

POLITECNICO DI MILANO



POLITECNICO
MILANO 1863

INSURANCE AND ECONOMETRICS

Solvency II project - Group 12

Authors:

Luca AMADORI

Lorenzo BRACCI

Ludovico COSTA

May 17, 2024

Contents

1	The project	3
1.1	Text of the project	3
1.2	Summary table	5
2	Specifications about the calculations	6
2.1	Formulas	6
2.1.1	Rates and discounts	6
2.1.2	Life tables	6
2.1.3	Fund	7
2.1.4	Probabilities	7
2.1.5	Benefits	8
2.1.6	Liabilities	8
2.1.7	BoF and PVFP	8
2.2	BSCR	9
2.3	Martingale test	10
2.4	Market interest	11
2.5	Market equity	11
2.6	Market property	12
2.7	Life mortality	12
2.8	Life lapse	12
2.9	Life CAT	12
2.10	Expenses	13
3	Deterministic calculations	13
3.1	PVFP and leakage	15
4	Open questions	16
4.1	First open question	16

4.2	Second open question	17
5	Matlab code	17

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 ${}_t p_x$ (which is the probability that a life aged x will survive to age $x + t$):

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

$$p_x = 1 - q_x$$

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

where

$${}_0 p_x = 1$$

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 .

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

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.

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

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 1000000€. In the following graph we show the mean value of the fund discounted over the years.

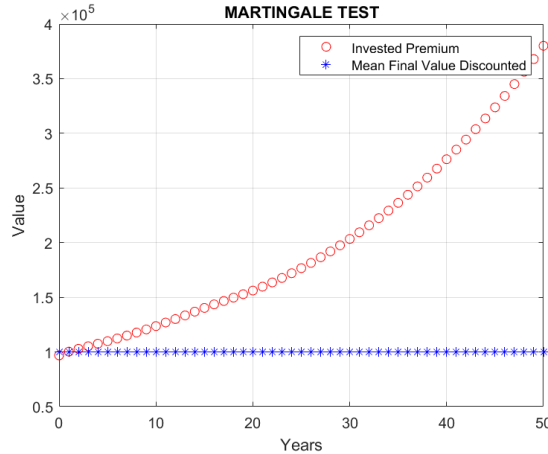


Figure 1: Value of the fund discounted over the years

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:

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

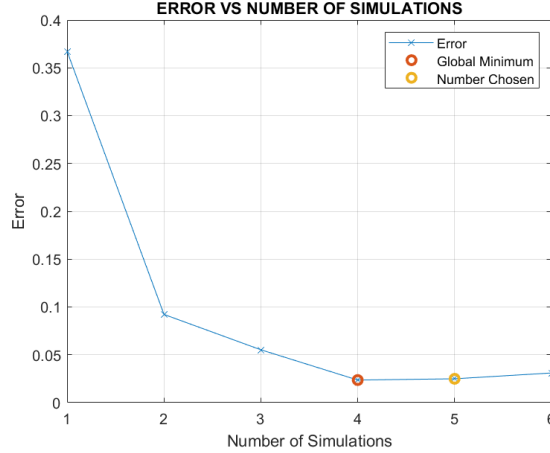


Figure 2: The x axis is the power to which 10 is elevated

We see that the value of this error is always positive and in particular the global minimum 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_{down}^{IR} 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 observe 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.

