A Tale of Two Pension Plans

Measuring Pension Plan Risk from an Economic Capital Perspective

Pradip Tapadar

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

Longevity 15 Conference, September 2019

Acknowledgement: SoA has provided a grant to support my attendance at this conference.

The formal report was prepared as part of a project funded by the SoA's Retirement Section Research Committee.

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

Agenda

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

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:

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

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. $D_{(s,t)} = I_{(s,t)}^{-1}$.

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):

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

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:

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

Risk Measurement Framework: Risk Measures

Standardisation to account for currency and scale:

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

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

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

- Value-at-Risk (VaR) defined as $\mathrm{P}\left[V_0^\star \leq VaR\right] = p$; or
- Expected shortfall (ES) defined as $\mathrm{E}\left[V_0^\star \mid V_0^\star \leq VaR\right]$;

for a given probability p.

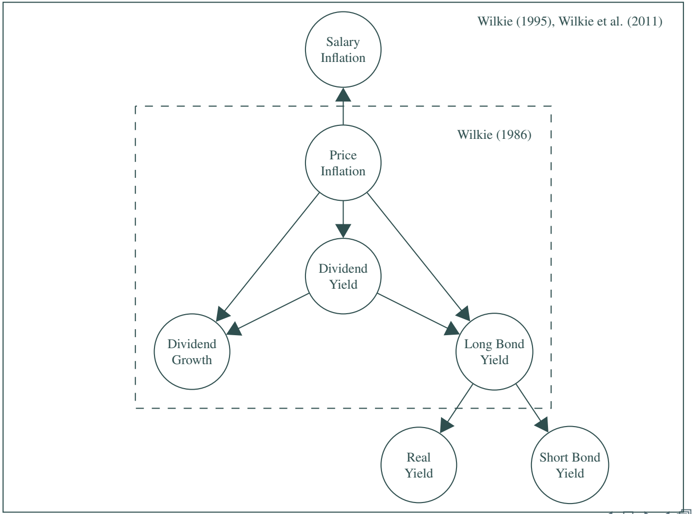
↳ In our results, we will show entire distributions of $V_0^\star$,

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

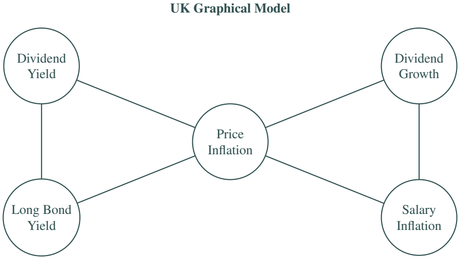
Agenda

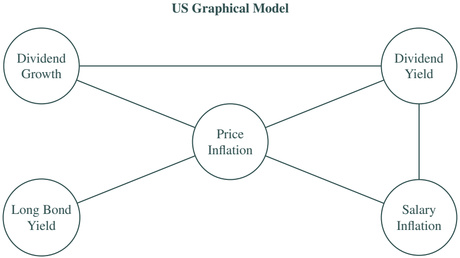
- Introduction
- **Stochastic models**
- Model assumptions
- Results
- Conclusions

Economic Scenario Generator: Wilkie Model (UK only)



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





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

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

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):

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

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

Agenda

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

Membership Profile: Model Points

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

Membership types	Age	Number	Accrued service/benefit
Active	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
Deferred	45	110,430	Accrued pension of £2,373 per year
Pensioner	71	70,380	Accrued pension of £17,079 per year

Other assumptions:

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

Retirement Benefits

USS

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

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.

