Politecnico di Milano

Insurance and econometrics

Solvency II project - Group 12

Authors:
Luca Amadori
Lorenzo Bracci
Ludovico Costa

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1 The project

1.1 Text of the project

Consider a simplified insurance company whose assets and liabilities sides are characterized as follows:

ASSETS

- There is a single fund made of equity (80%) and property (20%), $F_t = EQ_t + PR_t$.
- At the beginning ($t = 0$) the value of the fund is equal to the invested premium $F_0 = C_0 = 100,000$.
- **Equity Features:**
  - Listed in the regulated markets in the EEA.
  - No dividend yield.
  - To be simulated with a Risk Neutral GBM ($\sigma = 20\%$) and a time-varying instantaneous rate r.
- **Property Features:**
  - Listed in the regulated markets in the EEA.
  - No dividend yield.
  - To be simulated with a Risk Neutral GBM ($\sigma = 10\%$) and a time-varying instantaneous rate r.

LIABILITIES

- **Contract Terms:**
  - Whole Life policy.
  - **Benefits:**
    * In case of lapse, the beneficiary gets the value of the fund at the time of lapse, with 20 euros of penalties applied.
    * In case of death, the beneficiary gets the maximum between the invested premium and the value of the fund.
  - **Others:**
    * Regular Deduction, RD of 2.20%.
    * Commissions to the distribution channels, COMM (or trailing) of 1.40%.

- **Model Points:**
  - Just 1 model point.
  - Male with insured aged $x = 60$ at the beginning of the contract.
- **Operating Assumptions:**
  - Mortality rates derived from the life table SI2022 (`https://demo.istat.it/index_e.php`).
  - Lapse: flat annual rates $l_t = 15\%$.
  - Expenses: constant unitary (i.e. per policy) cost of 50 euros per year, that grows following the inflation pattern.
- **Economic Assumption:**
  - Risk-free rate r derived from the yield curve (EIOPA IT without VA 31.03.24).
  - Inflation: flat annual rate of 2%.

Other Specifications:

- Time horizon for the projection: 50 years.
- In case of an outstanding portfolio in $T = 50$, let all the people leave the contract with a massive surrender.
- The interest rates dynamic is deterministic, while the equity and property ones are stochastic.

QUESTIONS

1. Code a Matlab/Python script to compute the Basic Solvency Capital Requirement via Standard Formula and provide comments on the results obtained. The risks to be considered are:
   - Market Interest
   - Market equity
   - Market property
   - Life mortality
   - Life lapse
   - Life cat
   - Expense

2. Split the BEL value into its main PV components: premiums (=0), death benefits, lapse benefits, expenses, and commissions.

3. Replicate the same calculations in an Excel spreadsheet using a deterministic projection.

   - Do the results differ from 1? If so, what is the reason behind?
   - For the base case only

     (a) Calculate the Macaulay duration of the liabilities.

     (b) Calculate the sources of profit for the insurance company, deriving its PVFP.

     (c) Check the magnitude of leakage by verifying the equation $MVA = BEL + PVFP$ (i.e. $MVA = BEL + PVFP + LEAK$).

     (d) Sense check the PVFP using a proxy calculation, based on the annual profit and the duration of the contract.

4. Open questions:

   - What happens to the asset and liabilities when the risk-free rate increases/decreases with a parallel shift of, say, 100bps? Describe the effects for all the BEL components.
   - What happens to the liabilities if the insured age increases? What if there were two model points, one male and one female?

1.2 Summary table

RESULTS	MVA	BEL	BoF	ΔBoF	Dur_L
Base	100000	95676.71	4323.28	0	4.75
Rates up	100000	94421.99	5578.00	0	4.73
Rates down	100000	96745.93	3254.06	1069.21	4.76
Equity shock	64600	63714.23	885.76	3437.51	4.82
Property shock	95000	91149.12	3850.87	472.40	4.76
Mortality shock	100000	95834.67	4165.32	157.95	4.71
Lapse up	100000	96309.82	3690.17	633.10	3.07
Lapse down	100000	95681.55	4318.44	4.83	8.49
Lapse mass	100000	97725.38	2274.61	2048.66	2.46
Catastrophe	100000	95683.32	4316.67	6.60	4.74
Expenses	100000	95723.44	4276.56	46.72	4.75
BSCR	5362.87	-	-	-	-

Table 1: Summary table of the results of the Matlab script

Comparing the results between the Matlab and the Excel we notice an important thing: the numbers are very similar, in the sense that the magnitude of the the variables considered are very similar.

2 Specifications about the calculations

In the computations we used the time index t, which represents the year of interest and goes from 0 to $T = 50$.

2.1 Formulas

2.1.1 Rates and discounts

The first quantities that we computed are the spot rates (in continuous capitalization), the discount factors and the forward discount factors, using the following formulas:

$$r_{spot}(0,t) = ln(1 + r(t))$$

$$B(0,t) = e^{-r_{spot}(0,t)\cdot t}$$

$$B(0;t,t+1) = \frac{B(0,t+1)}{B(0,t)}$$

where $r(t)$ is the risk free rate derived from the EIOPA IT yield curve from 31.03.24 (`https://www.eiopa.europa.eu/tools-and-data/risk-free-interest-rate-term-structures_en`).