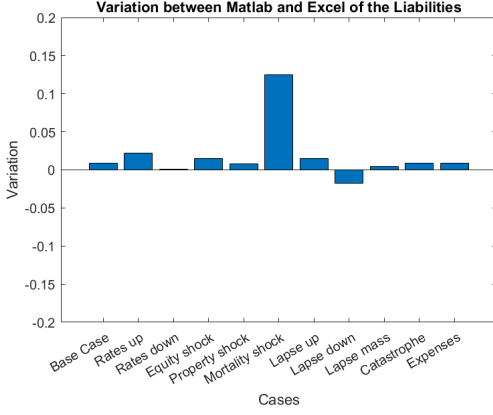


Figure 3: Liabilities Variation

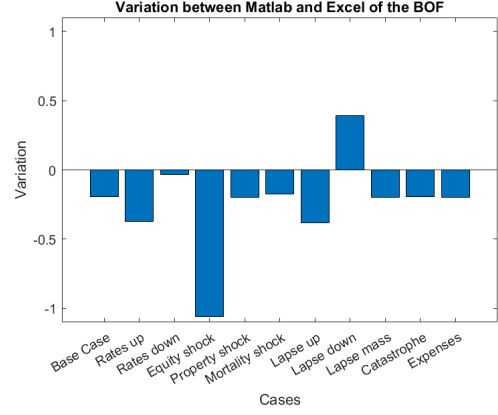


Figure 4: BOF Variation

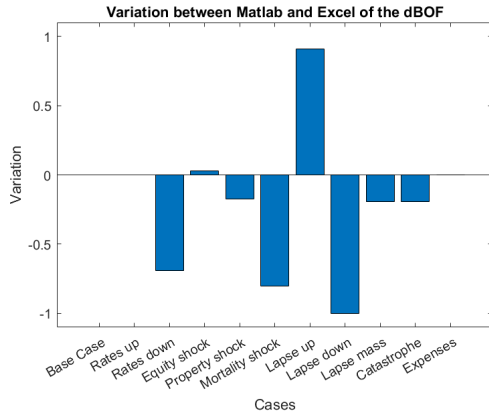


Figure 5: dBOF Variation

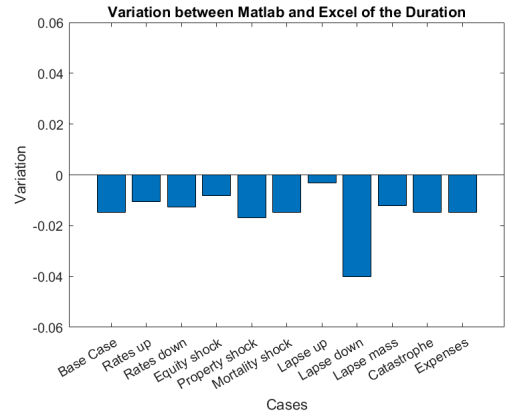


Figure 6: Duration Variation

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).

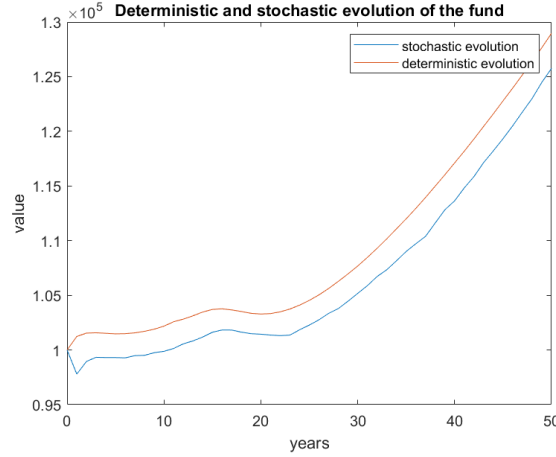


Figure 7: fund evolution

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.