Contributions, Assets and Liabilities

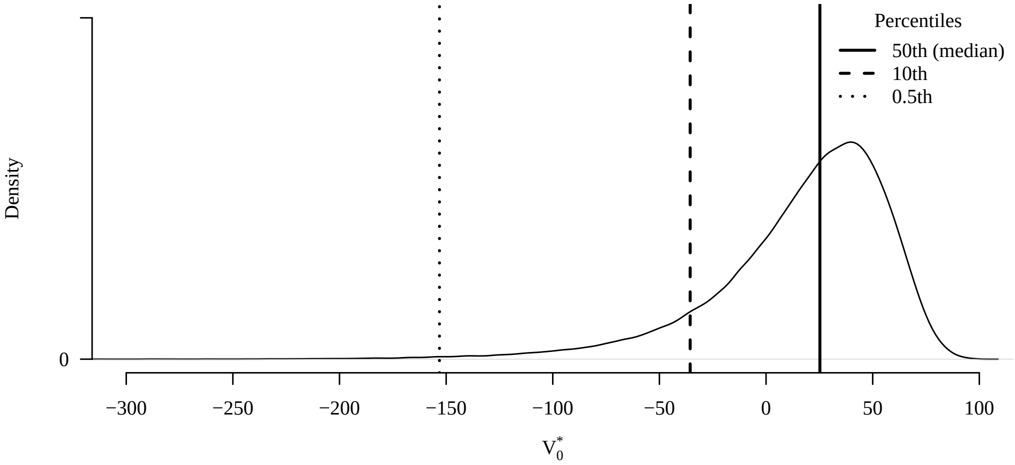
	USS	Stylised US plan
Contributions	22.5% of salary	10.8% of salary
Assets	£41.6b	\$ 26.1b
Liabilities	£46.9b	\$ 32.6b

Asset allocation:

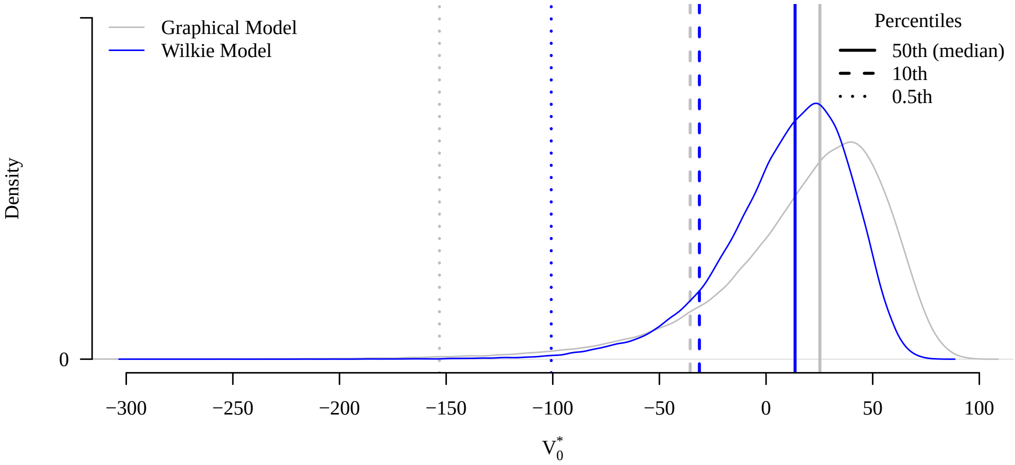
- USS: 70% equities and 30% bonds.
- Stylised US plan: 50% equities and 50% bonds.

