



“Model for sample report”

User-File-Model

101-8377-35370

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1. Introduction

This is an automatically generated report for the model with identifier 101-8377-35370. It contains details of the model structure and the data to which it is fitted. Where technical terms are used, there is usually a link to the part of our website which documents the term and what it means.

The software used to fit this model and generate this report is Longevitas. This is a service specifically tailored to the needs of analysts wanting to analyse the demographic experience of a given portfolio. The most common application is analysing mortality and longevity risk within a pension schemes or annuity portfolios.

For projecting future rates of mortality, we recommend our companion service, the Projections Toolkit, which enables users to quickly build stochastic projection models.

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3. Errors and warnings

This chapter of the report details the errors and warning produced by the expert system. In general errors are problems which may invalidate the model and any conclusions drawn from it, while warnings may be for information only and need not represent a serious error.

3.1 Errors

There are no errors to report.

3.2 Warnings

- The presence of zero-valued benefit amounts may invalidate a model using SizeBand or weighting by benefit size.

3.3 Recommendations

There are no recommendations to report.

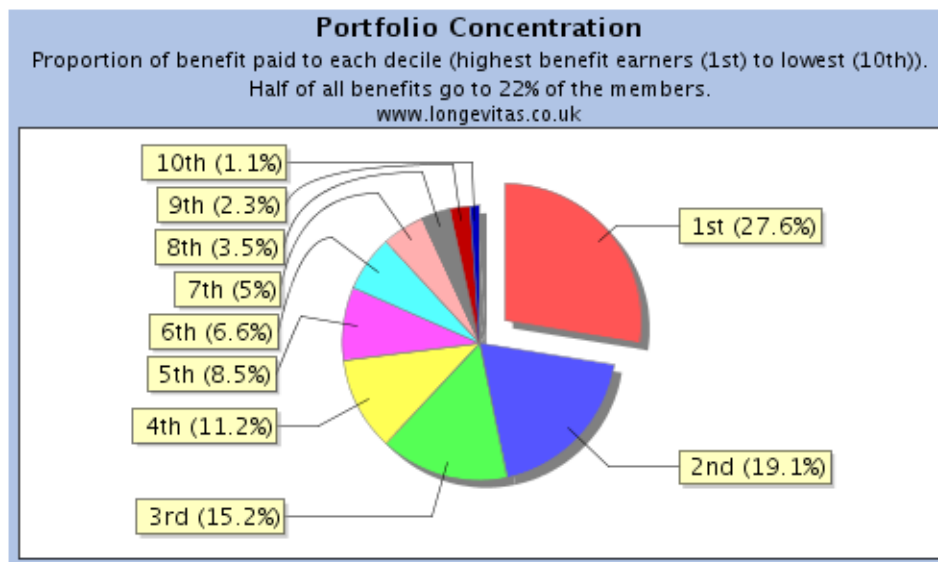
4. Data

4.1 Concentration of liabilities

Benefit amounts usually differ widely in size, with a large proportion of liabilities typically concentrated in a relatively small number of hands. One measure of inequality in income distribution is the Gini Index. It ranges from 0% (perfect equality) to 100% (one person has all the income). The Office for National Statistics gave the UK as a whole a value of 34% in 2008/9, whereas the figure for this portfolio is 44.17%.

An alternative approach is to show the proportion of benefit amounts for each decile of lives as in Figure 4.1.