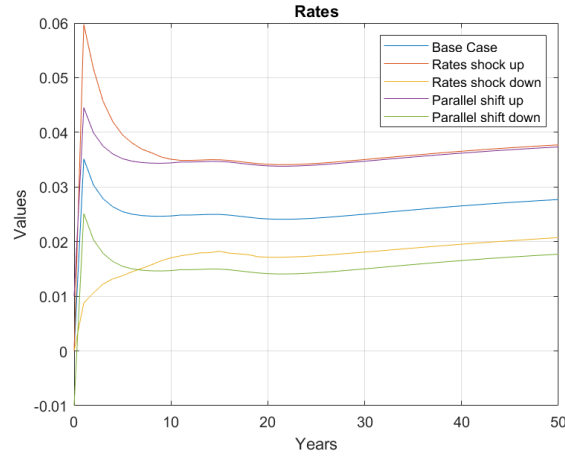


Figure 8: Rates in different cases

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.

```

1 clear all
2 clc
3 T = 50;
4 numSimulation = 1e5;
5 format long
6
7 ASSIGNMENT DATA
8 ASSETS
9 equityPercentage = 0.80;
10 propertyPercentage = 0.20;
11 investedPremium = 100000;
12 equityValue = equityPercentage*investedPremium;
13 propertyValue = propertyPercentage*investedPremium;
14 sigmaEquity = 0.20;
15 sigmaProperty = 0.10;
16 LIABILITIES
17 penaltyLapse = 20;
18 RD = 0.0220;
19 COMM = 0.0140;
20 pLapse = 0.15;
21 expensesYear = 50;
22 inflationRate = 0.02;
23
24 BASE CASE
25 TERM STRUCTURE
26 fileName = 'PROGETTO';
27 opts = spreadsheetImportOptions('NumVariables',5);
28 opts.Sheet = 2;
29 opts.DataRange = 'A4:E54';
30 opts.VariableNames(1) = {'YEAR'};
31 opts.VariableNames(2) = {'RATES'};
32 opts.VariableNames(3) = {'SPOTRATES'};
33 opts.VariableNames(4) = {'DISCOUNTS'};
34 opts.VariableNames(5) = {'FORWARD'};
35 opts = setvartype(opts,'YEAR',{'double'});
36 opts = setvartype(opts,'RATES',{'double'});
37 opts = setvartype(opts,'SPOTRATES',{'double'});
38 opts = setvartype(opts,'DISCOUNTS',{'double'});
39 opts = setvartype(opts,'FORWARD',{'double'});
40
41 temp = readtable(fileName, opts);
42 years = temp.YEAR;
43 rates = temp.RATES;
44 spotRates = temp.SPOTRATES;
45 discounts = temp.DISCOUNTS;
46 forward = temp.FORWARD;
47 LIFE TABLE
48 opts = spreadsheetImportOptions('NumVariables',5);

```

```

49 opts.Sheet = 4;
50 opts.DataRange = 'A3:E53';
51 opts.VariableNames(1) = {'AGE'};
52 opts.VariableNames(2) = {'QXTHOUSEND'};
53 opts.VariableNames(3) = {'QX'};
54 opts.VariableNames(4) = {'PX'};
55 opts.VariableNames(5) = {'PXCUMULATIVE'};
56 opts = setvartype(opts, 'AGE', {'double'});
57 opts = setvartype(opts, 'QXTHOUSEND', {'double'});
58 opts = setvartype(opts, 'QX', {'double'});
59 opts = setvartype(opts, 'PX', {'double'});
60 opts = setvartype(opts, 'PXCUMULATIVE', {'double'});
61
62 temp = readtable(fileName, opts);
63 age = temp.AGE;
64 qx = temp.QX;
65 px = temp.PX;
66 pxCumulative = temp.PXCUMULATIVE;
67 SIMULATION
68 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
69 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
70 fundEvolution = equityEvolution + propertyEvolution;
71 PROBABILITIES
72 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
73 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
74 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
75 BENEFITS
76 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
77 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
78 OTHER
79 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
80 LIABILITIES
81 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
82 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
83 totalLiabilities = sum(BEL)
84 BOF
85 BOF_BASE_CASE = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
86 DURATION_BASE_CASE = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
87 PLOT
88 opts = spreadsheetImportOptions('NumVariables', 1);
89 opts.Sheet = 5;

```

```

90 opts.DataRange = 'R3:R53';
91 opts.VariableNames(1) = {'FUND'};
92 opts = setvartype(opts,'FUND',{'double'});
93 temp = readtable(fileName, opts);
94 fundEvolotuionDeterministic = temp.FUND;
95
96 fg = figure(1);
97 clf(fg)
98 hold off
99 plot(years, mean(fundEvolution, 2));
100 hold on
101 plot(years, fundEvolotuionDeterministic)
102 legend('stochastic evolution', 'deterministic evolution')
103 title('Deterministic and stochastic evolution of the fund')
104 xlabel('years')
105 ylabel('value')
106
107 RATES SHOCK UP
108 TERM STRUCTURE
109 fileName = 'PROGETTO';
110 opts = spreadsheetImportOptions('NumVariables',5);
111 opts.Sheet = 2;
112 opts.DataRange = 'G4:K54';
113 opts.VariableNames(1) = {'YEAR'};
114 opts.VariableNames(2) = {'RATES'};
115 opts.VariableNames(3) = {'SPOTRATES'};
116 opts.VariableNames(4) = {'DISCOUNTS'};
117 opts.VariableNames(5) = {'FORWARD'};
118 opts = setvartype(opts,'YEAR',{'double'});
119 opts = setvartype(opts,'RATES',{'double'});
120 opts = setvartype(opts,'SPOTRATES',{'double'});
121 opts = setvartype(opts,'DISCOUNTS',{'double'});
122 opts = setvartype(opts,'FORWARD',{'double'});
123
124 temp = readtable(fileName, opts);
125 years = temp.YEAR;
126 rates = temp.RATES;
127 spotRates = temp.SPOTRATES;
128 discounts = temp.DISCOUNTS;
129 forward = temp.FORWARD;
130 LIFE TABLE
131 opts = spreadsheetImportOptions('NumVariables',5);
132 opts.Sheet = 4;
133 opts.DataRange = 'A3:E53';
134 opts.VariableNames(1) = {'AGE'};
135 opts.VariableNames(2) = {'QXTHOUSEND'};
136 opts.VariableNames(3) = {'QX'};
137 opts.VariableNames(4) = {'PX'};