2.1.2 Life tables

For the life tables we used the ISTAT data from 2023 (`http://dati.istat.it/Index.aspx?DataSetCode=DCIS_MORTALITA1&Lang=en#`). In particular we used the table relative to the 60 years old Italian male. For our calculations we used the "probability of death (per thousand) q_x" (which we will call q_x^T) column to compute mortality probability q_x (which is the probability that a life aged x dies in the following year), surviving probability p_x (which is the probability that a life aged x survives in the following year) and cumulative surviving probability ${}_tp_x$ (which is the probability that a life aged x will survive to age $x + t$):

$$q_x = \frac{q_x^T}{1000}$$

$$p_x = 1 - q_x$$

$${}_tp_x = {}_{t-1}p_x \cdot p_x$$

where

$${}_0p_x = 1$$

since the probability of surviving to age x starting from age x is obviously 1.

2.1.3 Fund

Then we computed the value of the equity throughout the years. In the Excel file we used:

$$EQ_t = EQ_{t-1} \cdot \frac{1}{B(0; t-1, t)} \cdot (1 - RD)$$

whereas in the Matlab file, we computed it by using a Monte Carlo simulation on the evolution of the equity, which follows a GBM. In particular, at each year we use the following relation:

$$EQ_t = EQ_{t-1} \cdot e^{(r(0;t-1,t) - \frac{\sigma^2}{2}) + \sigma \cdot Z} \cdot (1 - RD)$$

where $r(0; t-1, t)$ is the forward rate between $t-1$ and t, while Z is the simulated Gaussian random variable and σ is the given volatility. Notice that each year we take away a percentage equal to RD from the evolution of the equity. This represents the margin that the insurance company makes. We used the same approach for the computation of the property. Then we computed the evolution of the fund as the sum of equity and property.

2.1.4 Probabilities

We computed 3 probabilities for each year: the lapse probability (which is the probability that the insured will lapse during the year $[t, t+1]$), the death probability (which is the probability that the insured will die during the year $[t, t+1]$) and the probability that the insured is still in the contract at the end of the year t.

$$P_{lapse}(t) = {}_tp_x \cdot p_{x+t} \cdot (1 - l)^t \cdot l$$

With this formula we are asking that the insured survives until year t, that he survives in the following year, that he didn't lapse in the previous years and that he will lapse in the following year.

$$P_{death}(t) = {}_tp_x \cdot (1 - l)^t \cdot q_{x+t}$$

This formula is very similar to the previous one since we are asking that the insured is alive at the beginning of the year, that he didn't lapse in the previous years and that he will die in the following year.

$$P_{in}(t) = P_{in}(t-1) \cdot (1 - q_{x+t}) \cdot (1 - l)$$

where l=0.15 and $P_{in}(-1)$=1. With this last formula we are asking that the insured was in the contract at the end of the year before and that he will not die or lapse in the following year.

2.1.5 Benefits

In the analysis of the benefits, we compute two main values throughout the years related to the possibility of lapse or death of the insured:

$$Ben_{lapse}(t) = P_{lapse}(t) \cdot (F_t - pen) \cdot B(0,t)$$

where pen is the penalty fee equal to 20€.

$$Ben_{death}(t) = P_{death}(t) \cdot max(F_t, F_0) \cdot B(0,t)$$

where F_t represents the value of the fund at time t.

2.1.6 Liabilities

We split the liabilities in 4 components: Lapse, Death, Commission and Expenses. The first two components are equal to the benefits that we guarantee to the insurer in case of lapse or death respectively. It remains to compute the last two components: we assume that the commissions are paid at the end of each year (apart from the first one) since they are related to the evolution of the fund.

$$Comm(t) = \frac{F_t}{1 - RD} \cdot COMM \cdot B(0,t) \cdot P_{in}(t-1)$$

where $COMM$ is the commission percentage equal to 1.40%. In this formula we are taking the value of the fund and dividing it by $1 - RD$ so that we obtain the value of the fund before the Regular Deduction. Then we multiply this value for the commission percentage, for the discount and finally for the probability that the insured is still in the contract at the beginning of the year. For the expenses we have the following formula:

$$Exp(t) = expenses(t) \cdot B(0,t) \cdot P_{IN}(t-1)$$

where $expenses(t)$ is the cost per policy at time t, after considering the inflation.
In addition, we computed the values of best estimate liabilities by summing over the years the benefits, the commissions and the expenses.

2.1.7 BoF and PVFP

In order to compute the BoF, we used the following:

$$BoF = F_0 - liabilities_{tot}$$

where $liabilities_{tot}$ is the total value of the liabilities, computed by summing the best estimate liabilities. Notice that F_0 is always equal to 100.000€ except for the "Equity shock" and "Property shock" cases.