Figure 4.1: Concentration of liabilities

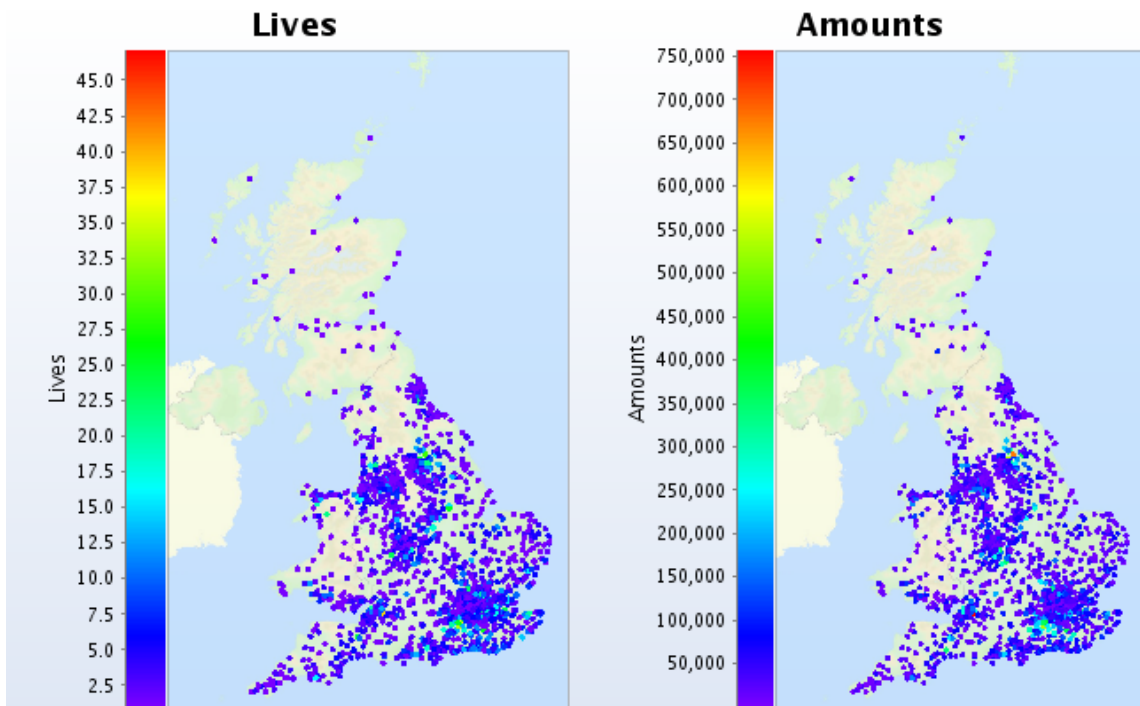


4.2 Geographic spread of liabilities

Figure 4.2 shows the geographic spread of lives and amounts for records with valid UK postcodes (data aggregated and plotted at postcode district level).

For financial modelling it is important to use the size of benefit or reserve. When modelling risk it is helpful to split the population into a number of size bands, which Longevitas does by splitting the population into equal numbers of lives (or as near to equal as is possible). The number of size bands can be set by the user at the outset of each model fit under

Figure 4.2: Geographical spread of liabilities by lives (left) and amounts (right). Map © Crown copyright Ordnance Survey. All rights reserved.



Advanced Options→Benefit/Reserve bands. The following tables show how the data have been split for this model.

Table 4.1: SizeBand definition

SizeBand	Range:		Lives	Deaths	Exposure (years)
	From...	...to			
S1	0	5687.76	2327	668	10521.8
S2	5687.76	14110.08	2324	398	11320.5
S3	14110.08	286727.04	2324	270	11919.8

4.3 High-level summary of data

Figure 4.3 shows the actual number of deaths by age (points) and the expected number according to the fitted model (line). In a good model, the two should be broadly overlapping.

Table 4.2: ReserveSizeBand definition

ReserveSizeBand	Range:		Lives	Deaths	Exposure (years)
	From...	...to			
S1	0	48734.91	2326	742	10628.6
S2	48734.91	132811.83	2325	399	11403.2
S3	132811.83	3802723.38	2324	195	11730.3

Table 4.3: High-level summary of data

Lives	6975
Deaths	1336
Exposure	33762.2
Lives under age 60	0
Lives over age 105	0

Figure 4.4 shows the actual number of deaths by calendar year (points) and the expected number according to the fitted model (line). In a good model, the two should be broadly overlapping. A systematic difference between the two may be evidence of a trend which should be added to the model. Major discontinuities may be evidence of missing data which requires refining the age or data range specified for the model.

Figure 4.5 shows the actual number of lives by age (points) and the exposure time (solid area). The exposure time will always be less than the number of lives due to the presence of decrements, meaning that on average one life will contribute less than one year of exposure time.

Figure 4.6 shows the actual number of lives by calendar year (points) and the exposure time (solid area). The exposure time will always be less than the number of lives due to the presence of decrements, meaning that on average one life will contribute less than one year of exposure time.

Table 4.4 describes the various factors present in the data.

