# Pricing latest-generation insurance-linked securities

## A disease-based modelling approach

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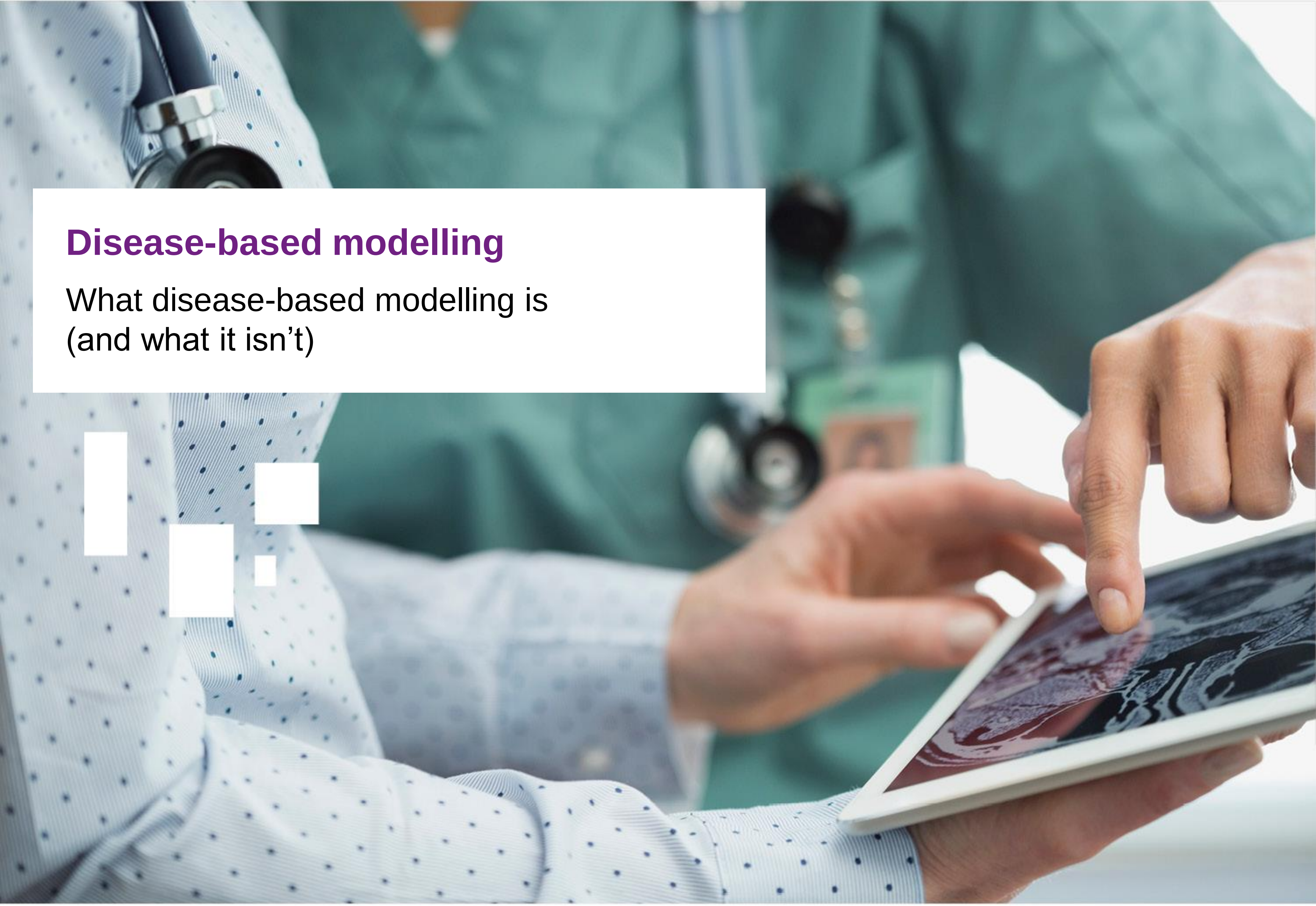
September 2017



Willis Towers Watson

# Agenda

- Disease-based modelling
- Insurance-linked securities
- Pricing non-catastrophic mortality-linked securities
- Summary of results
- Discussion of implications for risk transfer



# Disease-based modelling

What disease-based modelling is
(and what it isn't)

# Brief overview of general mortality modelling approaches

| Extrapolative Models | | |
|---|---|---|
| **Examples** | **Features** | **Pros and cons** |
| ➢ Lee-Carter<br>➢ Cairns-Blake-Dowd<br>➢ Age-Period-Cohort | ➢ Take past mortality data and fit a functional form.<br>➢ Fit a time-series model to changes in the fitted parameters for those functional forms over time.<br>➢ Project the time-series forward.<br>➢ Deduce future mortality rates. | ✓ Can be statistically robust.<br>✓ Some models fit well to past data for certain populations.<br>x Tacit assumption that future mortality will replicate behaviour seen in the past.<br>x The data window available for calibration is limited.<br>x Less able to tailor to specific portfolios. |

# Brief overview of general mortality modelling approaches

| Explanatory Models (Type 1: "Cause of death" or "Cause of cause of death" models) | | |
|---|---|---|
| **Examples** | **Features** | **Pros and cons** |
| ➢ RMS Life Risks *Longevity Risk Model* | ➢ Divide mortality between causes of death.<br>➢ Determine trends in the numbers of deaths from each cause.<br>➢ Or determine links from drivers of mortality to deaths from each cause.<br>➢ Project individual trends forward and aggregate back to all-cause mortality. | ✓ Allow insight into the drivers of mortality rate evolution.<br>✓ Can reflect medical insights, e.g. emerging treatments.<br>x Do not typically account well for competing drivers of mortality.<br>x More difficult to make the models statistically robust.<br>x Less able to tailor to specific portfolios. |