```

```

138 opts.VariableNames(5) = {'PXCUMULATIVE'};
139 opts = setvartype(opts,'AGE',{'double'});
140 opts = setvartype(opts,'QXTHOUSEND',{'double'});
141 opts = setvartype(opts,'QX',{'double'});
142 opts = setvartype(opts,'PX',{'double'});
143 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
144
145 temp = readtable(fileName, opts);
146 age = temp.AGE;
147 qx = temp.QX;
148 px = temp.PX;
149 pxCumulative = temp.PXCUMULATIVE;
150 SIMULATION
151 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
152 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
153 fundEvolution = equityEvolution + propertyEvolution;
154 PROBABILITIES
155 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
156 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
157 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
158 BENEFITS
159 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
160 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
161 OTHER
162 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
163 LIABILITIES
164 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
165 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
166 totalLiabilities = sum(BEL)
167 BOF
168 BOF_SHOCK_UP = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
169 dBOF_SHOCK_UP = max(BOF_BASE_CASE - BOF_SHOCK_UP, 0)
170 DURATION_SHOCK_UP = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
171
172 RATES SHOCK DOWN
173 TERM STRUCTURE
174 fileName = 'PROGETTO';
175 opts = spreadsheetImportOptions('NumVariables',5);
176 opts.Sheet = 2;
177 opts.DataRange = 'M4:Q54';
178 opts.VariableNames(1) = {'YEAR'};

```

```

179 opts.VariableNames(2) = {'RATES'};
180 opts.VariableNames(3) = {'SPOTRATES'};
181 opts.VariableNames(4) = {'DISCOUNTS'};
182 opts.VariableNames(5) = {'FORWARD'};
183 opts = setvartype(opts,'YEAR',{'double'});
184 opts = setvartype(opts,'RATES',{'double'});
185 opts = setvartype(opts,'SPOTRATES',{'double'});
186 opts = setvartype(opts,'DISCOUNTS',{'double'});
187 opts = setvartype(opts,'FORWARD',{'double'});
188
189 temp = readtable(fileName, opts);
190 years = temp.YEAR;
191 rates = temp.RATES;
192 spotRates = temp.SPOTRATES;
193 discounts = temp.DISCOUNTS;
194 forward = temp.FORWARD;
195 LIFE TABLE
196 opts = spreadsheetImportOptions('NumVariables',5);
197 opts.Sheet = 4;
198 opts.DataRange = 'A3:E53';
199 opts.VariableNames(1) = {'AGE'};
200 opts.VariableNames(2) = {'QXTHOUSEND'};
201 opts.VariableNames(3) = {'QX'};
202 opts.VariableNames(4) = {'PX'};
203 opts.VariableNames(5) = {'PXCUMULATIVE'};
204 opts = setvartype(opts,'AGE',{'double'});
205 opts = setvartype(opts,'QXTHOUSEND',{'double'});
206 opts = setvartype(opts,'QX',{'double'});
207 opts = setvartype(opts,'PX',{'double'});
208 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
209
210 temp = readtable(fileName, opts);
211 age = temp.AGE;
212 qx = temp.QX;
213 px = temp.PX;
214 pxCumulative = temp.PXCUMULATIVE;
215 SIMULATION
216 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
217 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
218 fundEvolution = equityEvolution + propertyEvolution;
219 PROBABILITIES
220 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
221 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
222 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
223 BENEFITS
224 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);

