INSTITUTE AND FACULTY OF ACTUARIES

SUMMARY

September 2017

CA2: Model Documentation, Analysis and Reporting

Paper 2

Health campaign project

Objective

The client, the Department of Health, is considering launching one of two proposed health campaigns – "Get Active" and "Eat Healthily". The purpose of this project is to aid the client in deciding which campaign to undertake.

The objectives of the project are to determine the life expectancies of female and male citizens at ages 65 and 75 exact and assess the impact on those life expectancies of each campaign, using the following improvements to mortality rates:

- *Get Active* campaign – an improvement of 2% per annum at all ages

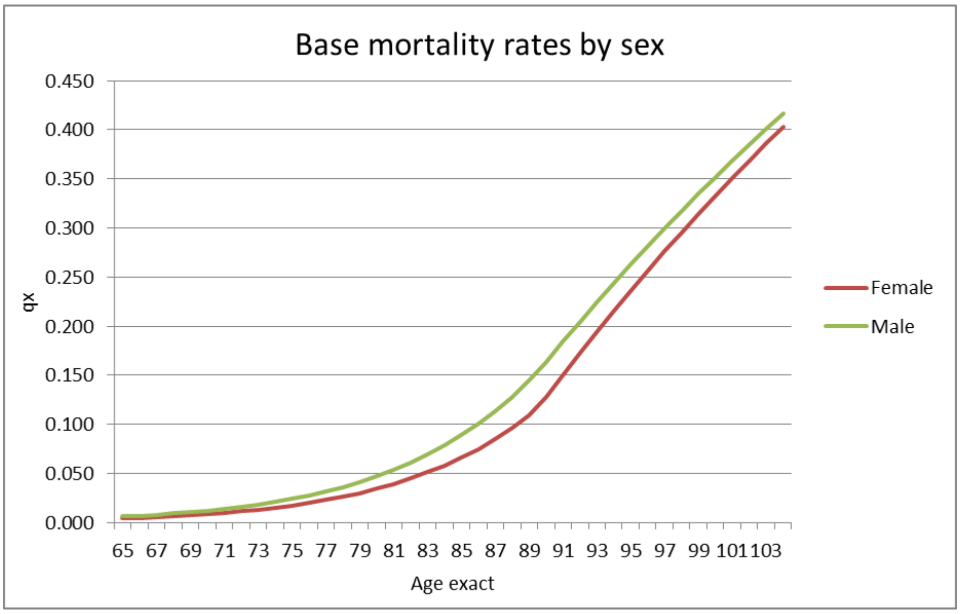
- *Eat Healthily* campaign – an improvement of 4% per annum in the first year, falling to a rate of 1% per annum from the 11th year and remaining at that rate thereafter

The Department of Pensions wishes to investigate the likely impact on the cost of providing pensions and the project therefore estimates the impact on annuity-due factors as a result of each campaign.

Data

Mortality rate data for both females and males, at each age exact from age 65 to 105 inclusive have been provided by the Actuarial Association.

These mortality rates are illustrated in the chart below:



A high level review by eye suggests that the pattern of mortality rates is reasonably smooth for both sexes. The shape (low initially, then increasing more rapidly with age) is also appropriate. This suggests that no data items are missing or materially misstated.

Auto checks have also been performed on the mortality rates to ensure they are always non-negative and don't exceed 1.

Assumptions

The following assumptions were made in the model:

- 105 is the limiting age under all scenarios.
- The mortality rate data provided is correct and contains no errors.
- The mortality improvement factors indicated by the Department of Health are valid.
- The mortality improvements start immediately, i.e. as soon as the health campaigns start.
- **The mortality improvement factors are constant over time.**
- **The mortality improvement factors are the same for both sexes.**
- **The mortality improvement factors follow the same pattern for all ages.**
- **The health campaign effect will be sustained indefinitely.**
- **5% is an appropriate interest rate to use for the annuity due factors.**
- **Annual annuity-due factors at age 65 are sufficient for the Department of Pensions' purposes, i.e. that there is no requirement to consider more complex factors such as those including a spouse's pension or for older ages.**

Method

Base scenario

The probabilities of survival (p_x) are determined as $1 - q_x$ for both sexes and at each age from 65 to 105, and these are used to determine the cumulative probabilities of survival from age 65 to age 65 + t (${}_t p_{65}$), for $t = 1$ to 40. These ${}_t p_{65}$ are calculated as the product of p_x from ages $x = 65$ to $65 + t - 1$.

The expectation of life at 65 years of age for both sexes is calculated by summing the ${}_tp_{65}$ over the range $t = 1$ to 40.

