

# Impact of the Choice of Risk Assessment Time Horizons on Defined Benefit Pension Schemes

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# Agenda

- Introduction
- Risk measurement framework
- Stochastic models
- Scheme profile
- Results
- Conclusions

# Background

- Years of high inflation and good investment returns during the 1970s and 1980s created the illusion that DB pension schemes 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:

- ① Quantify DB pension scheme risk from an economic capital perspective.
- ② Ascertain the impact of choice of risk assessment time horizons on DB pension schemes.

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# Economic capital

## Economic Capital

Economic capital of a pension scheme is the proportion by which its existing assets would need to be augmented in order to meet net benefit obligations with a prescribed degree of confidence.

A pension scheme's net benefit obligations are all obligations in respect of current scheme members, including future service, net of future contributions to the scheme.

Notations:

$A_t$ : Value of pension scheme assets at time  $t$ ;

$L_t$ : Value of pension scheme 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.  $D_{(s,t)} = I_{(s,t)}^{-1}$ .

# 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):

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

**Time horizons considered in this research:**

Long term run-off approach:  $V_0^{(\infty)} = A_0 - \sum_{t=0}^{\infty} X_t D_{(0,t)}$ , as  $L_{\infty} = 0$ .

Short term 3-year time horizon:  $V_0^{(3)} = A_0 - \sum_{t=0}^3 X_t D_{(0,t)} - L_3 D_{(0,3)}$ .

# Risk measures

Standardisation to account for currency and scale:

$V_0^{(T)}$  expressed as a percentage of initial assets  $A_0$ .

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

Using  $V_0^{(T)}$ , for a given probability  $p$ , economic capital can be quantified as:

- **Value-at-Risk (VaR)** defined as:  $P \left[ V_0^{(T)} \leq VaR \right] = p$ .
- **Expected shortfall (ES)** defined as:  $E \left[ V_0^{(T)} \mid V_0^{(T)} \leq VaR \right]$ .

↳ In our results, we will show entire distributions of  $V_0^{(T)}$ ,

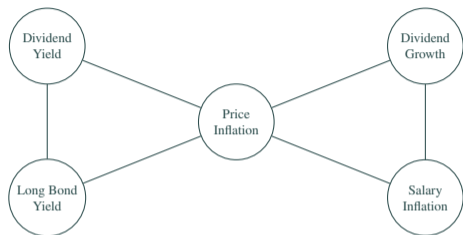
↳ highlighting the following percentiles: 50<sup>th</sup> (median) and 10<sup>th</sup>.

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# Economic scenario generator: Graphical model



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

$$\mu_x = \mathbb{E} [X_t], \quad (\text{i.e. averaging over time});$$

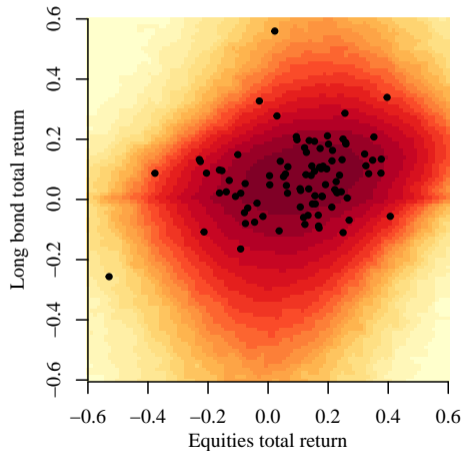
$$Z_t = X_t - \mu_x, \quad \text{for } t = 0, 1, 2, \dots, H;$$

$$Z_t = \beta_x Z_{t-1} + e_{x,t}, \quad \text{for } t = 1, 2, \dots, H; \text{ where } e_{x,t} \sim N(0, \sigma_x^2).$$

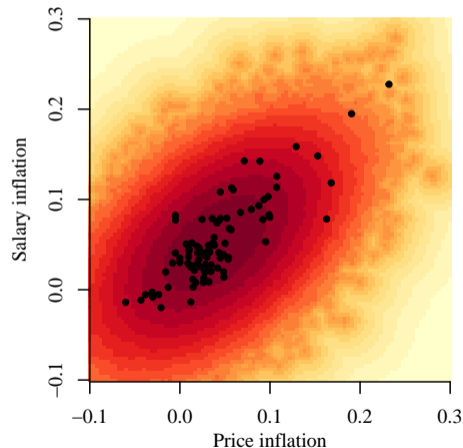
The error terms which are directly connected to each other are dependent, while those which are indirectly connected are still dependent, but more weakly so.