Figure 4.3: Actual and expected deaths by age

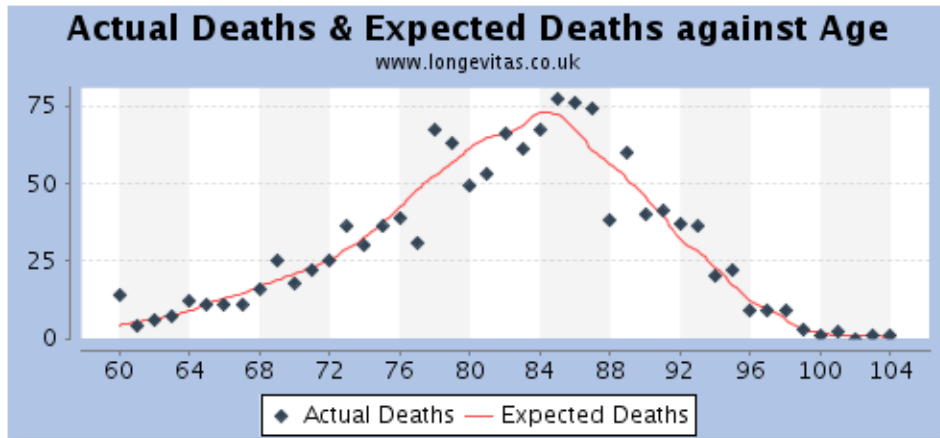


Figure 4.4: Actual and expected deaths by calendar time

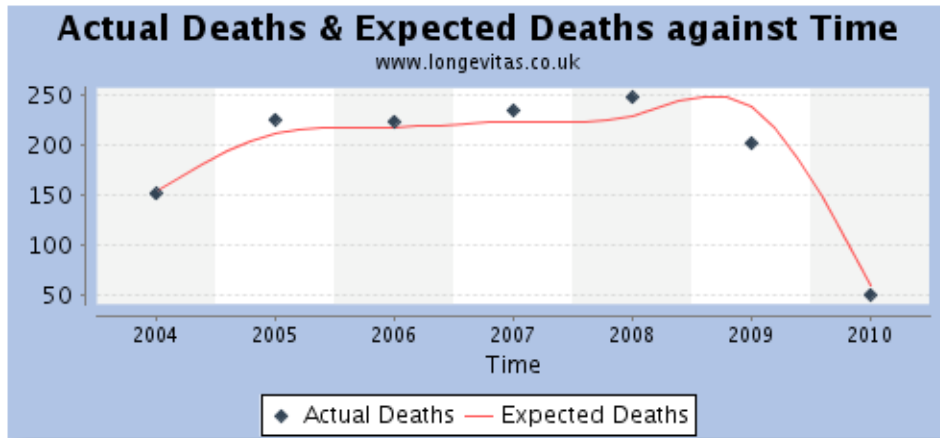


Figure 4.5: Lives and exposure time by age

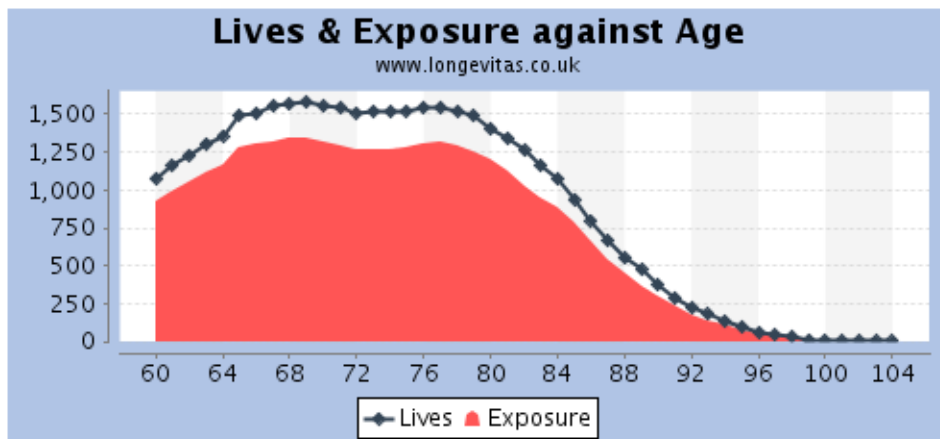


Figure 4.6: Actual and expected deaths by calendar time

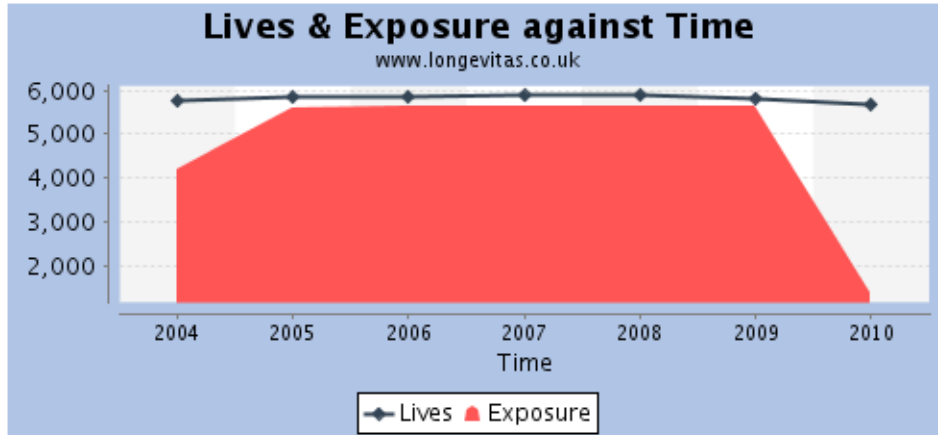


Table 4.4: Factor summary

Name	Levels	Type
Gender	2	binary factor
ReserveSizeBand	3	multi-level factor
SizeBand	3	multi-level factor

Table 4.5: Factor-level details for Gender

Level	Lives	Exposure	Deaths	Baseline
F	2683	12234.8	660	Baseline
M	4292	21527.3	676	

Table 4.6: Factor-level details for ReserveSizeBand

Level	Lives	Exposure	Deaths	Baseline
S1	2326	10628.6	742	Baseline
S2	2325	11403.2	399	
S3	2324	11730.3	195	

Table 4.7: Factor-level details for SizeBand

Level	Lives	Exposure	Deaths	Baseline
S1	2327	10521.8	668	Baseline
S2	2324	11320.5	398	
S3	2324	11919.8	270	

5. Model

This section documents the high-level structure of the model, including whether it is a μ_x -type or q_x -type of model and which mortality law was fitted.

The model is internal to Longevity and the functional form for the risk is:

$$\mu_{x,r,y} = \frac{e^{\alpha+\beta x+\gamma r+\delta y}}{1 + e^{\alpha+\beta x+\gamma r+\delta y}} \quad (5.1)$$

where x is age, r is duration since inception and y is calendar time.

A model for $\mu_{x,r,y}$ is a survival model. This is a model of the lifetime of an individual. Note that we are modelling mortality at the level of the individual, not the group.

This is an unweighted statistical model, i.e. each observation has the same weight as all the others.

Table 5.1: Model overview

Decrement modelled	DEATH
Mortality law	Perks
Model type	survival
AIC	10063
BIC	10097.2
DIC	5835.96
Deviance	5830.96
Log-likelihood	-5026.5
Model terms	4
Parameters	5

Table 5.2 lists some technical details of the model-fitting procedure, and where the user can change them in Longevity under Settings→Configuration→Modelling.