2.2 BSCR

The Basic Solvency Capital Requirement (BSCR) aggregates various risks that a company may encounter over its operations. These risks can be categorized into two modules: Market Risk (including equity, property, and interest rate risks) and Life Risk (covering mortality, lapse, expenses, and CAT risks). We tried to assess how these risks impact on our Basic own Funds (BoF), by calculating the difference between such value in the base case with respect to the ones obtained in the stressed scenarios. When this difference is negative, we set it to 0 as it doesn't affect our risks evaluation. From these differences, we are then able to compute the Solvency Capital Requirements (SCRs) for each source of risk. These SCRs are subsequently aggregated to derive the final result, which is the BSCR. We have that

Market Risk

$$SCR_{mkt} = \sqrt{\sum_{i,j} Corr_{i,j} \cdot SCR_i \cdot SCR_j}$$

$$Corr_{mkt} = \begin{bmatrix} 1 & A & A \\ A & 1 & 0.75 \\ A & 0.75 & 1 \end{bmatrix}$$

where $A = 0$ if exposed to IR_{up} and $A = 0.5$ if exposed to IR_{down}. In our case we will see that $A = 0.5$.

Life Risk

$$SCR_{life} = \sqrt{\sum_{i,j} Corr_{i,j} \cdot SCR_i \cdot SCR_j}$$

$$Corr_{life} = \begin{bmatrix} 1 & 0 & 0.25 & 0.25 \\ 0 & 1 & 0.5 & 0.25 \\ 0.25 & 0.5 & 1 & 0.25 \\ 0.25 & 0.25 & 0.25 & 1 \end{bmatrix}$$

BSCR:

$$BSCR = \sqrt{\sum_{i,j} Corr_{i,j} \cdot SCR_i \cdot SCR_j}$$

$$SCR = [SCR_{mkt} \quad SCR_{life}]$$

$$Corr_{BSCR} = \begin{bmatrix} 1 & 0.25 \\ 0.25 & 1 \end{bmatrix}$$

2.3 Martingale test

As mentioned before, in the Matlab file the evolution of equity and property follows a Geometric Brownian Motion, which is a martingale. The evolution of the fund is the sum of equity and property so that it is itself a martingale, since the sum of two martingales is a martingale. Knowing this we can see if our computations are correct by doing a "Martingale Test". We need to see the evolution of equity and property without the contribution of the regular deduction so that the relation needed is:

$$EQ_t = EQ_{t-1} \cdot \frac{1}{B(0; t-1, t)}$$

and the same for the property evolution. Now we can compute the mean value of the fund for $t = 50$ over all simulations and discount it to the present ($t = 0$) (we will call this value MFVD). We should obtain that the value is equal to the invested premium, which is 100000€. In the following graoh we show the mean value of the fund discounted over the years.

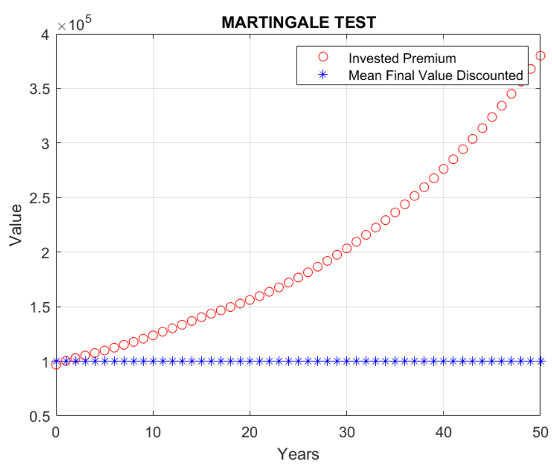

Figure 1: Value of the fund discounted over the years

As shown in the above graph we obtain a number that is very close to the invested premium, since we see that the mean value of the fund discounted over the years converges to the invested premium. By varying the number of the Monte Carlo Simulation we can get different values of the MFVD and we can construct an error on this value:

$$error = 1 - \frac{MFVD}{investedPremium}$$

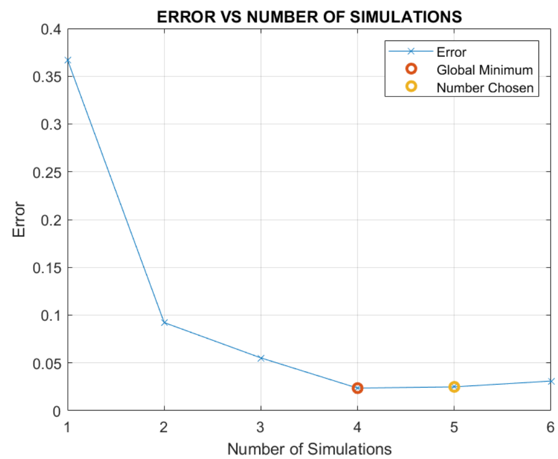

Figure 2: The x axis is the power to which 10 is elevated

We see that the value of this error is always positive and in particular the global minim is reached for 10.000 simulations. We choose instead to do 100.000 simulations since 10.000 seemed too small for a Monte Carlo Simulation and because the error value is very close between the two cases.