# Economic scenario generator: Simulation and historical data

## Long bond vs equities returns



## Salary vs price inflation



# Stochastic mortality model

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

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

- $q(t, x)$  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.

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# Membership profile: Model points

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

Membership types	Age	Number	Salary	Accrued service/benefit
Active	30	50,264	£25,500	7 years past service
	40	50,264	£42,500	11 years past service
	50	33,509	£52,500	15 years past service
	60	33,509	£58,500	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.

# Benefit structure

## Retirement benefits

Cash lump sum =  $3 \times$  Annual pension.

Annual Pension (inflation-linked) = Pensionable salary  $\times$  Pensionable service  $\times$  Accrual rate.

Accrual rate of 1.25% on final salary basis until 2014 and 1.33% on career revalued benefits basis post 2014.

## Withdrawal benefits

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

## Death benefits

- On death of active member, lump sum payment of 3 times the annual salary is paid; along with
- spouse's pension of half the amount the member would have received on retirement.

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

# Contributions, assets and liabilities

Contributions:	22.5% of salary
Liabilities:	£46.9b
Assets:	£41.6b
Asset allocation:	70% equities and 30% bonds

Scheme liabilities are calculated using the **projected unit method**, which is a prospective valuation method in which liabilities are estimated based on the past service accrued on the valuation date, taking into account future salary inflation.

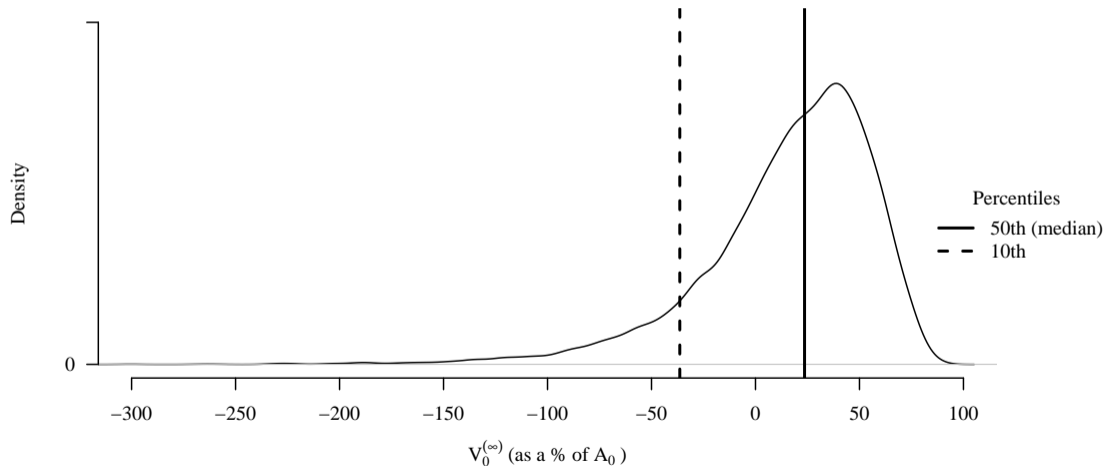
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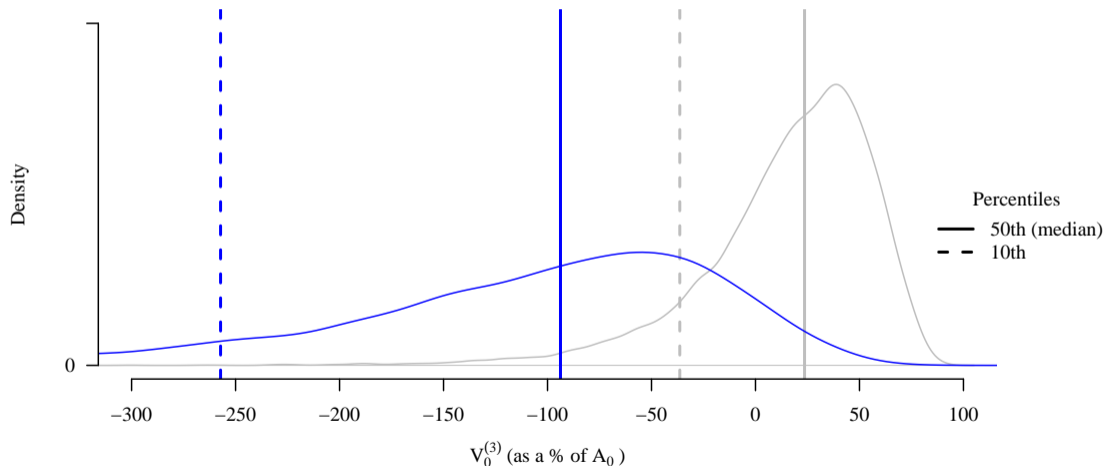
# Base case: Run-off