Agenda

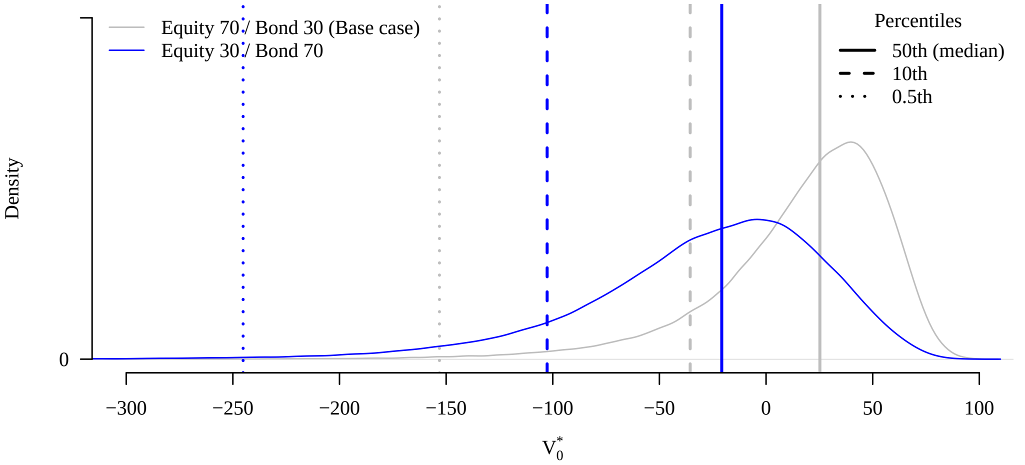
USS: Base Case Graphical Model



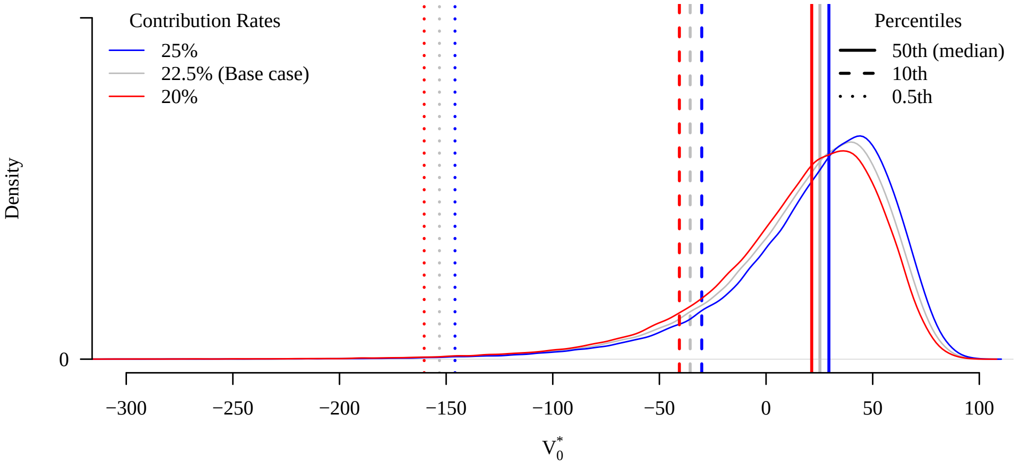
USS: Base Case Wilkie Model



USS: Sensitivity to Asset Allocation (Graphical Model)

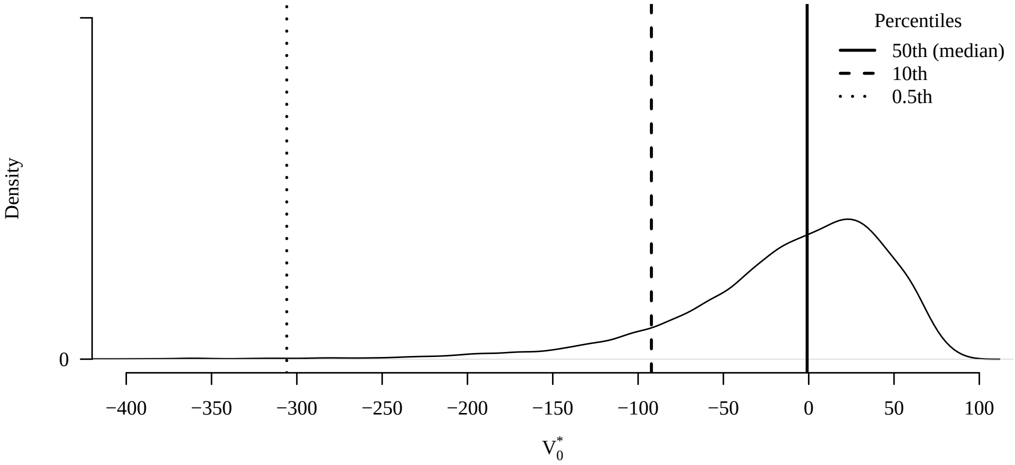


USS: Sensitivity to Contribution Rates (Graphical Model)