# Brief overview of general mortality modelling approaches

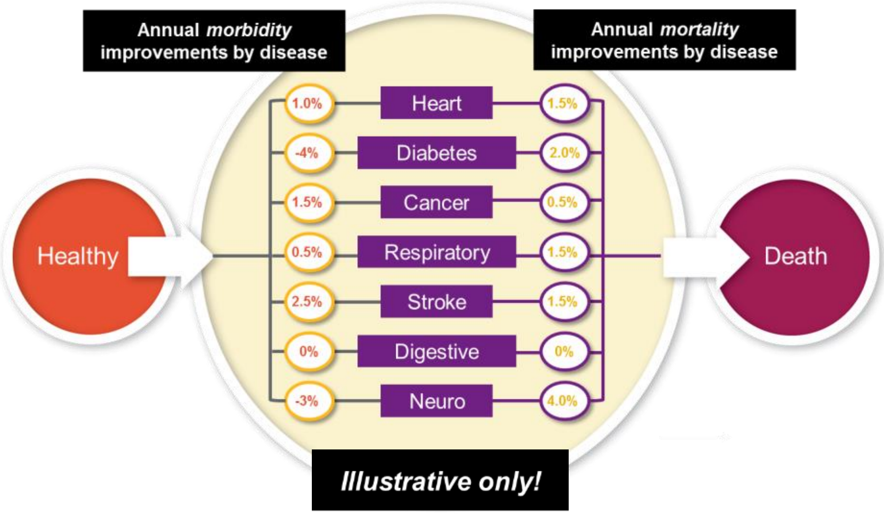
| Explanatory Models (Type 2: "Disease-based" models) | | |
|---|---|---|
| **Examples** | **Features** | **Pros and cons** |
| ➢ Willis Towers Watson *PulseModel* | ➢ Multi-state model of the underlying disease process.<br>➢ Model ***all-cause*** mortality in the presence of known past medical conditions.<br>➢ Rely on medical expert opinions to set rates of change for incidence and mortality transition rates. | ✓ Allow greater insight into the drivers of mortality rate evolution.<br>✓ Can capture the effects of non-stationarity in a population.<br>x Access to sufficiently granular medical data is usually heavily restricted.<br>x Quality of expert judgements will deteriorate over the projection term. |

# Projection model used for this work

## Willis Towers Watson PulseModel

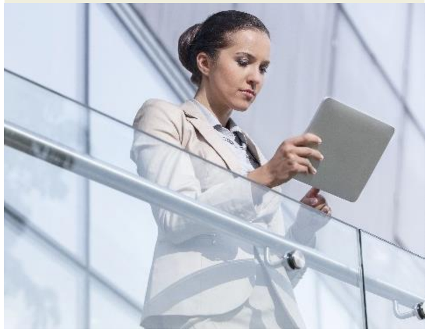
## Key Features

- Multi-state model which tracks disease status from healthy (or initial disease) through to death
- Parameters and risk factors from medical dataset
- Medically-informed views
- Existing UK calibration




## Medical input

- Primary care dataset CPRD for base parameterisation
- Risk factors include BMI, HbA1c, smoker status, postcode group and duration since diagnosis
- Future trends from panel of medical experts (parameters & rationale)



# Insurance Linked Securities

# Typical mortality-linked securities

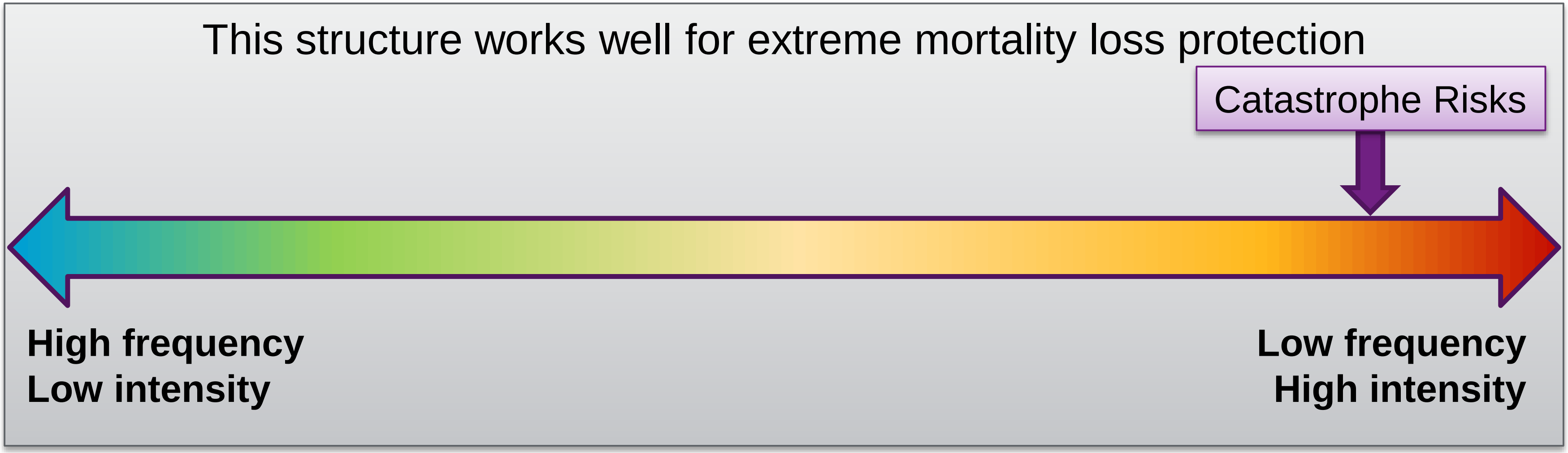
## Protection against catastrophic mortality events