The calculations are then repeated but instead of from 65 years of age the expectations of life are calculated from exact age 75. The cumulative probabilities of survival from age 75 to 75 + t (${}_t p_{75}$), for $t = 1$ to 30 are determined for both sexes, as above. Again the expectation of life from age 75 for both sexes is calculated by summing the ${}_t p_{75}$ over the range $t = 1$ to 30.

The annuity-due factors are calculated recursively for females and males. The value for age 105 is 1 as only one more payment is due for someone age 105 as it is assumed that 105 years is the oldest a citizen can be. Then the annuity factors can be calculated for ages 104 back to 65 by setting the factor equal to 1 plus the value of the annuity for the next year discounted both for the interest rate and for the probability of survival. This gives a series of annuity due factors for females and males back to age 65.

Get Active scenario

In this scenario the base mortality rates are updated to reflect the 2% mortality improvement from ages 65 and 75 separately. This is applied my multiplying each q_x by 1 minus the 2% mortality improvement factor raised to the power of the number of years from the relevant age to x plus 1.

The cumulative probabilities of survival are calculated as per the base scenario and the expectations of life are also calculated as the sum of the cumulative probabilities of survival from the relevant age.

Also the annuity-due factors are updated based on the updated mortality rates that have the mortality improvement factor applied from age 65.

Eat Healthily scenario

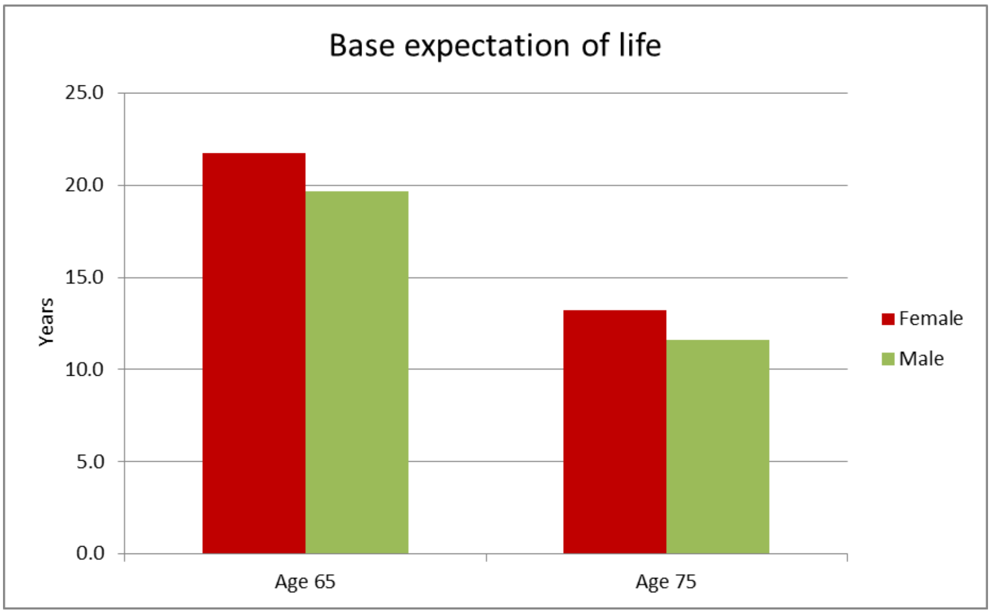
This scenario used an initial mortality improvement factor of 4% per annum, reducing linearly to the long-term mortality improvement rate of 1% per annum after ten years. The mortality improvement factors are updated for year 1 (4%) and year 11 onwards (1%) and there is a linear interpolation to calculate the mortality improvement factors for years 2 to 10. The mortality improvement rate decreases by 0.3% each year.

The adjusted mortality rates from age 65 are calculated by multiplying the original rates by the product of one minus the mortality improvement rates for all the years from age 65 to the relevant age. The same factors can be applied for females or males. A similar approach is used for age 75, using the mortality improvement factors as set out above.

Results

Base scenario

The base scenario expectations of life for 65 and 75 years of age for both sexes are illustrated on the following chart:



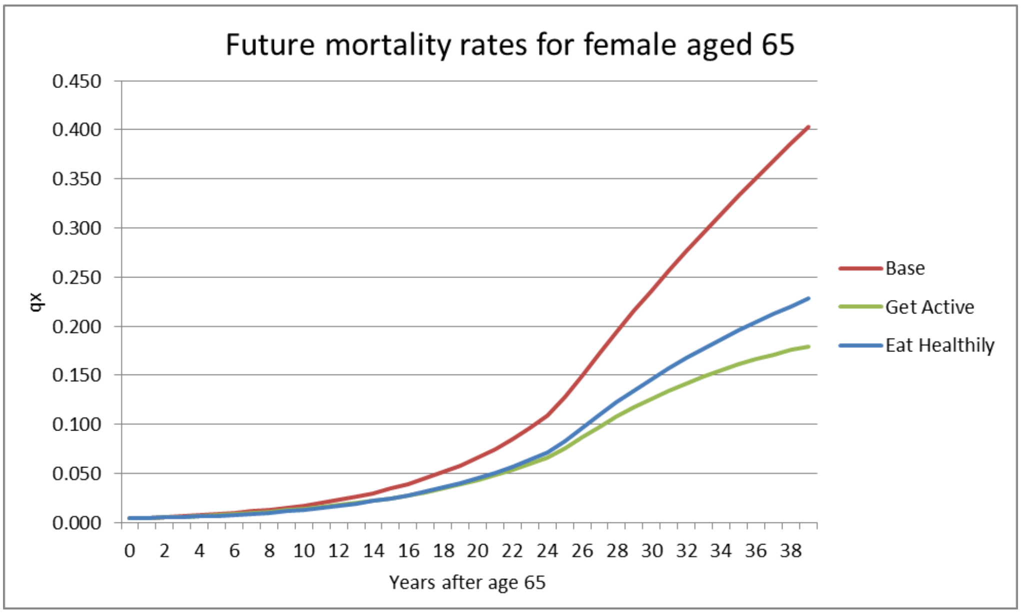
The expectations of life are lower for age 75 compared to age 65 which is to be expected because someone 10 years older will be expected to live for less time. But the reduction in the expectation of life between ages 65 and 75 is less than ten years because there is a likelihood that a 65 year old will die before they reach 75 years of age. So for example, the expectations of life for females at age 65 and 75 are 21.7 years and 13.2 years, respectively, which is a difference of 8.5 years compared to a ten year age gap.

Also we can see that the expectation of life for males is lower than females. This is consistent with the pattern shown in the base mortality rates chart which shows that mortality rates for males are higher than females at all ages.

Scenarios with mortality improvements

The calculations of expectations for life were repeated for females based on the assumed mortality improvements for the *Get Active* and *Eat Healthily* campaigns.

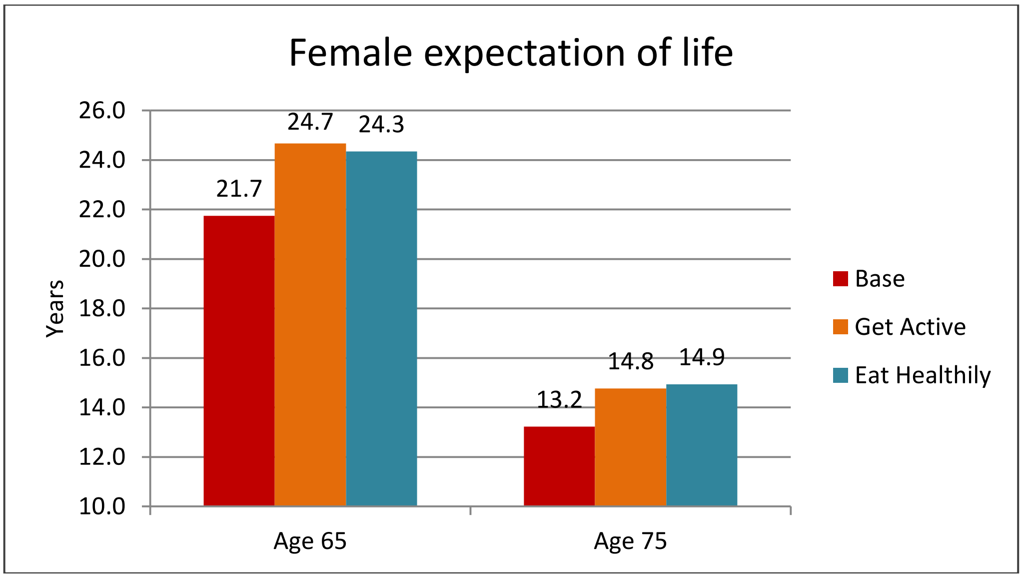
The revised female mortality rates from age 65 with the two mortality improvement assumptions are shown below:



The improvement factors reduce the q_x's at each age and we can see that the *Get Active* rates with a 2% mortality improvement are below the base q_x rates in the graph above, indicating a greater impact on mortality. The rates from the *Eat Healthily* scenario are also lower than the base scenario but they are not as low as the *Get Active* scenario. This is because while the initial mortality improvement rate of 4% is higher than the *Get Active* assumed rate of 2%, it quickly falls below the *Get Active* rate so in the long term the impact of *Eat Healthily* is less significant.

The mortality improvements increase each year as the impact is compounded and this can be observed in the chart above with the difference between the base rates and the rates with mortality improvements increasing over time.