Table 5.2: Model technical details

Age measured from	0	
Calendar time measured from	2000	Modelling→Calendar Base Year
Derivatives used	true	Technical→Gradient Calculation Method
Duration measured from	0	
Interval for numerical approximation	0.0001	Technical→Gradient Approximation Step
Iterations taken	13	
Observation weighting	equal	Calculation Core→Observation Weighting
Optimisations minimise the...	AIC	Calculation Core→Optimisation/Modelling Target

The model fitted is Age, Gender, SizeBand. The fitted values of the parameters are listed in Table 5.3.

Table 5.3: Model terms and parameters

Term	Parameter	Fixed	Sig.	Estimate	Std. err.	p-value
Age	Age		***	0.119476	0.00410333	0
Gender	Gender.M		***	0.3444	0.0707044	1.11043e-06
Intercept	Intercept		***	-12.4523	0.349866	1.88689e-277
SizeBand	SizeBand.S2		***	-0.330604	0.0729608	5.86342e-06
	SizeBand.S3		***	-0.645552	0.0881413	2.40586e-13

Table 5.4: Data contributing to estimation of model parameters

Term	Parameter	Lives	Deaths	Exposure
Age	Age	6975	1336	33762.2
Gender	Gender.M	4292	676	21527.3
Intercept	Intercept	6975	1336	33762.2
SizeBand	SizeBand.S2	2324	398	11320.5
	SizeBand.S3	2324	270	11919.8

Note that the parameterisation of internal models in Longevity follows the naming convention and rules set out in Richards (2010) [9]. In Longevity the parameters in a model may be freely estimated, or else over-ridden with specific values set by the user. Over-rides may sometimes be used to create stressed models which are nevertheless consistent with the experience data. All parameters in this model are free, i.e. they are the maximum-likelihood estimate in every case.

6. Residuals

A model fit may be assessed by comparing the actual number of events with the number predicted by the model. Subtracting the number of expected events from the number of actual ones can be standardised into a residual. Following McCullagh and Nelder (1989) [2], Longevitas uses deviance residuals in the following analyses. The underlying data are presumed to be based on individual lives, so the exposures and event counts are aggregated using the following result from Cox and Miller (1987) [1]:

$$D \sim \text{Poisson} \left(\sum_i H_{x_i}(t_i) \right) \quad (6.1)$$

where D is the total number of events observed in an arbitrary sub-group of the data and $\sum_i H_{x_i}(t_i)$ is the sum of the integrated hazard functions of the lives involved. The sub-group can be defined with respect to the mutually exclusive levels of a categorical factor, or subdivisions of a continuous variable like age, or both types simultaneously. Using these results, Table 6.1 details some statistical tests of how well the model fits the experience data.

Table 6.1: Badness-of-fit tests

Parameter	χ^2	df	p-value	Sig.
Age	61.373	43	0.0341337	*
Age:Gender.F	36.3092	42	0.718278	
Age:Gender.M	66.0104	37	0.00233679	**
Duration	57.1811	53	0.322653	
Duration:Gender.F	55.0416	52	0.360267	
Duration:Gender.M	44.7131	38	0.210593	
Time	10.8151	6	0.0942608	.
Time:Gender.F	7.09854	5	0.213414	
Time:Gender.M	14.456	5	0.0129582	*

6.1 Residuals by Age

Figure 6.1 plots the deviance residuals against Age.

6.2 Residuals by Age:Gender.F

Figure 6.2 plots the deviance residuals against Age:Gender.F.

Figure 6.1: Deviance residuals by Age

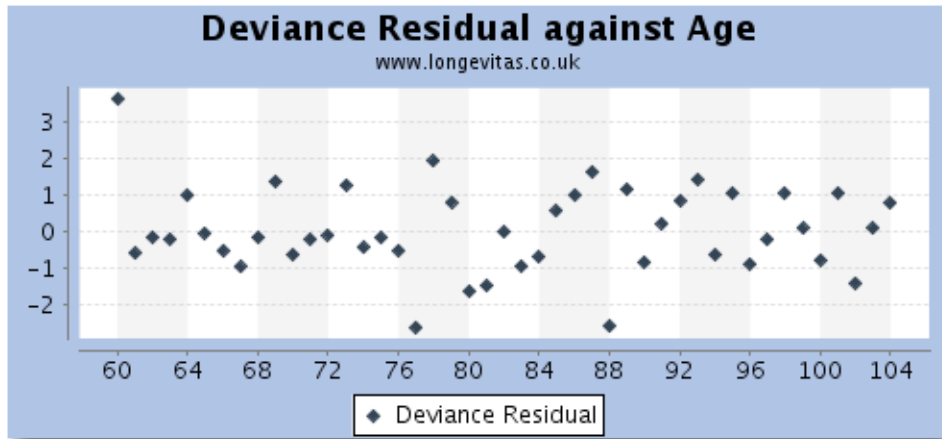
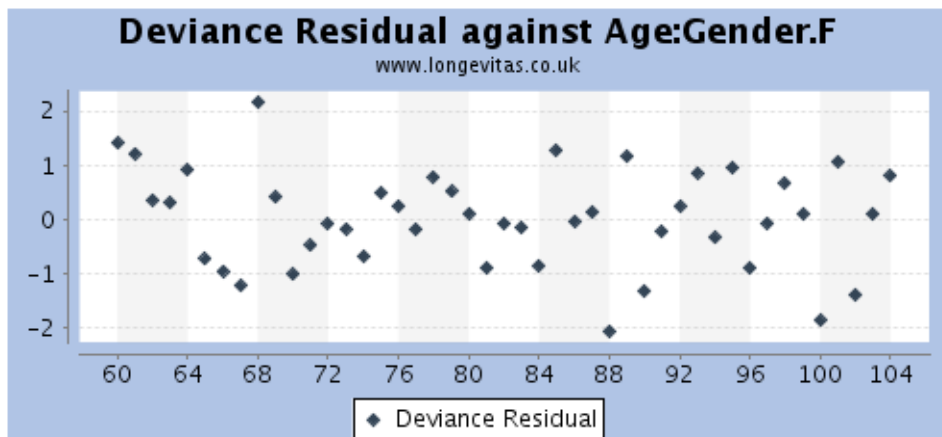