```

```

225 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
226 OTHER
227 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
228 LIABILITIES
229 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
        fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
230 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
231 totalLiabilities = sum(BEL)
232 BOF
233 BOF_SHOCK_DOWN = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
234 dBOF_SHOCK_DOWN = max(BOF_BASE_CASE - BOF_SHOCK_DOWN, 0)
235 DURATION_SHOCK_DOWN = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
236
237 EQUITY SHOCK
238 ASSETS
239 shock = 0.39;
240 symmetricAdjustment = 0.0525;
241 equityShocked = equityValue*(1-shock-symmetricAdjustment);
242 investedPremiumShocked = propertyValue + equityShocked;
243 TERM STRUCTURE
244 fileName = 'PROGETTO';
245 opts = spreadsheetImportOptions('NumVariables',5);
246 opts.Sheet = 2;
247 opts.DataRange = 'A4:E54';
248 opts.VariableNames(1) = {'YEAR'};
249 opts.VariableNames(2) = {'RATES'};
250 opts.VariableNames(3) = {'SPOTRATES'};
251 opts.VariableNames(4) = {'DISCOUNTS'};
252 opts.VariableNames(5) = {'FORWARD'};
253 opts = setvartype(opts,'YEAR',{'double'});
254 opts = setvartype(opts,'RATES',{'double'});
255 opts = setvartype(opts,'SPOTRATES',{'double'});
256 opts = setvartype(opts,'DISCOUNTS',{'double'});
257 opts = setvartype(opts,'FORWARD',{'double'});
258
259 temp = readtable(fileName, opts);
260 years = temp.YEAR;
261 rates = temp.RATES;
262 spotRates = temp.SPOTRATES;
263 discounts = temp.DISCOUNTS;
264 forward = temp.FORWARD;
265 LIFE TABLE
266 opts = spreadsheetImportOptions('NumVariables',5);
267 opts.Sheet = 4;

```



```

268 opts.DataRange = 'A3:E53';
269 opts.VariableNames(1) = {'AGE'};
270 opts.VariableNames(2) = {'QXTHOUSEND'};
271 opts.VariableNames(3) = {'QX'};
272 opts.VariableNames(4) = {'PX'};
273 opts.VariableNames(5) = {'PXCUMULATIVE'};
274 opts = setvartype(opts,'AGE',{'double'});
275 opts = setvartype(opts,'QXTHOUSEND',{'double'});
276 opts = setvartype(opts,'QX',{'double'});
277 opts = setvartype(opts,'PX',{'double'});
278 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
279
280 temp = readtable(fileName, opts);
281 age = temp.AGE;
282 qx = temp.QX;
283 px = temp.PX;
284 pxCumulative = temp.PXCUMULATIVE;
285 SIMULATION
286 equityEvolution = computeEquity(T, equityShocked, forward, RD, numSimulation,
    sigmaEquity);
287 propertyEvolution = computeProperty(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
288 fundEvolution = equityEvolution + propertyEvolution;
289 PROBABILITIES
290 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
291 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
292 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
293 BENEFITS
294 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
295 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
296 OTHER
297 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
298 LIABILITIES
299 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
300 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
301 totallLiabilities = sum(BEL)
302 BOF
303 BOF_EQUITY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremiumShocked)
304 dBOF_EQUITY = max(BOF_BASE_CASE - BOF_EQUITY, 0)
305 DURATION_EQUITY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totallLiabilities)
306
307 PROPERTY SHOCK
308 ASSETS