Typical approach to structuring and pricing a catastrophe bond:

| | |
|---|---|
| Define an index | For example: The ratio of mortality rates in consecutive periods. |
| Define a trigger | For example: Index value greater than *X*, or number of deaths due to a single infectious disease exceeding *N*. |
| Define pay-outs | For example: a formula linking index values to the pay-out, or losses incurred within *N* months of a trigger event. |
| Set coupon | Calculated exceedance curves and determine the coupon required on the maximum cover amount to be able to place the notes on the capital markets. |

# Typical mortality-linked securities

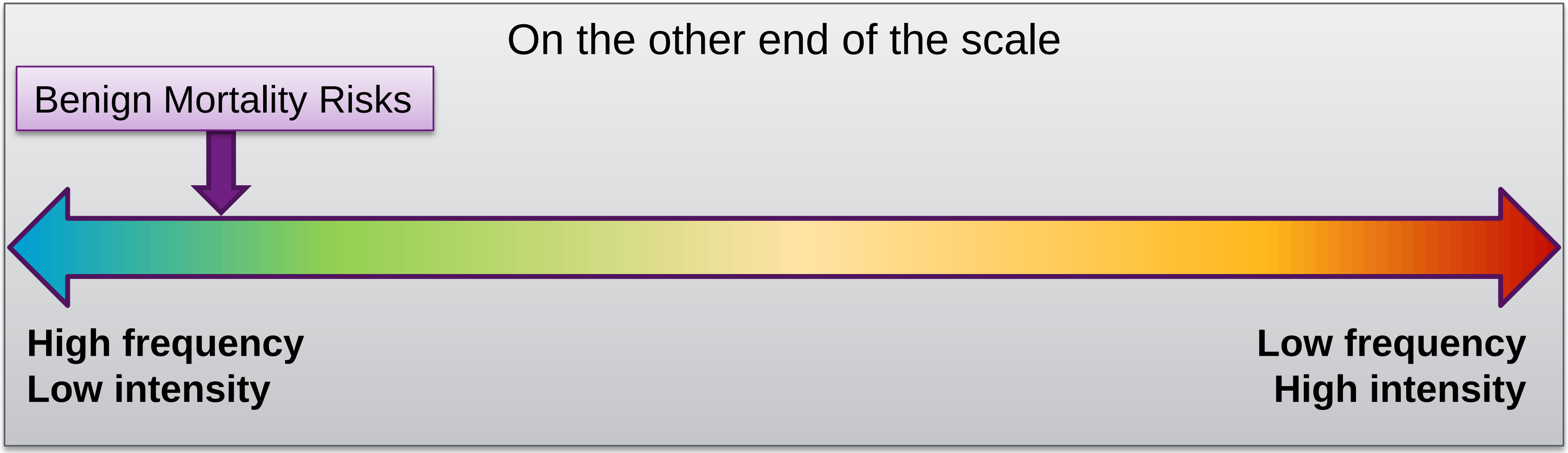
## Protection against extreme mortality losses




- Extreme mortality bonds have relatively stable value.
- Investors do not need to know (or care) about the benign changes in the underlying mortality rate.
- Only expectations of extreme mortality events (e.g. outbreaks of potential pandemic pathogens) will significantly affect the value of the notes.

# Not-so-typical mortality-linked securities

Protection against benign everyday mortality losses




- Here, every death counts, so notes will have more volatile values.
- Investors are exposed to small changes in the underlying mortality rates.
- This exposes information asymmetries between the issuer and the investor.
- Consequently, expected returns need to be higher to compensate the investors for the additional risk taken.

# Pricing non-catastrophic mortality-linked securities

# The problems of pricing non-catastrophic mortality-linked securities

Confidence in issuer's loss distribution

- Without expertise, investors rely on the issuer's assessment of the risks or a 3rd party model.

Differential impacts of risk events

- E.g. a cut in diabetes care budgets would affect existing diabetics more than current non-diabetics.

"New information" events

- Prices will react to new information about emerging treatments or bacterial resistance (not in data).

Allowance for over-dispersion

- Single mortality rate per age/gender will not capture heterogeneity in the non-recently-underwritten population.

# A mortality-linked security to mimic quota share reinsurance

## Notation

Consider a sidecar for which a proportion $\theta$ (the cession rate) of claims on a portfolio of level term assurance products is written off of the nominal value of the notes.