2.4 Market interest

The interest rate shock consists in a shift of the yield rate curve, that can be upwards or downwards. This shock affects both the assets and liabilities present value, since they are sensitive to discount factors changes. In our case, as we can see from Table 1, the scenario in which the risk is more impactful is when the rates are lowered. In particular, the main factor which contributed to the increase of the liabilities are the death benefits: this happens since the insurance company has to pay the maximum between the value of the fund and the invested premium, that in this scenario is always the second case. For this reason we fix the ΔBoF^{IR}_{down} as the capital requirement in the market interest case.

2.5 Market equity

The second stressed scenario is the one in which the equity assets price drastically decreases right after the beginning of the contract. This situation can be related to a possible sudden market crisis, that leads to changes in the value of both assets and liabilities. Of course we expect this shock to heavily reduce the value of the BoF, as our main source of income is directly related to such quantity; and as a matter of fact the ΔBoF_{equity} is the highest value among all stressed cases.

2.6 Market property

This scenario is simulated similarly to the previous one, but here what we modify is the property of interest. Considering that the magnitude of the shock is the half of the equity case, and knowing that only 20% of the fund is constituted by the property, the value of the $\Delta BoF_{property}$ is reasonably lower with respect to the previous one, but still relevant.

2.7 Life mortality

The mortality risk derives from potential inaccuracies in calculating death mortality rates or from unforeseen increases in the trend of this parameter. This situation results in a higher present value of liabilities, as the likelihood of dying year after year exceeds the originally projected rates (the death benefits liabilities increase). Consequently, the present values of benefits payable to policyholders increase due to the shorter time intervals between the present and the expected death dates. To model this risk, we introduce a scenario where mortality rates increase by 15%. Naturally, this perturbation reduces the required amount of BoF, as the potential liabilities are greater.

2.8 Life lapse

A different risk is the change of the annual lapse rate. In particular, we consider an increase up to 22.5% and a decrease up to 7.5% of the yearly lapse rate. It is reasonable to expect an increase of the benefits in case of lapse when such event occurs with a higher probability, and the vice versa is also true; this is reflected in a positive ΔBoF in case of lapse up, which we can observes in our result. On the other hand we see a null ΔBoF in case of lapse down, as forecast.
Also, we consider the case in which there is a lapse mass shock, i.e. there is a massive lapse rate of 40% only in the first year. A notable observation is that, even though the lapse mass shock is an increase of the lapse rate of the first year only, ΔBoF in this case is bigger than the one of the lapse up case. This is because the magnitude of the shock is significant, and in the event of policy lapse, the resulting amount is not heavily discounted.

2.9 Life CAT

As in the case of the mortality we expect the BoF to decrease and the ΔBoF to be positive, but the results don't change a lot with respect to the base case since the catastrophe consists in the increase of the first cell of the vector of mortalities of just 0.15%.

2.10 Expenses

This final stress case requires a change of the inflation rate and the value of the expenses. Again, the results are an increase in the liabilities, a decrease in the BoF and a positive ΔBoF, but as in the previous case all this numbers are very small with respect to the base case since the shock is not so significant.

3 Deterministic calculations

In the deterministic calculation, we do not consider anymore the stochastic dynamics of the equity and the property. The results are

RESULTS	MVA	BEL	BoF	ΔBoF	Dur_L
Base	100000	96520.32	3479.67	0	4.68
Rates up	100000	96504.13	3495.86	0	4.68
Rates down	100000	96850.00	3150.00	329.67	4.70
Equity shock	64600	64650.35	-50.34	3530.02	4.78
Property shock	95000	91910.05	3089.94	389.73	4.68
Mortality shock	100000	96551.62	3448.37	31.29	4.64
Lapse up	100000	97727.62	2272.37	1207.30	3.06
Lapse down	100000	93984.57	6015.43	0	8.15
Lapse mass	100000	98172.00	1828.00	1651.67	2.43
Catastrophe	100000	96525.65	3474.34	5.32	4.67
Expenses	100000	96567.05	3432.95	46.72	4.68
BSCR	4717.13	-	-	-	-

Table 2: Summary table of the results of the Excel

Now we can compare the results using the Matlab and the Excel tables. What we can see is that the magnitude of the results doesn't change too much between the two cases. To better understand the variations between the deterministic and the stochastic case we can construct 4 bar plots to see which result changes more:

$$plotValue = \frac{excelValue - matlabValue}{matlabValue}$$

Using this formula we see how much the Excel values differ from the Matlab ones.