```

```

309 shock = 0.25;
310 propertyShocked = propertyValue*(1-shock);
311 investedPremiumShocked = propertyShocked + equityValue;
312 TERM STRUCTURE
313 fileName = 'PROGETTO';
314 opts = spreadsheetImportOptions('NumVariables',5);
315 opts.Sheet = 2;
316 opts.DataRange = 'A4:E54';
317 opts.VariableNames(1) = {'YEAR'};
318 opts.VariableNames(2) = {'RATES'};
319 opts.VariableNames(3) = {'SPOTRATES'};
320 opts.VariableNames(4) = {'DISCOUNTS'};
321 opts.VariableNames(5) = {'FORWARD'};
322 opts = setvartype(opts,'YEAR',{'double'});
323 opts = setvartype(opts,'RATES',{'double'});
324 opts = setvartype(opts,'SPOTRATES',{'double'});
325 opts = setvartype(opts,'DISCOUNTS',{'double'});
326 opts = setvartype(opts,'FORWARD',{'double'});
327
328 temp = readtable(fileName, opts);
329 years = temp.YEAR;
330 rates = temp.RATES;
331 spotRates = temp.SPOTRATES;
332 discounts = temp.DISCOUNTS;
333 forward = temp.FORWARD;
334 LIFE TABLE
335 opts = spreadsheetImportOptions('NumVariables',5);
336 opts.Sheet = 4;
337 opts.DataRange = 'A3:E53';
338 opts.VariableNames(1) = {'AGE'};
339 opts.VariableNames(2) = {'QXTHOUSEND'};
340 opts.VariableNames(3) = {'QX'};
341 opts.VariableNames(4) = {'PX'};
342 opts.VariableNames(5) = {'PXCUMULATIVE'};
343 opts = setvartype(opts,'AGE',{'double'});
344 opts = setvartype(opts,'QXTHOUSEND',{'double'});
345 opts = setvartype(opts,'QX',{'double'});
346 opts = setvartype(opts,'PX',{'double'});
347 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
348
349 temp = readtable(fileName, opts);
350 age = temp.AGE;
351 qx = temp.QX;
352 px = temp.PX;
353 pxCumulative = temp.PXCUMULATIVE;
354 SIMULATION
355 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);

```

```

356 propertyEvolution = computeEquity(T, propertyShocked, forward, RD, numSimulation,
    sigmaProperty);
357 fundEvolution = equityEvolution + propertyEvolution;
358 PROBABILITIES
359 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
360 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
361 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
362 BENEFITS
363 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
364 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
365 OTHER
366 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
367 LIABILITIES
368 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
        fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
369 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
370 totalLiabilities = sum(BEL)
371 BOF
372 BOF_PROPERTY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremiumShocked)
373 dBOF_PROPERTY = max(BOF_BASE_CASE - BOF_PROPERTY, 0)
374 DURATION_PROPERTY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
375
376 MORTALITY SHOCK
377 TERM STRUCTURE
378 fileName = 'PROGETTO';
379 opts = spreadsheetImportOptions('NumVariables',5);
380 opts.Sheet = 2;
381 opts.DataRange = 'A4:E54';
382 opts.VariableNames(1) = {'YEAR'};
383 opts.VariableNames(2) = {'RATES'};
384 opts.VariableNames(3) = {'SPOTRATES'};
385 opts.VariableNames(4) = {'DISCOUNTS'};
386 opts.VariableNames(5) = {'FORWARD'};
387 opts = setvartype(opts,'YEAR',{'double'});
388 opts = setvartype(opts,'RATES',{'double'});
389 opts = setvartype(opts,'SPOTRATES',{'double'});
390 opts = setvartype(opts,'DISCOUNTS',{'double'});
391 opts = setvartype(opts,'FORWARD',{'double'});
392
393 temp = readtable(fileName, opts);
394 years = temp.YEAR;
395 rates = temp.RATES;
396 spotRates = temp.SPOTRATES;
397 discounts = temp.DISCOUNTS;

```

```

398 forward = temp.FORWARD;
399 LIFE TABLE
400 opts = spreadsheetImportOptions('NumVariables',5);
401 opts.Sheet = 4;
402 opts.DataRange = 'G3:K53';
403 opts.VariableNames(1) = {'AGE'};
404 opts.VariableNames(2) = {'QXTHOUSEND'};
405 opts.VariableNames(3) = {'QX'};
406 opts.VariableNames(4) = {'PX'};
407 opts.VariableNames(5) = {'PXCUMULATIVE'};
408 opts = setvartype(opts,'AGE',{'double'});
409 opts = setvartype(opts,'QXTHOUSEND',{'double'});
410 opts = setvartype(opts,'QX',{'double'});
411 opts = setvartype(opts,'PX',{'double'});
412 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
413
414 temp = readtable(fileName, opts);
415 age = temp.AGE;
416 qx = temp.QX;
417 px = temp.PX;
418 pxCumulative = temp.PXCUMULATIVE;
419 SIMULATION
420 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
421 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
422 fundEvolution = equityEvolution + propertyEvolution;
423 PROBABILITIES
424 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
425 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
426 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
427 BENEFITS
428 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
429 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
430 OTHER
431 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
432 LIABILITIES
433 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
434 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
435 totalLiabilities = sum(BEL)
436 BOF
437 BOF_MORTALITY = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
438 dBOF_MORTALITY = max(BOF_BASE_CASE - BOF_MORTALITY, 0)