**Notation:**

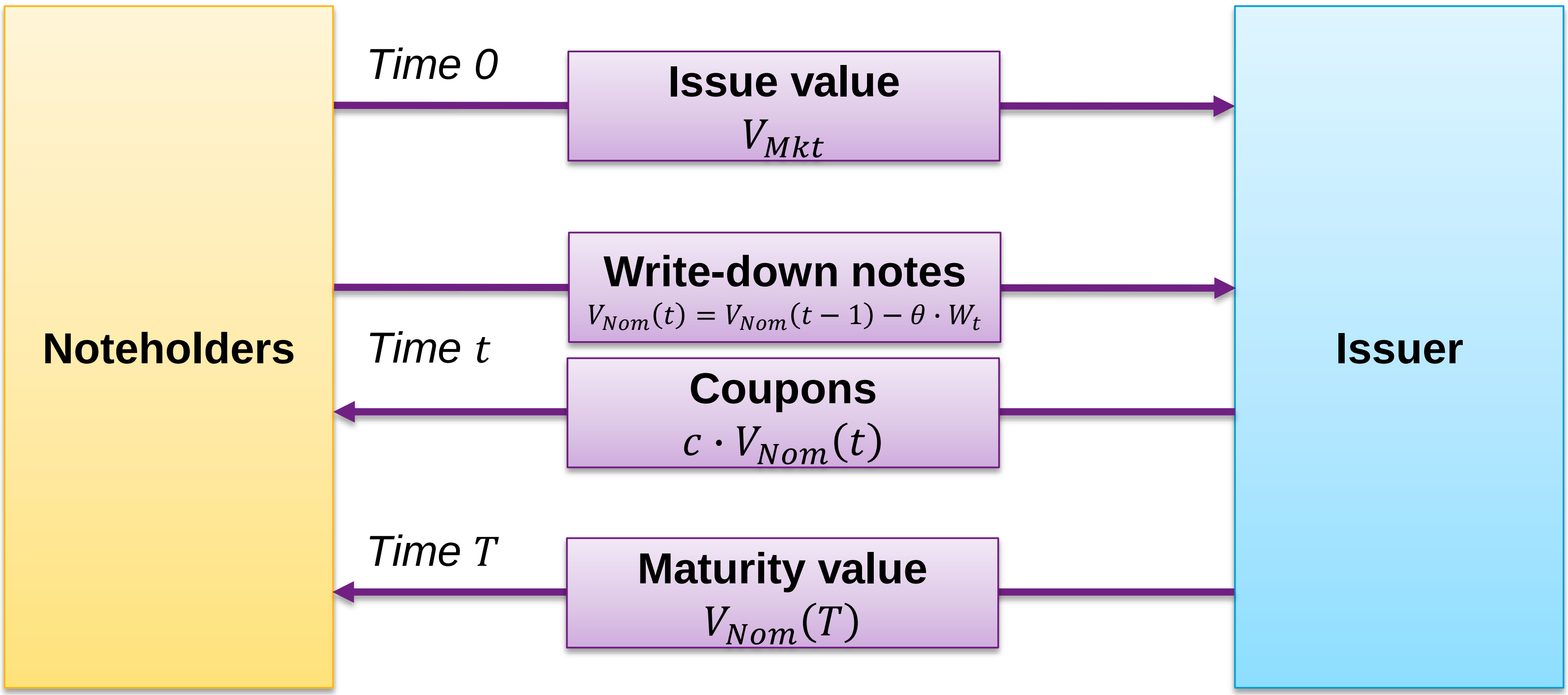
| | |
|---|---|
| Nominal value of the notes (time $t$) | $V_{Nom}(t)$ |
| Market value of the notes (time $t$) | $V_{Mkt}(t)$ |
| Claims in year $t$ | $W_t$ |
| Coupon rate | $c$ |
| Spot interest rate (term $t$) | $i_t$ |

# A mortality-linked security to mimic quota share reinsurance

## Aims of the investigation

# A mortality-linked security to mimic quota share reinsurance

## Modelling approach: Cash-flows




Ignoring: Extensions (IBNR), Premiums, Lapses, Tax

# A mortality-linked security to mimic quota share reinsurance

Modelling approach: present value of cash-flows

The present value of the notes can be represented as follows:

$$K_{Mkt}(0) = K_{Nom}(0)\left((1+i_T)^{-T} + c\sum_{t=1}^{T}(1+i_t)^{-t}\right) - \theta\sum_{t=1}^{T}\left((1+i_T)^{-T} + c\;{}_{t-1|}a_{\overline{T-(t-1)|}}\right)W_t$$

This comprises:

Present value of maturity payment after write-downs

$$(1+i_T)^{-T}\left(K_{Nom}(0) - \theta\sum_{t=1}^{T}W_t\right)$$

Present value of coupon payments after write-downs

$$c\sum_{t=1}^{T}\left(K_{Nom}(0)(1+i_t)^{-t} - \theta W_t \cdot {}_{t-1|}a_{\overline{T-(t-1)|}}\right)$$

${}_{t-1|}a_{\overline{T-(t-1)|}}$ *is the present value of a deferred annuity of 1 p.a. payable in arrears, deferred by* $t-1$ *years for a fixed term of* $T-(t-1)$ *years.*

# A mortality-linked security to mimic quota share reinsurance

## Modelling approach: Generating an example portfolio

Generate 600 random postcodes
(100 each for IMD deciles 5 to 10)

↓

Assign ages and genders
(equal numbers 40M,40F,50M,50F)

