Graphical Model

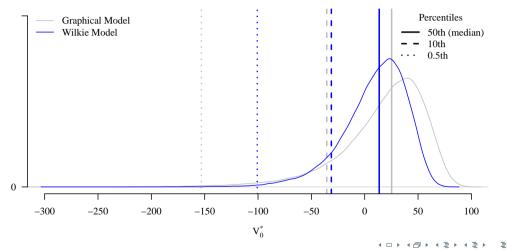


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Density

Longevity 15 18/28

### USS: Base Case Wilkie Model



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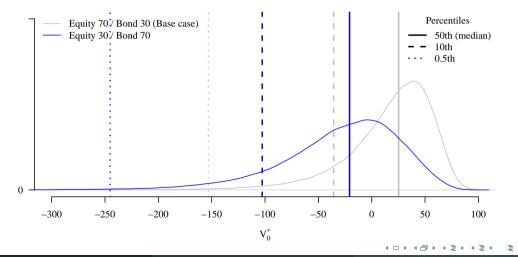
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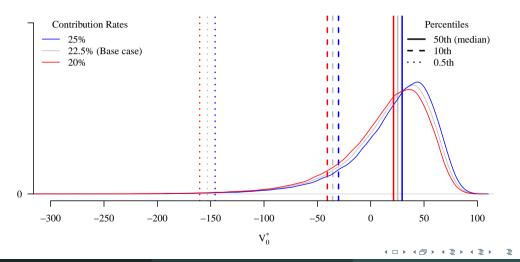
### USS: Sensitivity to Asset Allocation (Graphical Model)



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Results UK's USS

### USS: Sensitivity to Contribution Rates (Graphical Model)



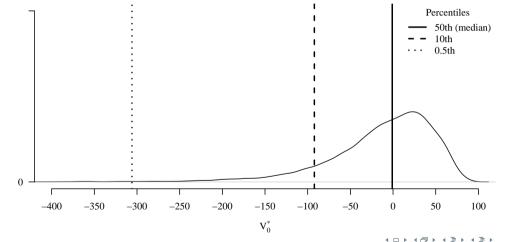
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- Introduction 0
- Stochastic models •
- Model assumptions •
- Results
  - UK's USS
  - Stylised US plan
- Conclusions

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Results

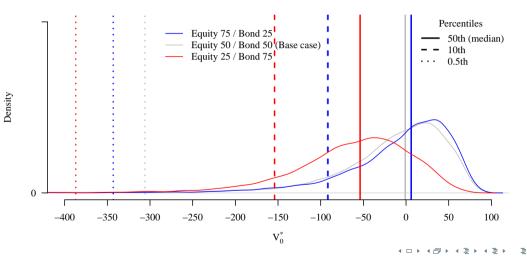
### Stylised US Plan: Base Case Graphical Model (With Amortisation)



Density

Results Stylised US plan

### Styled US Plan: Sensitivity to Asset Allocation (Graphical Model)

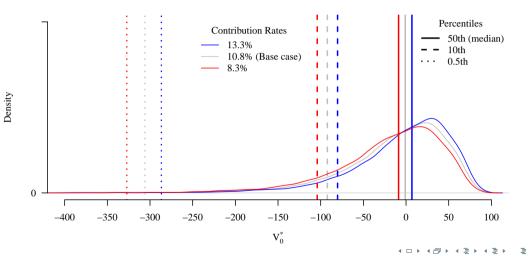


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Longevity 15 24/28

Results Stylised US plan

### Styled US Plan: Sensitivity to Contribution Rates (Graphical Model)



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Longevity 15 25/28

- Introduction
- Stochastic models
- Model assumptions
- Results
- Conclusions

### Conclusions

- Range of results is very wide this is a function of using the long run-off approach.
- Impact of changes in asset allocation is much larger than for changes to plan contributions.
- As a percentage of starting assets, stylised US plan is more volatile than the USS plan.
- Benefits of greater bond investment is greater for the stylised US plan than for USS.

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#### Conclusions

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