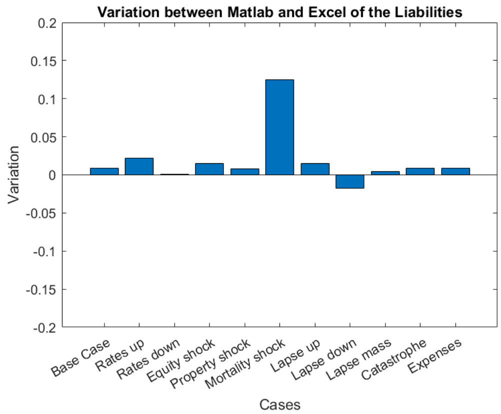

Figure 3: Liabilities Variation

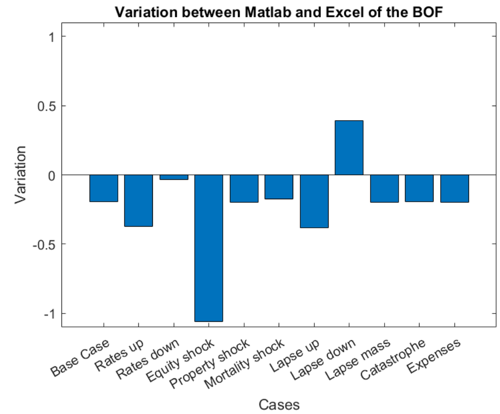

Figure 4: BOF Variation

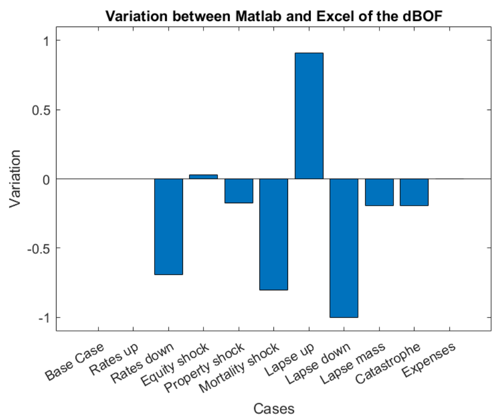

Figure 5: dBOF Variation

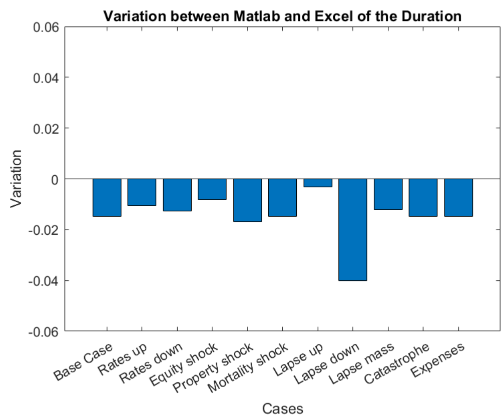

Figure 6: Duration Variation

By looking at the graphs we can see that the liabilities and the duration between the two cases are very similar since the variations are very small. What seems to change more are BoF and ΔBoF. To see even better why the results don't change too much between the two cases we can plot the evolution of the fund in the deterministic and stochastic case (the evolution of the stochastic case is obtained by doing the mean of the evolution over all simulations).

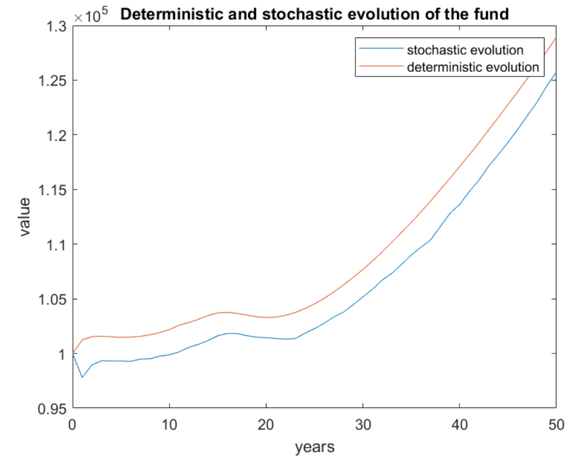

Figure 7: fund evolution

We can clearly see that the behaviour of the fund in the two cases is very similar, hence we obtain very similar results.

3.1 PVFP and leakage

We computed the yearly gains of the insurance company and the losses linked to commissions and expenses.

$$Gain(t) = \frac{F_t}{1 - RD} \cdot RD \cdot B(0,t) \cdot P_{in}(t-1)$$

This quantity is what we previously called the margin of the insurance company.

$$Loss_{ext}(t) = Comm(t) + Exp(t)$$

In order to check the accuracy of our calculations, we also computed the leak as

$$LEAK = \sum_{t=0}^{t=50} (Gain(t) - Loss_{ext}(t)) - liabilities_{tot} - F_0$$

We obtain a very low value for the leak, that is 16.38€. This indicates that our computations and assumptions are reasonable.