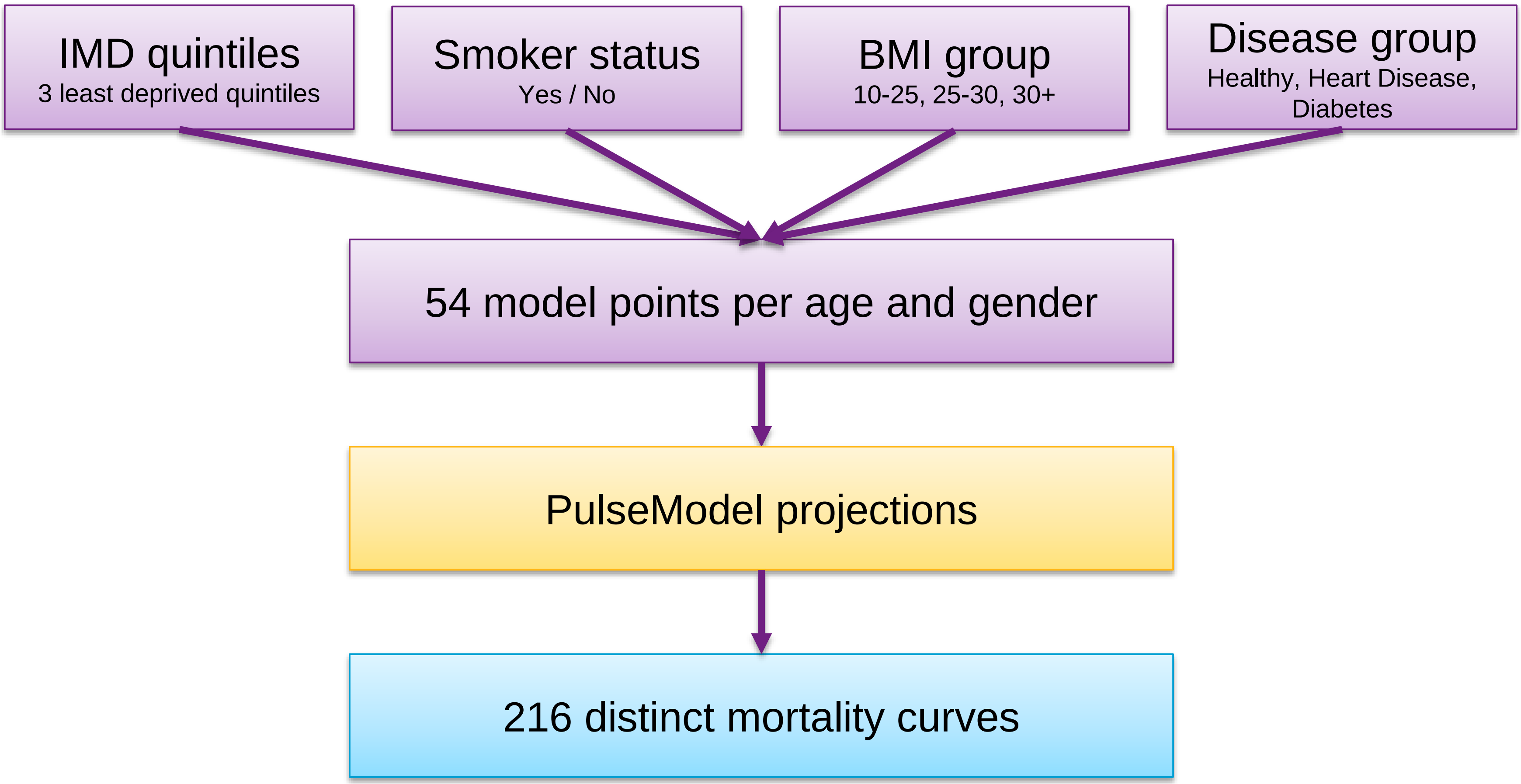
↓

Assign sums assured
Amounts outstanding on 25yr mortgages taken out at age 35

**Deliberately simplistic portfolio**

# A mortality-linked security to mimic quota share reinsurance

## Modelling approach: Model pointing for mortality curves



# A mortality-linked security to mimic quota share reinsurance

## Modelling approach: Weighting of conditions and rating factors

3rd party database

Per-postcode, age-banded propensities:

*Smoker*

*BMI>30*

*Previous heart condition*

*Diabetic*

**Combining propensities**

Smoker status
Yes / No

×

BMI group
10-25, 25-30, 30+

×

Disease group
Healthy, Heart Disease, Diabetes

54 distinct mortality curves per age/gender

↓

Weights per policyholder for a set of 18 curves (relevant IMD quintile)

↓

Per-policyholder best-estimate curve

# A mortality-linked security to mimic quota share reinsurance

## Modelling approach: Monte-Carlo simulation

Weights per policyholder for a set of 18 curves (relevant IMD quintile)

↓

Convert to a cumulative distribution function $F$

↓

Sample from Uniform(0,1) and compare to $F$ to select a mortality curve

↓

Project using single selected mortality curve and treat deaths per year as Bernoulli trials