```

```

439 DURATION_MORTALITY = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
440
441 LAPSE SHOCK UP
442 LIABILITIES
443 shock = 1.5;
444 lapseShocked = min(pLapse*shock, 1);
445 TERM STRUCTURE
446 fileName = 'PROGETTO';
447 opts = spreadsheetImportOptions('NumVariables',5);
448 opts.Sheet = 2;
449 opts.DataRange = 'A4:E54';
450 opts.VariableNames(1) = {'YEAR'};
451 opts.VariableNames(2) = {'RATES'};
452 opts.VariableNames(3) = {'SPOTRATES'};
453 opts.VariableNames(4) = {'DISCOUNTS'};
454 opts.VariableNames(5) = {'FORWARD'};
455 opts = setvartype(opts,'YEAR',{'double'});
456 opts = setvartype(opts,'RATES',{'double'});
457 opts = setvartype(opts,'SPOTRATES',{'double'});
458 opts = setvartype(opts,'DISCOUNTS',{'double'});
459 opts = setvartype(opts,'FORWARD',{'double'});
460
461 temp = readtable(fileName, opts);
462 years = temp.YEAR;
463 rates = temp.RATES;
464 spotRates = temp.SPOTRATES;
465 discounts = temp.DISCOUNTS;
466 forward = temp.FORWARD;
467 LIFE TABLE
468 opts = spreadsheetImportOptions('NumVariables',5);
469 opts.Sheet = 4;
470 opts.DataRange = 'A3:E53';
471 opts.VariableNames(1) = {'AGE'};
472 opts.VariableNames(2) = {'QXTHOUSEND'};
473 opts.VariableNames(3) = {'QX'};
474 opts.VariableNames(4) = {'PX'};
475 opts.VariableNames(5) = {'PXCUMULATIVE'};
476 opts = setvartype(opts,'AGE',{'double'});
477 opts = setvartype(opts,'QXTHOUSEND',{'double'});
478 opts = setvartype(opts,'QX',{'double'});
479 opts = setvartype(opts,'PX',{'double'});
480 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
481
482 temp = readtable(fileName, opts);
483 age = temp.AGE;
484 qx = temp.QX;
485 px = temp.PX;

```

```

486 pxCumulative = temp.PXCUMULATIVE;
487 SIMULATION
488 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
489 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
490 fundEvolution = equityEvolution + propertyEvolution;
491 PROBABILITIES
492 lapse = lapseProbabilities(T, px, lapseShocked, pxCumulative, years);
493 death = deathProbabilities(T, qx, lapseShocked, pxCumulative, years);
494 in = inProbabilities(T, qx, lapseShocked, pxCumulative, years);
495 BENEFITS
496 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
497 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
498 OTHER
499 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
500 LIABILITIES
501 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
502 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
503 totalLiabilities = sum(BEL)
504 BOF
505 BOF_LAPSE_UP = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
506 dBOF_LAPSE_UP = max(BOF_BASE_CASE - BOF_LAPSE_UP, 0)
507 DURATION_LAPSE_UP = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
508
509 LAPSE SHOCK DOWN
510 LIABILITIES
511 shock = 0.5;
512 lapseShocked = max(pLapse*shock, pLapse-0.2);
513 TERM STRUCTURE
514 fileName = 'PROGETTO';
515 opts = spreadsheetImportOptions('NumVariables',5);
516 opts.Sheet = 2;
517 opts.DataRange = 'A4:E54';
518 opts.VariableNames(1) = {'YEAR'};
519 opts.VariableNames(2) = {'RATES'};
520 opts.VariableNames(3) = {'SPOTRATES'};
521 opts.VariableNames(4) = {'DISCOUNTS'};
522 opts.VariableNames(5) = {'FORWARD'};
523 opts = setvartype(opts,'YEAR',{'double'});
524 opts = setvartype(opts,'RATES',{'double'});
525 opts = setvartype(opts,'SPOTRATES',{'double'});
526 opts = setvartype(opts,'DISCOUNTS',{'double'});