**Base case: Asset allocation (70% Equity, 30% Bond): Contribution (22.5%)**



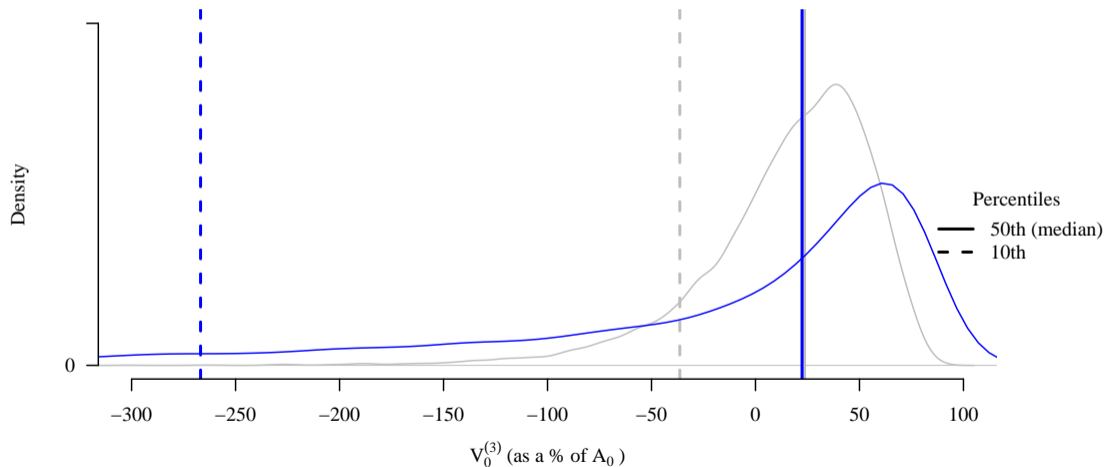
# Base case: 3-year time horizon: Valuation rate based on bond yields