Repeat for 10,000 scenarios

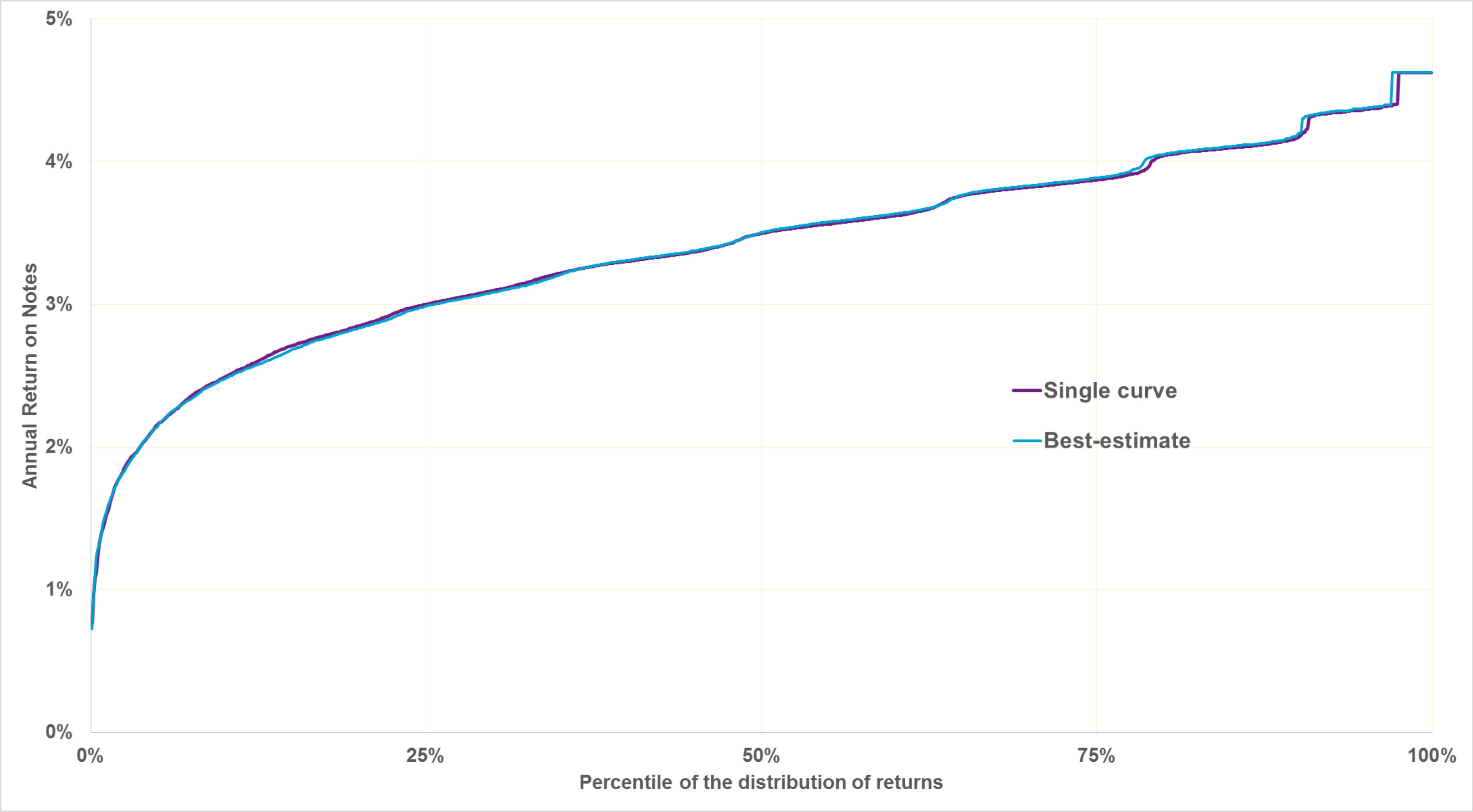
# Results of modelling

# Results of modelling

5 year capital-at-risk notes with a 4.99% coupon; 50% retention.

$\boldsymbol{V_{Nom}(0) = V_{Mkt}(0) = £3.5m}$ priced at 3% above 30 Jun 2017 RFR.

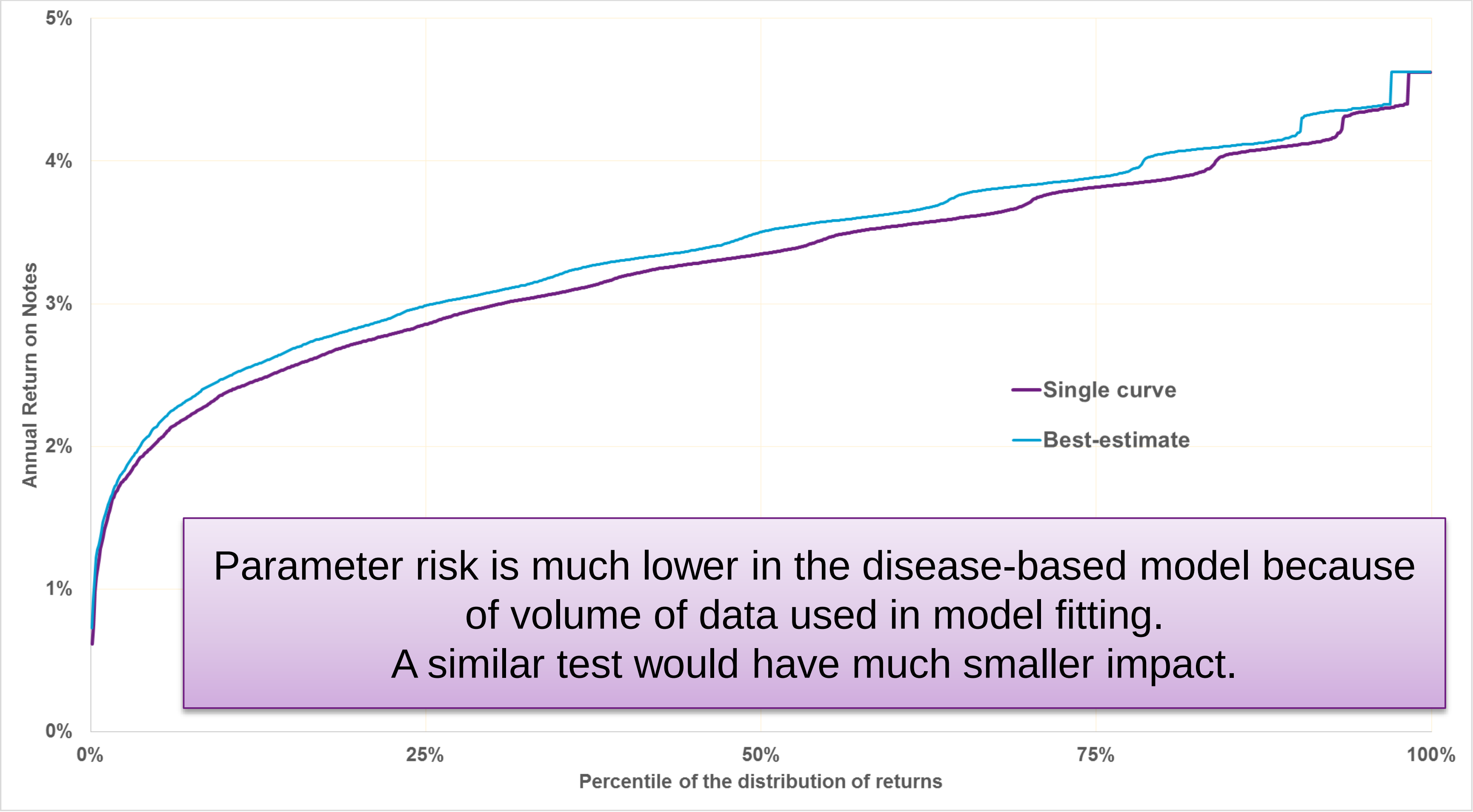
## Loss distributions using PulseModel vs. fitted % of TxNL/TxSL tables