Figure 6.2: Deviance residuals by Age:Gender.F

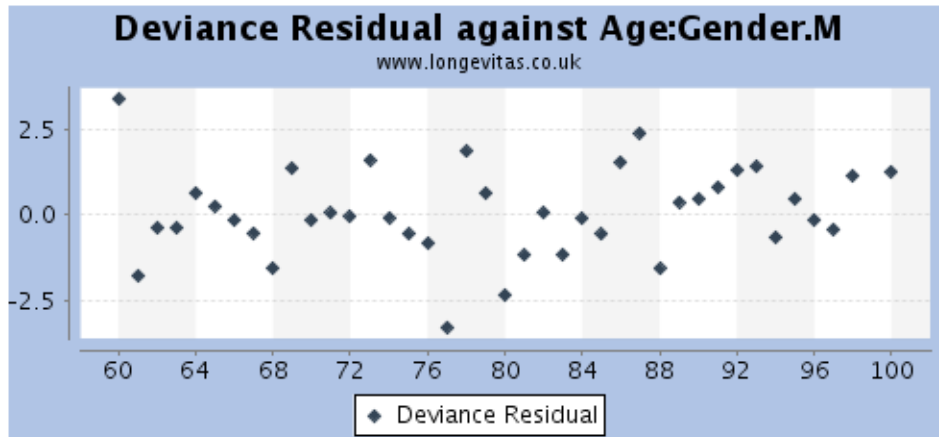


6.3 Residuals by Age:Gender.M

Figure 6.3 plots the deviance residuals against Age:Gender.M. Below are some comments on the deviance residuals against Age:Gender.M:

- The p-value of the X statistic suggests that the residuals are too large on average to be entirely random. This suggests that the model can be improved, possibly by (i) changing the model type, (ii) adding other risk factors, or (iii) working with a subset of the data

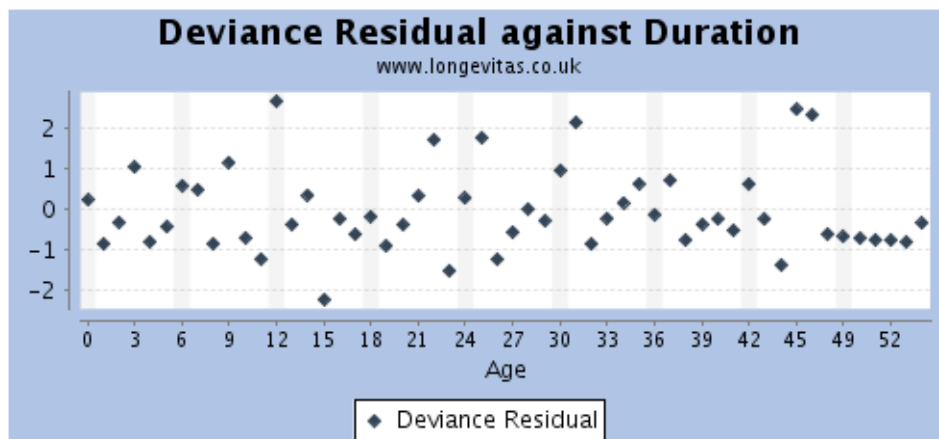
Figure 6.3: Deviance residuals by Age:Gender.M



6.4 Residuals by Duration

Figure 6.4 plots the deviance residuals against Duration.

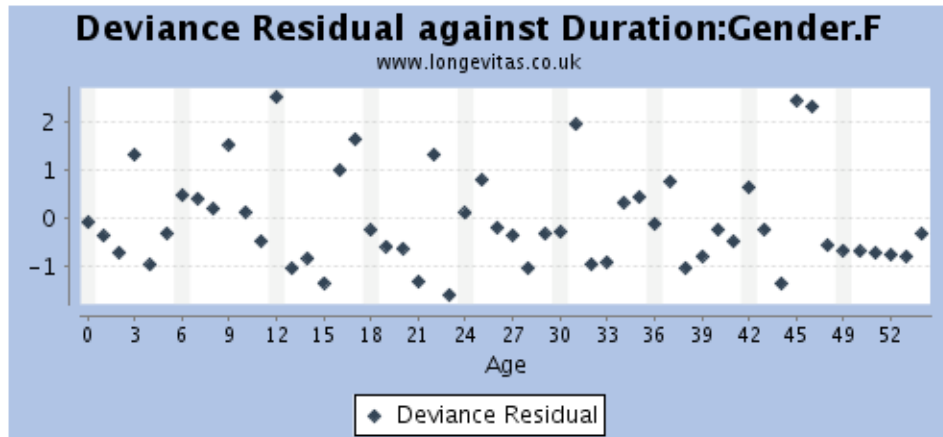
Figure 6.4: Deviance residuals by Duration



6.5 Residuals by Duration:Gender.F

Figure 6.5 plots the deviance residuals against Duration:Gender.F.