Now we can try to sense check the result of the PVFP to understand if our numbers are correct. In order to do so we can say that:

$$PVFP \simeq (MEF \cdot (RD - COMM) - MEE) \cdot MPI \cdot 50$$

where

- MEF = Mean Evolution of the Fund, which is the mean of the deterministic evolution of the fund. By multiplying this value for (RD - COMM) we compute the mean profit of the insurance company
- MEE = Mean Evolution of the Expenses, which is the mean of the evolution of the expenses
- $MPI = (1 - l) \cdot (1 - MPD)$, where MPD is the Mean Probability of Death (mean of q_x) and MPI is the Mean Probability In (mean probability of being in the contract)

With this formula we get the mean annual value of the profit of the insurance company and we multiply it by 50, obtaining the mean profit over the time span of the contract. We obtain a value of 4023.27€, which is very close to the real value.

4 Open questions

4.1 First open question

We start answering the first question by plotting the rates, in order to have an idea of how our results will change.

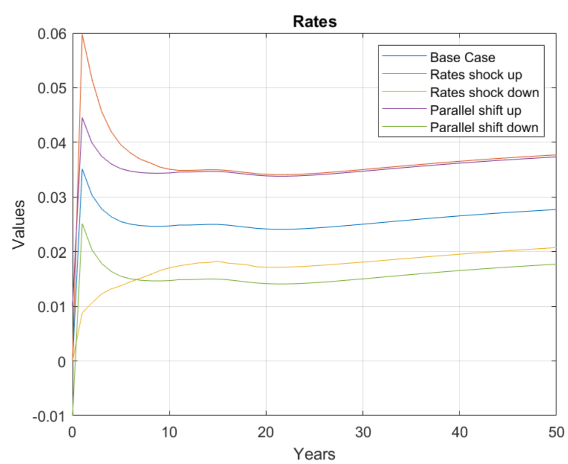

Figure 8: Rates in different cases

Looking at the plot we can notice that by adding 100 basis points to the rates of the base case we obtain a curve that is very similar to the "rates shock up" case: the two curves at the beginning have different values but from the tenth years onwards they are almost indistinguishable. By this outcomes we expect that the results in the two cases will be almost the same. Indeed the evolution

RESULTS	LAPSE	DEATH	COMMISSION	EXPENSES
Rates up	83055.10	6573.24	6590.27	285.52
100 bps up	83054.88	6573.24	6590.27	289.47

Table 3: Confronting the results

of equity and property is very similar in the two cases and this holds also for the BEL components.

Going back to the plot of the rates we can notice that subtracting 100 basis points to the base case curve we obtain a curve that is very similar to the "rate shock down" one. In the case before the two curves were very similar also in the shape, now they are more different, but the magnitude of the rates is very close so that we expect similar results. In this case the evolution of the fund is less similar between the two cases than the previous scenario but the BEL components are again very similar.

RESULTS	LAPSE	DEATH	COMMISSION	EXPENSES
Rates down	83053.48	6888.67	6590.27	317.56
100 bps down	83053.52	6977.60	6590.27	317.61

Table 4: Confronting the results

4.2 Second open question

If the insured age increase we will have a decrease in the liabilities since we will consider less years in our computations. For example, if the insured age goes to 70 years old we will consider 10 years less than before and the liabilities will go from 96520.32€ to 13950.83€. Moreover, if we consider two model points, one male and one female, we will have also here a decrease in the liabilities: this is because the death probability decreases if we consider male and female in the population. Indeed we can compare the results:

RESULTS	LAPSE	DEATH	COMMISSION	EXPENSES
one model point	83054.24	6573.24	6590.27	302.57
two model point	84392.38	5067.98	6696.45	307.20

Table 5: Confronting the results

and we can notice that the value that changes more is the death liabilities.