# Results of modelling

Effect of a 10% error in the % of TxNL/TxSL based on parameter estimation

## Loss distributions using PulseModel vs. fitted % of TxNL/TxSL tables

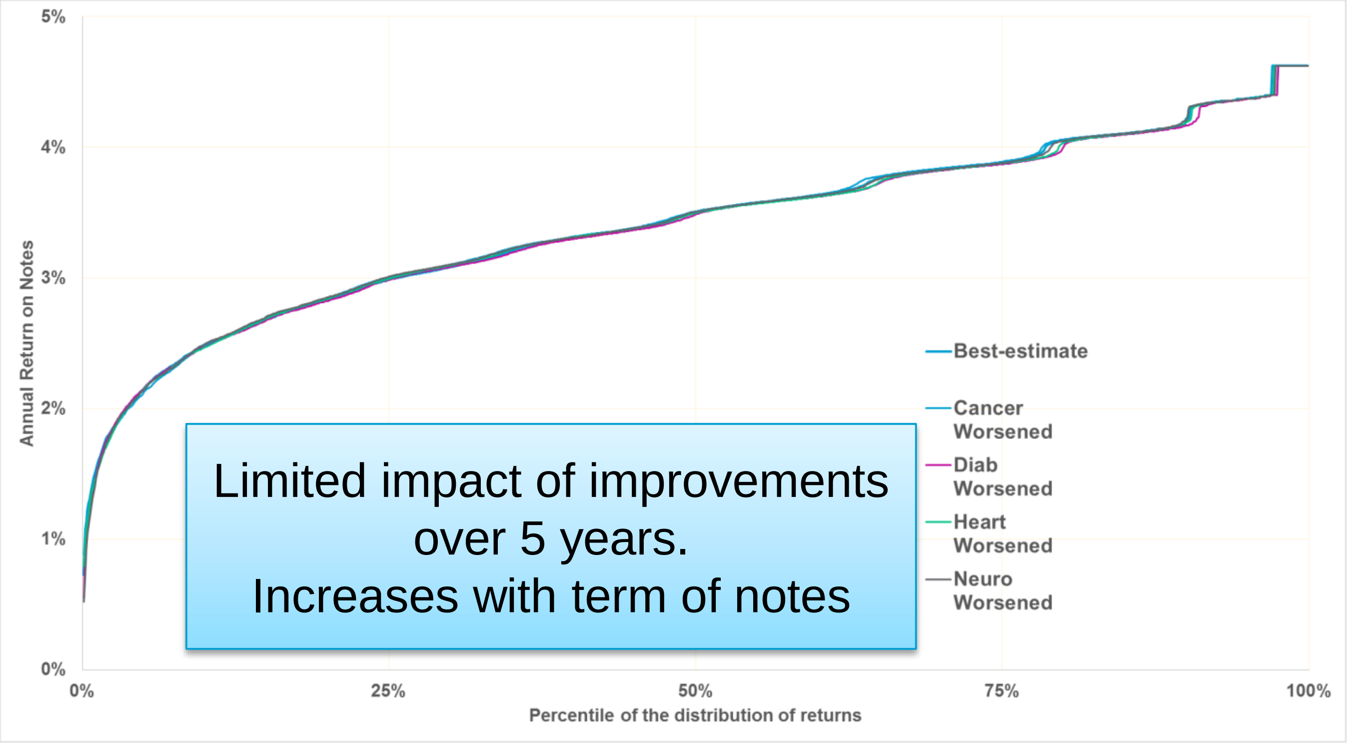


# Results of modelling

Impact of variations in mortality and morbidity improvements

**Based on medical expert opinions:**

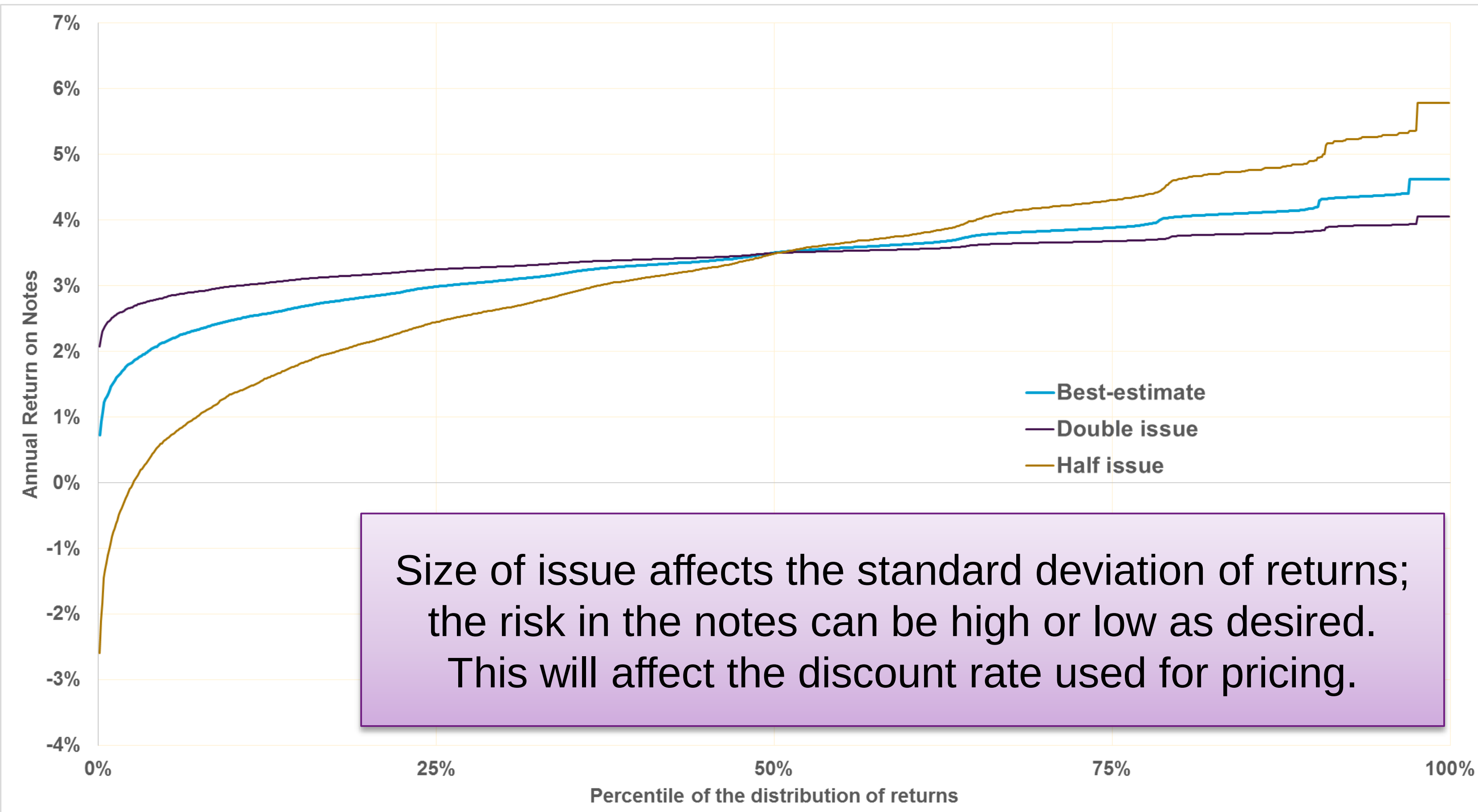
- Stresses to improvements in cancer, diabetes, heart disease, neurological conditions and stroke morbidity and mortality.
- Allowing for worsening of morbidity and mortality rates.



# Results of modelling

## Impact of variation in the issue amount

**We considered halving and doubling of the size of the issue of notes.**




Size of issue affects the standard deviation of returns; the risk in the notes can be high or low as desired. This will affect the discount rate used for pricing.

# Key findings from modelling exercise

Return profile similar to a percentage of the 08-series term tables

Different source of parameter risk
=
Different size of parameter risk

However, A/E is unlikely to return this percentage of the term tables

Size of issue allows loss profile to be tailored to find an optimal price for the transfer of mortality risk

# Implications for risk transfer

# How can disease-based modelling reduce issue costs?

**Less basis risk**
*Portfolio specific estimates*

**Less parameter risk**
*X million life-years in GLM vs. a few deaths for A/E*

**Risk communication**
*Impact of specific medical scenarios*