## Valuation rate based only on long-term bond yields



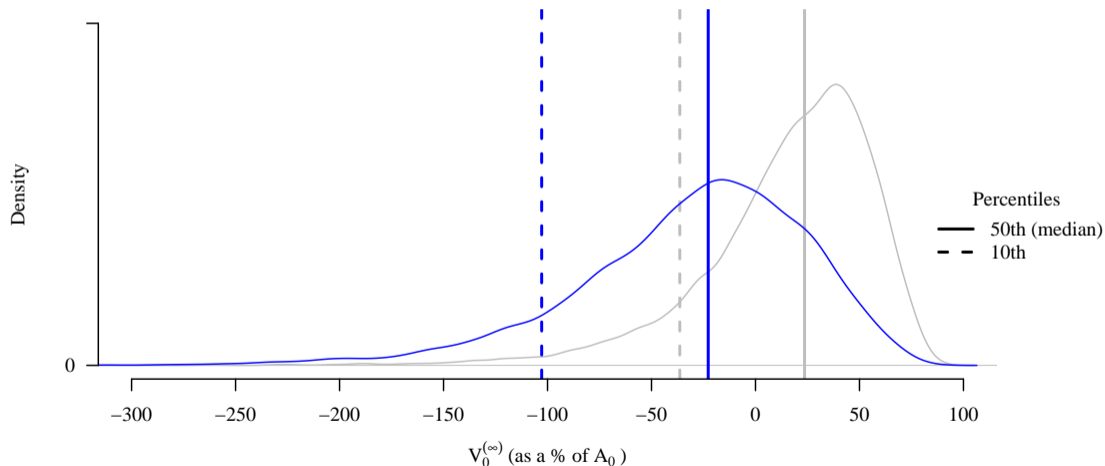
# Base case: 3-year time horizon: Valuation rate based on backing assets

## Valuation rate based on returns on backing assets



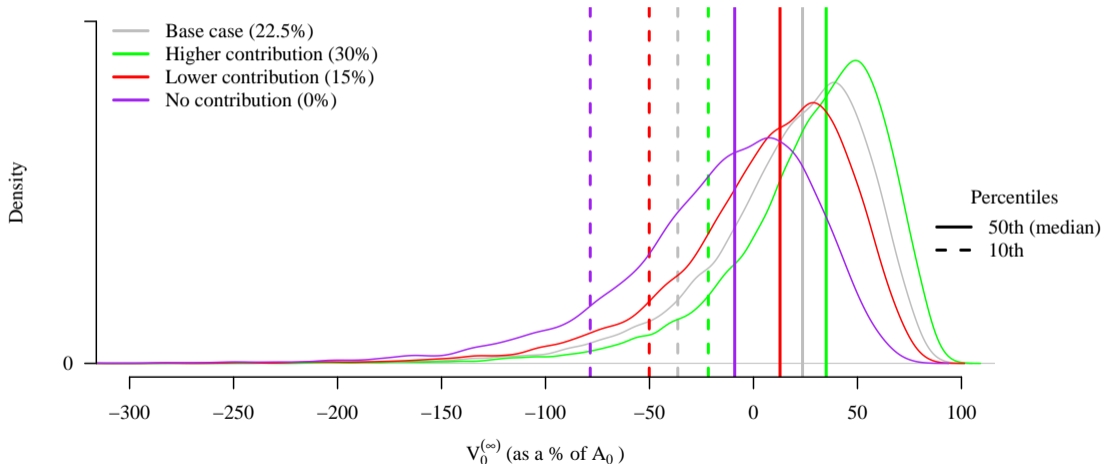
# Asset allocation sensitivity: Run-off

**Asset allocation sensitivity: Asset allocation (30% Equity, 70% Bond): Contribution (22.5%)**



# Contribution sensitivity: Run-off

## Contribution sensitivity: Asset allocation (70% Equity, 30% Bond): Contribution: Various



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# Conclusions

- Range of results is very wide.
- Risk assessment time horizon has a significant impact on pension scheme risk quantification.
- Difference in time horizon generates different conclusions regarding the best approach to manage risk through changes in asset allocation.
- Impact of changes in asset allocation is much larger than for changes to scheme contributions.

# Reference

ANDREWS, D., BONNAR, S., CURTIS, L.J., OBEROI, J. S., PITTEA, A. & TAPADAR, P. (2021). Impact of the choice of risk assessment time horizons on defined benefit pension schemes. *Annals of Actuarial Science*, doi:10.1017/S1748499521000178, 1–29. [Link to paper](#).