5 Matlab code

In this section we show the Matlab code: the functions mentioned are not reported but it is clear by their name which is their purpose.

```
clear all
clc
T = 50;
numSimulation = 1e5;
format long

ASSIGNEMENT DATA
ASSETS
equityPercentage = 0.80;
propertyPercentage = 0.20;
investedPremium = 100000;
equityValue = equityPercentage*investedPremium;
propertyValue = propertyPercentage*investedPremium;
sigmaEquity = 0.20;
sigmaProperty = 0.10;
LIABILITIES
penaltyLapse = 20;
RD = 0.0220;
COMM = 0.0140;
pLapse = 0.15;
expensesYear = 50;
inflationRate = 0.02;

BASE CASE
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
```

```
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_BASE_CASE = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
DURATION_BASE_CASE = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
PLOT
opts = spreadsheetImportOptions('NumVariables',1);
opts.Sheet = 5;
```

```
opts.DataRange = 'R3:R53';
opts.VariableNames(1) = {'FUND'};
opts = setvartype(opts,'FUND',{'double'});
temp = readtable(fileName, opts);
fundEvolotuionDeterministic = temp.FUND;

fg = figure(1);
clf(fg)
hold off
plot(years, mean(fundEvolution, 2));
hold on
plot(years, fundEvolotuionDeterministic)
legend('stochastic evolution', 'deterministic evolution')
title('Deterministic and stochastic evolution of the fund')
xlabel('years')
ylabel('value')

RATES SHOCK UP
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'G4:K54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
```

```
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_SHOCK_UP = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_SHOCK_UP = max(BOF_BASE_CASE - BOF_SHOCK_UP, 0)
DURATION_SHOCK_UP = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

RATES SHOCK DOWN
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'M4:Q54';
opts.VariableNames(1) = {'YEAR'};
```

```
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
```

```
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_SHOCK_DOWN = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_SHOCK_DOWN = max(BOF_BASE_CASE - BOF_SHOCK_DOWN, 0)
DURATION_SHOCK_DOWN = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

EQUITY SHOCK
ASSETS
shock = 0.39;
symmetricAdjustment = 0.0525;
equityShocked = equityValue*(1-shock-symmetricAdjustment);
investedPremiumShocked = propertyValue + equityShocked;
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
```

```
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityShocked, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeProperty(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_EQUITY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremiumShocked)
dBOF_EQUITY = max(BOF_BASE_CASE - BOF_EQUITY, 0)
DURATION_EQUITY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

PROPERTY SHOCK
ASSETS
```

```
shock = 0.25;
propertyShocked = propertyValue*(1-shock);
investedPremiumShocked = propertyShocked + equityValue;
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
```

```
propertyEvolution = computeEquity(T, propertyShocked, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_PROPERTY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremiumShocked)
dBOF_PROPERTY = max(BOF_BASE_CASE - BOF_PROPERTY, 0)
DURATION_PROPERTY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

MORTALITY SHOCK
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
```

```
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'G3:K53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_MORTALITY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_MORTALITY = max(BOF_BASE_CASE - BOF_MORTALITY, 0)
```

```
DURATION_MORTALITY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

LAPSE SHOCK UP
LIABILITIES
shock = 1.5;
lapseShocked = min(pLapse*shock, 1);
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
```

```
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, lapseShocked, pxCumulative, years);
death = deathProbabilities(T, qx, lapseShocked, pxCumulative, years);
in = inProbabilities(T, qx, lapseShocked, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_LAPSE_UP = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_LAPSE_UP = max(BOF_BASE_CASE - BOF_LAPSE_UP, 0)
DURATION_LAPSE_UP = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

LAPSE SHOCK DOWN
LIABILITIES
shock = 0.5;
lapseShocked = max(pLapse*shock, pLapse-0.2);
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
```

```
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, lapseShocked, pxCumulative, years);
death = deathProbabilities(T, qx, lapseShocked, pxCumulative, years);
in = inProbabilities(T, qx, lapseShocked, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
```

```
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_LAPSE_DOWN = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_LAPSE_DOWN = max(BOF_BASE_CASE - BOF_LAPSE_DOWN, 0)
DURATION_LAPSE_DOWN = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

LAPSE SHOCK MASS
LIABILITIES
shock = 0.4;
lapseShocked = pLapse+shock;
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
```

```
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = zeros(T+1,1);
lapse(1) = px(1)*lapseShocked;
lapse(2:end) = pxCumulative(1:end-1).*px(2:end).*(1-pLapse).^(years(2:end)-1).*
    pLapse.*(1-lapseShocked);

death = zeros(51,1);
death(1) = qx(1);