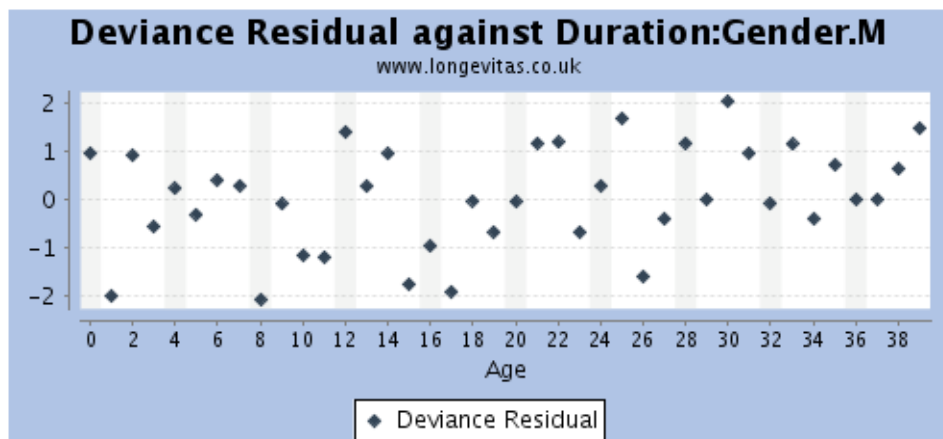
Figure 6.5: Deviance residuals by Duration:Gender.F



6.6 Residuals by Duration:Gender.M

Figure 6.6 plots the deviance residuals against Duration:Gender.M.

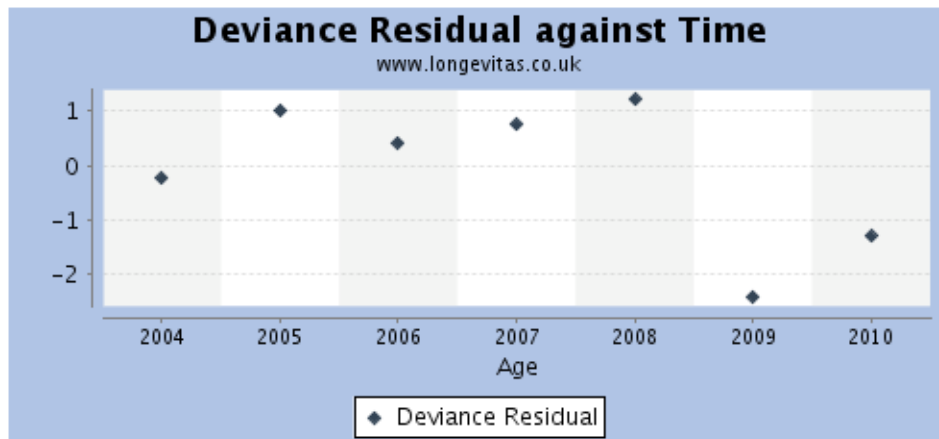
Figure 6.6: Deviance residuals by Duration:Gender.M



6.7 Residuals by Time

Figure 6.7 plots the deviance residuals against Time.

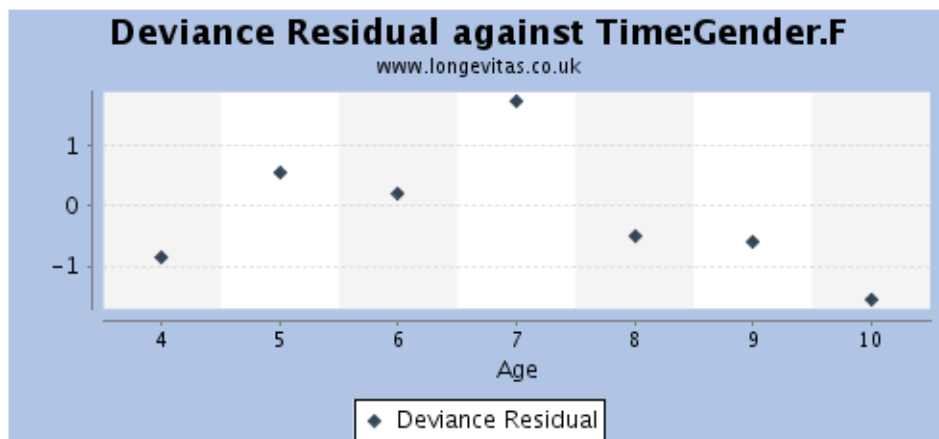
Figure 6.7: Deviance residuals by Time



6.8 Residuals by Time:Gender.F

Figure 6.8 plots the deviance residuals against Time:Gender.F.