**Increased investor confidence in analysis**

**Lower margin in required discount rate**

Ability to apply the same approach directly to portfolios in which individual lives are known to have pre-existing conditions.

Not reliant on simple +50% or +100% type loadings for known diseases.

# Downsides to disease-based modelling for ILS pricing?

Heavy data requirements
*e.g. Primary care data*

Policyholder health status estimation
*e.g. postcode links*

Application across national boundaries

Complex model
*Parsimonious? Over-fitting?*

Long-term notes
*Deterioration of expert judgements (improvements)*

# Future for mortality-linked securities

How viable are mortality-linked securities as an alternative to reinsurance?

## Insurance-linked securities vs. traditional reinsurance

- Compare an ILS designed to indemnity the issuer for a share of all mortality claims on a portfolio of term-assurance policies to a quota-share reinsurance treaty.

| Feature | Reinsurance | ILS |
| --- | --- | --- |
| Cost | Reinsurance premiums (include implicit pricing margins) | Coupons (Explicit cost) |
| Capital | Counterparty default risk | Depends on investment of proceeds of issue |
| Knowledge of parties | Reinsurers have independent mortality expertise | Investors typically rely on 3rd party views |
| Extent of cover | Can cover as-yet-unwritten business on an agreed basis for underwriting of new business | Closed blocks of business easier to cover. (Investors exposed to future underwriting risk for new business) |