Life Insurance Reserves Calculator

R

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1 Project Objectives

Using mortality tables, we want to project required life insurance reserves. To this end, we will make an industry-standard stochastic interest rates model, simulate a fictional portfolio of policyholders, and use CRAN's lifecontingencies package to make values for $A_x n$ and a.

2 The Datasets

The first dataset is a mortality table from the Office of National Statistics (ONS) in the UK (Office of National Statistics, 2025). After cleaning it up using dplyr, we obtain mx, qx, lx, dx, and ex values for the UK. Our second dataset are the yield curves from the Bank of England (Bank of England, 2025). For this investigation, we use the UK implied real spot curve since we want to model the real interest rate in the model, and assert that these are the real required amounts to reserve, which would need to match inflation in the future. In our yield curve dataset, we have implied real rates from 2.5 to 40 years.

3 Stochastic Interest Rate Modelling

In this investigation, we will be using the Vasicek Model:

$$dr_t = a(b - r)dt + \sigma dW_t$$

Where a is a "speed of reversion", quantifying how fast interest rates return to equilibria, b operates as a long-term mean interest rate, σ acts as the constant of volatility, and W_t is standard Brownian motion.

First we start by putting a lagged, differential, and original 2.5 year real yield curve rate into one dataset, and then regressing the change in the differential interest rate on the current rates. We can rewrite the Vasicek model as:

$$dr_t = ab - ar \cdot dt + \sigma dW_t$$

Compared to our regression model:

$$dr_t = \beta_0 + \beta_1 r \cdot dt + \epsilon$$

Which means that:

a is just the second coefficient sign swapped, b is the first coefficient divided by a, and s is the goodness of fit of the residuals.

From our regression, we get that:

$$dr_t = 1.04498(1 - 0.4537031\ r_t)dt + 0.014356dW_t$$

We can now perform the Vasicek simulation

```
vasicek_sim <- function(a, b, s, size) {
  dt <- 1
  r <- numeric(size)
  r[1] <- b

  for (i in 2:size) {
    dW_t <- rnorm(1, mean = 0, sd = sqrt(dt))
    r[i] <- r[i-1] + a * (b - r[i-1]) * dt + s * dW_t
  }

  return(r)
}
```

Figure 1: Vasicek Model R Code

After setting a seed, we can now run a simulation for the next 7 years of interest rates.
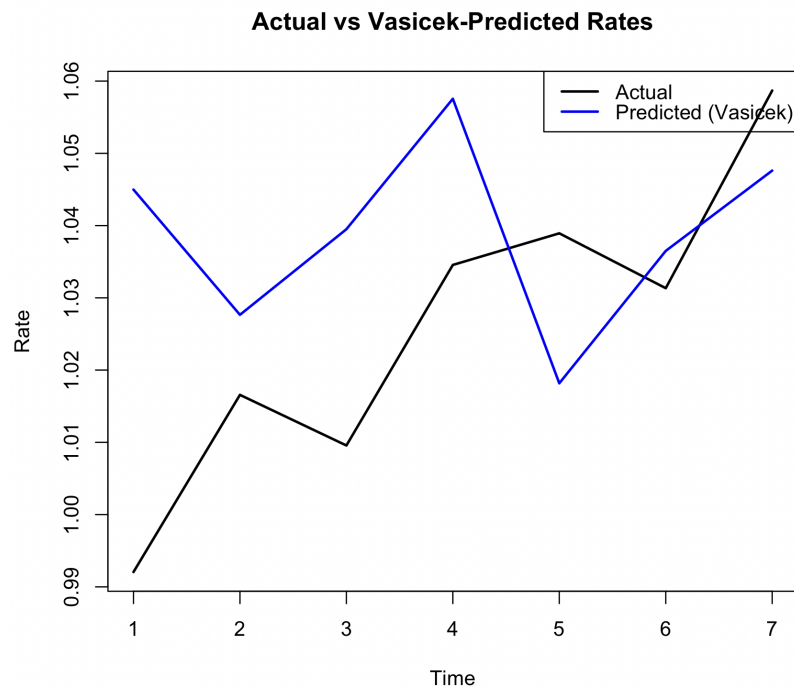

Actual vs Vasicek-Predicted Rates

Figure 2: Future Interest Rate Simulation

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Armed with a set of interest rate projections and mortality rates, all we need to predict insurance rate reserves for a portfolio of policyholders is a portfolio of policyholders. This can easily be simulated using R's random selection features and Monte Carlo sampling. For our portfolio of policyholders, we simulate:

1. An ID,

2. their age,

3. their gender,

4. smoking status,

5. the term of their policy,

6. whether they drive,

7. their sum assured (using a log normal wealth simulation),

8. the starting year of their terms (between 2014 and 2024).

We can now calculate insurance premiums for every person on the portfolio using the lifecontingencies model. We know from the actuarial equivalence principle that:

$$P = \frac{S \times A_x}{a_{[x]:n}}$$

Since we have mortality tables, ages, and terms, we can very easily make a premium calculating function that uses lifecontingencies to calculate A_x and a_x:

```
premiumCalculator <- function(benefit, age, term, table) {

    ## lifecontingencies is happy to calculate A and a for us
    A = Axn(actuarialtable = table, x = age, n = term)

    a = axn(actuarialtable = table, x = age, n = term)

    Premium = benefit * A / a
    return(Premium)
}
```

Figure 3: Premium Calculating function

Since we have both male and female mortality rates, we can also write a small utility to apply specific tables to both genders.
This leaves us with the new portfolio:

Table 1: Policyholder Portfolio with Insurance Premia

ID	Age	Gender	Smoker	Policy Term	Driver	Sum Assured	Policy Start Year	Premium
1	51	female	yes	22	driver	131000	2024	177.0
2	56	male	no	18	driver	146000	2022	295.0
3	39	male	no	11	driver	129000	2014	413.0
4	43	female	no	5	driver	139000	2015	92.6
5	23	female	no	22	driver	209000	2023	26.1

4 Calculating General Reserve Requirements

We now need to evaluate the value of the reserve, based off the principle that the value
of the reserve is the future insurance benefits minus the discounted value of the
insurance premia.

$$V_x = S \times A_{x+t} - P_x \times a_{x+t}$$

Where V_x is the value of the reserve. We can therefore extremely easily write a quick
Reserve Calculator in R:

```
reserveCalculator <- function(benefit, age, term, t, premium, table) {

  remaining_term <- term - t # remaining policy duration
  new_age <- age + t

  if (remaining_term <= 0) {
    return(0)
  }

  ## Same lifecontingencies utilities as before
  A_remaining <- Axn(table, x = new_age, n = remaining_term)
  a_remaining <- axn(table, x = new_age, n = remaining_term)

  reserve <- benefit * A_remaining - premium * a_remaining
  return(reserve)
}
```

Figure 4: Reserve Calculator

We can arbitrarily select a policy term of 10 to see the required reserves for the next
ten years. Doing this, we find that:

1. Ten year premium values: £363,600.20

2. Ten year required reserves: £1,077,670

(These may vary depending on how the function is used since the portfolio generation
could vary depending on what functions are called after the seed is set.)

5 References

Bank of England (2025). *Latest yield curve data*.
Office of National Statistics (2025). *National life tables: UK*.