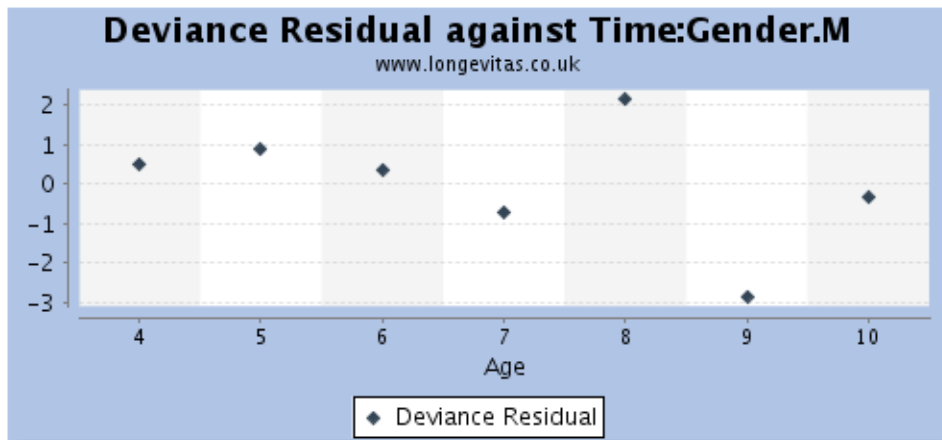
Figure 6.8: Deviance residuals by Time:Gender.F



6.9 Residuals by Time:Gender.M

Figure 6.9 plots the deviance residuals against Time:Gender.M.

Figure 6.9: Deviance residuals by Time:Gender.M



7. Yield curve

This section of the report details the yield curve used in discounting cashflows. The formula used to fit the yield curve is as follows:

$$\hat{y}(m) = e_0^\beta + (e^{\beta_1} - e^{\beta_0}) \frac{1 - e^{-\frac{m}{e^{\tau_1}}}}{\frac{m}{e^{\tau_1}}} + \beta_2 \left(\frac{1 - e^{-\frac{m}{e^{\tau_1}}}}{\frac{m}{e^{\tau_1}}} - e^{-\frac{m}{e^{\tau_1}}} \right) + \beta_3 \left(\frac{1 - e^{-\frac{m}{e^{\tau_2}}}}{\frac{m}{e^{\tau_2}}} - e^{-\frac{m}{e^{\tau_2}}} \right) \quad (7.1)$$

where $\hat{y}(m)$ is the fitted annualised yield applying from time 0 to time m . The parameters used in the model are listed in Table 7.1, along with some technical details of the model-fitting procedure. More details are given in Svensson (1994) [10].

Table 7.1: Details of the fitted yield-curve model

Model name or description	Svensson
Reference	Svensson (1994) and Technical Guide
Number of fitting attempts	500
Intervals for numeric integration of $\bar{a}_{\overline{m} }$	10000
Sum of squared deviations	0.0189236
Iterations to fit this model	29
β_0	0.976239
β_1	-1.2724
β_2	6.31879
β_3	-2.86729
τ_1	2.31482
τ_2	0.87425

8. TAS-D

This section is designed to help users who have to adhere to the standard for data used in actuarial work, TAS-D [3], laid down by the Board of Actuarial Standards in the United Kingdom. It may be useful for users in other territories. The data used in generating this report might form part of actuarial work to which the stipulations of TAS-D will apply. The information that follows is to assist in the creation of such TAS-D-compliant material.

8.1 Data definitions (TAS-D C.5.3)

The data used are the exact date of birth, the gender, the exact date of commencement, the annual benefit, the end date (date of death) and the UK postcode (if available). Other risk factors might be included in the model and a list of possible factors is given in Table 4.4.

8.2 Validation (TAS-D C.5.6)

The data used in this report were validated when uploaded. The checks carried out include:

- Dates of birth lie in a valid range.
- Gender codes are either M for male or F for female.
- Commencement dates are valid and consistent with the date of birth.
- Benefit amounts are valid numbers and are non-negative.
- End dates (including dates of death) are valid and consistent with the date of birth and the commencement date.

Records failing the above checks are excluded from the calculations in this report. Note that records with missing or invalid postcodes **are** included in all calculations, and such records are assigned separate default profile codes if the postcode is non-residential or is unrecognised or corrupted.

9. TAS-R

This section is designed to help users who have to adhere to the standard for actuarial reports, TAS-R [4], laid down by the Board of Actuarial Standards in the United Kingdom. It may be useful for users in other territories. Material within this report might form part of a component report within the definitions of TAS-R, and may therefore be used to assist in the creation of an aggregate report to which the stipulations of TAS-R will apply. The information that follows is to assist in the creation of such TAS-R-compliant material.

9.1 Relevance (TAS-R C.3)

The purpose of this report is to describe the calculations used in fitting a risk model to the data set in question. There are two facets to this risk explored in this model:

- Underwriting risk, i.e. what are current mortality rates likely to be and how do they change with age?
- Trend risk, i.e. to what extent are mortality rates changing in time?

9.2 Data (TAS-R C.4.1)

The data used in generating this report are summarised in Section 4.3. The data have undergone basic validation checks as described in Section 8.2.

9.3 Assumptions (TAS-R C.4.4)

The model fitted is a statistical model for the length of time a person will live without the risk event occurring. Normally this is a model for the future lifetime of a pensioner. The model is fitted using the method of maximum likelihood. The details of this model-building process are set out in Richards (2008) [8] and Richards (2010) [9].

10. TAS-M

This section is designed to help users who have to adhere to the standard for actuarial models, TAS-M [7], laid down by the Board of Actuarial Standards in the United Kingdom. It may be useful for users in other territories.