death(2:end) = pxCumulative(1:end-1).*qx(2:end).*(1-pLapse).^(years(2:end)-1).*(1-
    lapseShocked);

in = zeros(T+1,1);
in(1) = (1-qx(1))*(1-lapseShocked);
for i = 2:T+1
    in(i) = in(i-1)*(1-qx(i))*(1-pLapse);
end
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_LAPSE_MASS = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_LAPSE_MASS = max(BOF_BASE_CASE - BOF_LAPSE_MASS, 0)
DURATION_LAPSE_MASS = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
```

```
CATASTROPHE
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'N3:R53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
```

```
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
BOF
BOF_CATASTROPHE = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_CATASTROPHE = max(BOF_BASE_CASE - BOF_CATASTROPHE, 0)
DURATION_CATASTROPHE = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

EXPENSES
expensesShock = 0.1;
expensesYearShocked = expensesYear*(1+expensesShock);
inflationShock = 0.01;
inflationRateShocked = inflationRate + inflationShock;
TERM STRUCTURE
fileName = 'PROGETTO';
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 2;
opts.DataRange = 'A4:E54';
opts.VariableNames(1) = {'YEAR'};
opts.VariableNames(2) = {'RATES'};
opts.VariableNames(3) = {'SPOTRATES'};
opts.VariableNames(4) = {'DISCOUNTS'};
opts.VariableNames(5) = {'FORWARD'};
opts = setvartype(opts,'YEAR',{'double'});
opts = setvartype(opts,'RATES',{'double'});
opts = setvartype(opts,'SPOTRATES',{'double'});
opts = setvartype(opts,'DISCOUNTS',{'double'});
opts = setvartype(opts,'FORWARD',{'double'});

temp = readtable(fileName, opts);
```

```
years = temp.YEAR;
rates = temp.RATES;
spotRates = temp.SPOTRATES;
discounts = temp.DISCOUNTS;
forward = temp.FORWARD;
LIFE TABLE
opts = spreadsheetImportOptions('NumVariables',5);
opts.Sheet = 4;
opts.DataRange = 'A3:E53';
opts.VariableNames(1) = {'AGE'};
opts.VariableNames(2) = {'QXTHOUSEND'};
opts.VariableNames(3) = {'QX'};
opts.VariableNames(4) = {'PX'};
opts.VariableNames(5) = {'PXCUMULATIVE'};
opts = setvartype(opts,'AGE',{'double'});
opts = setvartype(opts,'QXTHOUSEND',{'double'});
opts = setvartype(opts,'QX',{'double'});
opts = setvartype(opts,'PX',{'double'});
opts = setvartype(opts,'PXCUMULATIVE',{'double'});

temp = readtable(fileName, opts);
age = temp.AGE;
qx = temp.QX;
px = temp.PX;
pxCumulative = temp.PXCUMULATIVE;
SIMULATION
equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
fundEvolution = equityEvolution + propertyEvolution;
PROBABILITIES
lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
in = inProbabilities(T, qx, pLapse, pxCumulative, years);
BENEFITS
benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
OTHER
expensesYearEvolution = computeExpenses(T, expensesYearShocked,
    inflationRateShocked);
LIABILITIES
[lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
totalLiabilities = sum(BEL)
```

```
BOF
BOF_EXPENSES = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
dBOF_EXPENSES = max(BOF_BASE_CASE - BOF_EXPENSES, 0)
DURATION_EXPENSES = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

BASIC SOLVENCY CAPITAL REQUIREMENT
MARKET
if dBOF_SHOCK_UP > dBOF_SHOCK_DOWN
    a = 0;
else
    a = 0.5;
end
marketCorrelationMatrix = [1 a a; a 1 0.75; a 0.75 1];
dBOF_MARKET = max(dBOF_SHOCK_UP, dBOF_SHOCK_DOWN);
marketSCR = [dBOF_MARKET; dBOF_EQUITY; dBOF_PROPERTY];
totalMarket = sqrt(marketSCR'*marketCorrelationMatrix*marketSCR)
LIFE
lifeCorrelationMatrix = [1 0 0.25 0.25; 0 1 0.5 0.25; 0.25 0.5 1 0.25; 0.25 0.25
    0.25 1];
dBOF_LAPSE = max([dBOF_LAPSE_UP; dBOF_LAPSE_DOWN; dBOF_LAPSE_MASS]);
lifeSCR = [dBOF_MORTALITY; dBOF_LAPSE; dBOF_EXPENSES; dBOF_CATASTROPHE];
totalLife = sqrt(lifeSCR'*lifeCorrelationMatrix*lifeSCR)
TOTAL
totalCorrelationMatrix = [1 0.25; 0.25 1];
totalSCR = [totalMarket; totalLife];
BSCR = sqrt(totalSCR'*totalCorrelationMatrix*totalSCR)

MARTINGALE TEST
equityEvolutionTest = computeEquity(T, equityValue, forward, 0, numSimulation,
    sigmaEquity);
propertyEvolutionTest = computeProperty(T, propertyValue, forward, 0,
    numSimulation, sigmaProperty);
fundEvolutionTest = equityEvolutionTest + propertyEvolutionTest;

meanFundFinal = mean(fundEvolutionTest(T+1, :));
discountsTest = discounts(T+1)./discounts;
meanFundFinalDiscounted = meanFundFinal*discountsTest;

fg = figure(2);
clf(fg)
hold off
plot(years, meanFundFinalDiscounted, 'or')
hold on
plot(years, investedPremium*ones(T+1), '*b')
grid on
title('MARTINGALE TEST')
```

```
legend('Invested Premium', 'Mean Final Value Discounted')
ylabel('Value')
xlabel('Years')

NUMBER OF SIMULATIONS
for i = 1:6
    numSimulation = 10^i;
    equityEvolutionTest = computeEquity(T, equityValue, forward, 0, numSimulation,
     sigmaEquity);
    propertyEvolutionTest = computeProperty(T, propertyValue, forward, 0,
    numSimulation, sigmaProperty);
    fundEvolutionTest = equityEvolutionTest + propertyEvolutionTest;

    meanFundFinal = mean(fundEvolutionTest(T+1, :));
    discountsTest = discounts(T+1)./discounts;
    meanFundFinalDiscounted = meanFundFinal*discountsTest;
    error(i) = 1 - meanFundFinalDiscounted(1)/investedPremium;
end

fg = figure(3);
clf(fg)
hold off
plot((1:6), error, 'x-')
grid on
hold on
plot(4, error(4), 'o', 'LineWidth', 2)
plot(5, error(5), 'o', 'LineWidth', 2)
title('ERROR VS NUMBER OF SIMULATIONS')
xlabel('Number of Simulations')
ylabel('Error')
legend('Error', 'Global Minimum', 'Number Chosen')
```