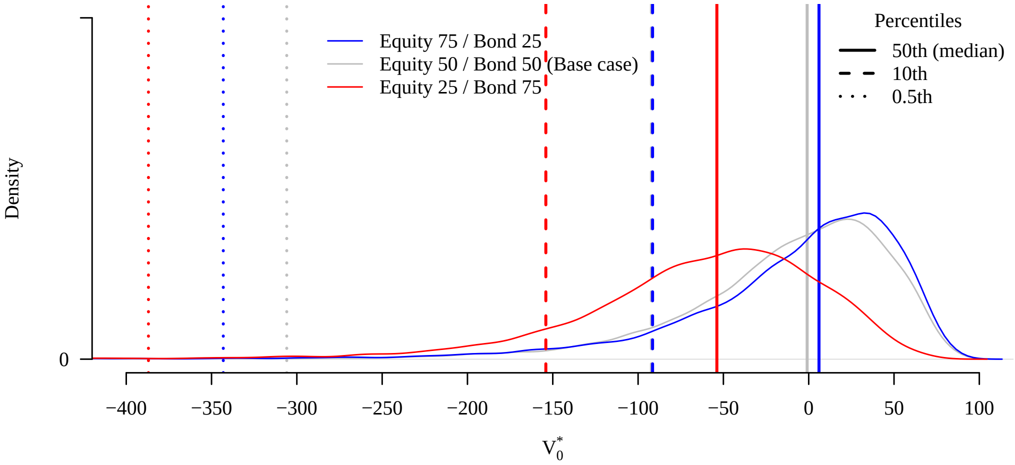


Agenda

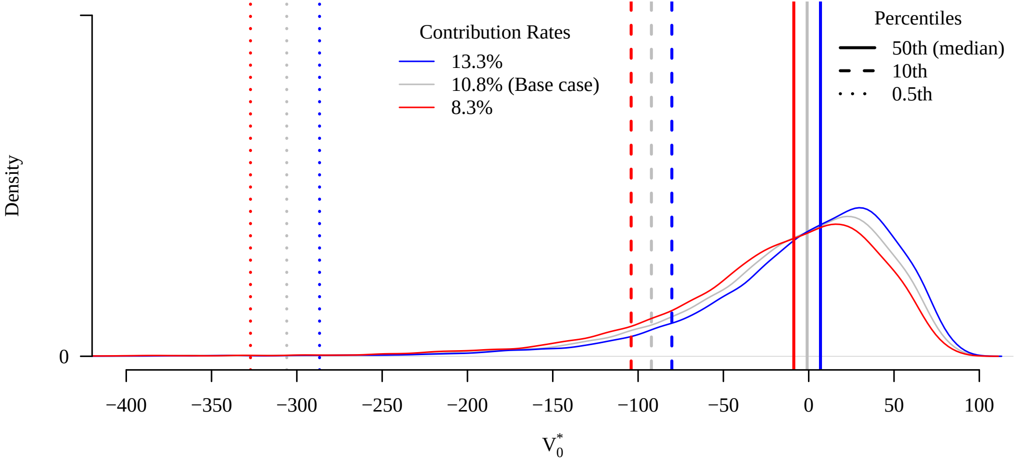
Stylised US Plan: Base Case Graphical Model (With Amortisation)



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



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



Agenda

- 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.

References

- ANDREWS, D., BONNAR, S., CURTIS, L.J., OBEROI, J. S., PITTEA, A. & TAPADAR, P. (2019). A tale of two pension plans: Measuring pension plan risk from an economic capital perspective. *Forthcoming*.
- 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)**, 1–35.
- OBEROI, J.S., PITTEA, A., & TAPADAR, P. (2019). A graphical model approach to simulating economic variables over long horizons. *Annals of Actuarial Science*, **doi:10.1017/S1748499519000022**, 1–22.
- PORTEOUS, B.T., TAPADAR, P. & YANG, W. (2012). Economic capital for defined benefit pension schemes: An application to the UK Universities Superannuation Scheme. *Journal of Pension Economics and Finance*, **11(4)**, 471–499.
- WILKIE, A.D. (1986). A Stochastic Asset Model for Actuarial Use. *Transactions of the Faculty of Actuaries*, **39**, 341–403.
- WILKIE, A.D. (1995). More on a Stochastic Asset Model for Actuarial Use. *British Actuarial Journal*, **5**, 777–964.
- WILKIE, A.D., SAHIN, S., CAIRNS, A.J.G. & KLEINOW, T. (2011). Yet more on a Stochastic Asset Model: Part 1: Updating and Refitting, 1995 to 2009. *Annals of Actuarial Science*, **5(1)**, 53–99.
- YANG, W. & TAPADAR, P. (2015). Role of the Pension Protection Fund in Financial Risk Management of UK Defined Benefit Pension Sector: A Multi-period Economic Capital Study. *Annals of Actuarial Science*, **9**, 134–166.