10.1 Checks (TAS-M C.3.5)

The data used in parameterising the rating model in this report was subjected to numerous individual checks described in Section 8.2. Records failing these checks are excluded from the model-fitting process. Several other advisory checks are carried out which require user decisions as to whether they are important or not:

- Whether or not bias is introduced through the exclusion of failed records.
- Whether commonly occurring values are symptomatic of a data problem, or are a feature of the data.
- Whether deduplication is adequate enough, or whether too much of it has occurred.

For example, if there are a thousand records with the date of birth 1901-01-01, this is suggestive of a fake date of birth. However, if several hundred records in a large pension scheme share the same commencement date, this might simply be due to an early-retirement programme.

10.2 Neutral measures (TAS-M C.3.10)

The parameter estimates in Table 5.3 are maximum-likelihood estimates. The test applied to the residuals in Section 6 aim to show that residuals are without bias.

10.3 Parsimony (TAS-M C.3.14)

The number of parameters in a model is under the user's control, but the AIC and BIC in Table 5.1 can be used to compare models and ensure that each parameter is necessary in the model by balancing fit against model complexity.

10.4 Reproducibility (TAS-M C.3.17)

The model fitted in this report is a regression-type model, i.e. a fit of a model to the data. As long as the data and model selection are unchanged, the fit will be reproducible.

10.5 Assumptions (TAS-M C.4.18)

The key assumption underlying the model described in this report is that the events being modelled are independent from each other. Where a portfolio contains policy or benefit records, i.e. where one person can have more than one record, deduplication must be used to ensure the validity of the independence assumption.

11. Pensions TAS

This section is designed to help users who have to adhere to the standard for “reserved work” concerning pension schemes, the so-called Pensions TAS [6], laid down by the Board of Actuarial Standards in the United Kingdom. It may be useful for users in other territories.

11.1 Assumptions (Pensions TAS D.2.2)

See Section 9.3.

11.2 Mortality (Pensions TAS D.2.17, D.2.18 and D.2.19)

The mortality rates modelled in this report are historic data and contain no projections. The current mortality rates used in this report are intended to reflect the characteristics of the portfolio outlined in Table 4.3.

11.3 Risks and uncertainty (Pensions TAS E.2.3)

There are three principal sources of risk for the model described in this report:

- Data quality. The model is parameterized to the given data, and so the model can only be as good as the quality of the underlying data.
- Completeness. The model may not incorporate all significant (or financially significant) risk factors.
- Transferability. The model may not be applicable to any other portfolio.

12. Insurance TAS

This section is designed to help users who have to adhere to the standard for insurance liabilities, the so-called Insurance TAS [5], laid down by the Board of Actuarial Standards in the United Kingdom. It may be useful for users in other territories.

12.1 Assumptions (Insurance TAS D.2.2)

See Section 9.3.

13. Environment

This section documents the configuration parameters applying when the model in this report was fitted. These options are under user control in Longevity under the menu option Settings→Configuration.

Table 13.1: Summary of environmental variables

Benefit Switch Age	65
Benefit Type	annuity
Calendar Base Year	2000
Calendar Period Alignment	01
Calendar Period Category Type	01
Calendar Slice Width	0.0000
Decrement Benefit Revaluation Pct	0
Decrement Modelled	DEATH
Discard Exposure Date	Not set
Early Commencement Age	50
Estimate Reserves	YES
Exclude	EXCLUDE NONE
Fitting Step Size	0.1
Fixed Parameters	
Generate Kaplan Meier Curves	YES
Generate Rate Tables	Yes
Generate Residuals File	NO
Generate R Integration File	NO
Generate Survival Curves	No
Geographic Map Shows	ALL EXPERIENCE
Gradient Approximation Step	0.0001
Gradient Calculation Method	DERIVATIVES
Include Data Audit	NO
Late Commencement Age	9999
Maximum Age	105
Minimum Age	60
Modelling End Date	2010-04-01
Modelling Start Date	2004-04-01
Model Time Type	Age
Observation Weighting	equal
Optimisation Target Metric	AIC
Optimiser Mode	NONE
Pension Bands	3
<i>Continued on next page...</i>	

Table 13.1 — Continued

Perform Bootstrap Analysis	NO
Per Member Files Include	All
Rate Table Maximum Duration	0
Rate Table Projection	No - Static
Rate Table Start Age	60
Rate Table Start Year	2011
Reject Beyond Age	105
Reserve Calculation Standard Table	S1PA
Select Period Category Width (years)	0
Select Period Duration (years)	1
Simulated Annealing Changes	5
Simulated Annealing Runs	0
Spouse Benefit Percentage	50
Spouse Female Age Difference (years)	-3
Tracking	101 8377 35370
User Defined Mappings	
Yield Curve Data	8426
Yield Curve Model	Svensson
Yield Model Parameters	10000,500
Version	v2.719 2011-10-27
Executable termination code	0

14. System details

The system settings in place when this report was run are detailed in Table 14.1. They are primarily technical and seldom need to be changed, although if you do want to change them they can be found under Settings→Configuration→Modelling→Technical.

Table 14.1: System parameters

Version and date	v2.719 2011-10-27
ALF	0.0001
AIC multiplier	2
EPS	1e-10
Gradient tolerance	1e-10
Maximum iterations	500
Mode	threaded
Step maximum	0.1
Symmetry	used
Threads	on

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