The expectations of life, for females only, for ages 65 and 75 under the base scenario and the two health campaign scenarios are illustrated on the following chart:



Under the health campaign scenarios:

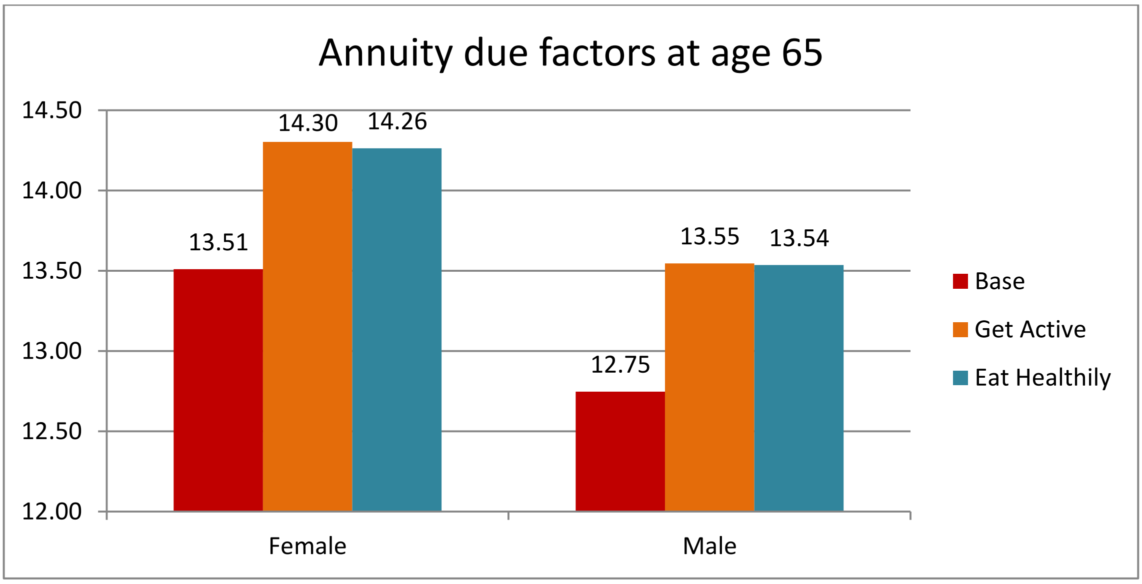
- The expectations of life increase as the assumed mortality rates are lower so the citizens would be expected to live for longer.

- The impact of the mortality improvements is slightly greater for the *Get Active* campaign for 65 year olds but the *Eat Healthily* campaign is slightly greater for 75 year olds. This is because the 65 years olds are more impacted by the long term mortality improvement rate as they are younger and the *Get Active* campaign has the better long term rate.

The impact is illustrated in the table of results below:

	(years)	***Base***	***Get Active***	***Eat Healthily***
Females	**Age 65**	21.7	24.7	24.3
	Age 75	13.2	14.8	14.9
Males	**Age 65**	19.7	22.4	22.2
	Age 75	11.6	13.0	13.2

The chart below sets out the estimated annuity-due factors for both females and males at age 65 under the three scenarios:



We can see that the annuity-due factors increase under both health campaign scenarios because if citizens live longer the present value of an annuity for the rest of their lives is higher. But comparing to the increase in the expectations of lives above the relative impact is smaller because of the effect of discounting of the future payments.

Conclusions

The expected impact of either health campaign will be to increase the expectations of lives for citizens over 65. The *Get Active* campaign is expected to have a slightly bigger impact than the *Eat Healthily* campaign for younger ages but *Eat Healthily* is expected to be slightly better for older ages. The actual outcome will depend on the actual mortality improvements achieved. Also there will be an increase in the present value of future pension liability for the Department of Pensions as a result of the higher annuity-due factors.

Next steps

- Validate the mortality rate data e.g. against another source.
- Check that the mortality rate data obtained is sufficiently up-to-date.
- If necessary, adjust the base mortality rate data for possible changes between the date at which the data was collected and the valuation date.
- If possible, validate the appropriateness of the two health campaigns' mortality improvement claims.
- Check that an interest rate of 5% is appropriate for use for a long term projection.
- Extend the mortality improvements beyond age 105 / remove or increase the limiting age.
- Adjust the model to allow for improvement factors which varies by sex.
- Adjust the model to allow for improvement factors which varies by age.
- Allow for other long term mortality improvement trends in the model, e.g. due to reduced levels of smoking.
- Enhance the model to test implications of the health campaign for morbidity (i.e. health) as well as mortality.
- Consider the impact of combining both campaigns.
- Solve for the improvement factor to different target expectations of life or improvement percentages.
- Sensitivity test the results by using different base mortality rates.
- Sensitivity test the results by using different improvement factors.
- Sensitivity test the interest rate assumption.
- Model the improvement factors stochastically so that a probability distribution of potential results can be produced.
- Test the model against emerging experience going forwards.
- Obtain a peer review of the work done to date.

END OF SUMMARY