```

```

527 opts = setvartype(opts,'FORWARD',{'double'});
528
529 temp = readtable(fileName, opts);
530 years = temp.YEAR;
531 rates = temp.RATES;
532 spotRates = temp.SPOTRATES;
533 discounts = temp.DISCOUNTS;
534 forward = temp.FORWARD;
535 LIFE TABLE
536 opts = spreadsheetImportOptions('NumVariables',5);
537 opts.Sheet = 4;
538 opts.DataRange = 'A3:E53';
539 opts.VariableNames(1) = {'AGE'};
540 opts.VariableNames(2) = {'QXTHOUSEND'};
541 opts.VariableNames(3) = {'QX'};
542 opts.VariableNames(4) = {'PX'};
543 opts.VariableNames(5) = {'PXCUMULATIVE'};
544 opts = setvartype(opts,'AGE',{'double'});
545 opts = setvartype(opts,'QXTHOUSEND',{'double'});
546 opts = setvartype(opts,'QX',{'double'});
547 opts = setvartype(opts,'PX',{'double'});
548 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
549
550 temp = readtable(fileName, opts);
551 age = temp.AGE;
552 qx = temp.QX;
553 px = temp.PX;
554 pxCumulative = temp.PXCUMULATIVE;
555 SIMULATION
556 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
557 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
558 fundEvolution = equityEvolution + propertyEvolution;
559 PROBABILITIES
560 lapse = lapseProbabilities(T, px, lapseShocked, pxCumulative, years);
561 death = deathProbabilities(T, qx, lapseShocked, pxCumulative, years);
562 in = inProbabilities(T, qx, lapseShocked, pxCumulative, years);
563 BENEFITS
564 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
565 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
566 OTHER
567 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
568 LIABILITIES
569 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);

```

```

570 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
571 totallLiabilities = sum(BEL)
572 BOF
573 BOF_LAPSE_DOWN = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
574 dBOF_LAPSE_DOWN = max(BOF_BASE_CASE - BOF_LAPSE_DOWN, 0)
575 DURATION_LAPSE_DOWN = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totallLiabilities)
576
577 LAPSE SHOCK MASS
578 LIABILITIES
579 shock = 0.4;
580 lapseShocked = pLapse+shock;
581 TERM STRUCTURE
582 fileName = 'PROGETTO';
583 opts = spreadsheetImportOptions('NumVariables',5);
584 opts.Sheet = 2;
585 opts.DataRange = 'A4:E54';
586 opts.VariableNames(1) = {'YEAR'};
587 opts.VariableNames(2) = {'RATES'};
588 opts.VariableNames(3) = {'SPOTRATES'};
589 opts.VariableNames(4) = {'DISCOUNTS'};
590 opts.VariableNames(5) = {'FORWARD'};
591 opts = setvartype(opts,'YEAR',{'double'});
592 opts = setvartype(opts,'RATES',{'double'});
593 opts = setvartype(opts,'SPOTRATES',{'double'});
594 opts = setvartype(opts,'DISCOUNTS',{'double'});
595 opts = setvartype(opts,'FORWARD',{'double'});
596
597 temp = readtable(fileName, opts);
598 years = temp.YEAR;
599 rates = temp.RATES;
600 spotRates = temp.SPOTRATES;
601 discounts = temp.DISCOUNTS;
602 forward = temp.FORWARD;
603 LIFE TABLE
604 opts = spreadsheetImportOptions('NumVariables',5);
605 opts.Sheet = 4;
606 opts.DataRange = 'A3:E53';
607 opts.VariableNames(1) = {'AGE'};
608 opts.VariableNames(2) = {'QXTHOUSEND'};
609 opts.VariableNames(3) = {'QX'};
610 opts.VariableNames(4) = {'PX'};
611 opts.VariableNames(5) = {'PXCUMULATIVE'};
612 opts = setvartype(opts,'AGE',{'double'});
613 opts = setvartype(opts,'QXTHOUSEND',{'double'});
614 opts = setvartype(opts,'QX',{'double'});

```



```

615 opts = setvartype(opts,'PX',{'double'});
616 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
617
618 temp = readtable(fileName, opts);
619 age = temp.AGE;
620 qx = temp.QX;
621 px = temp.PX;
622 pxCumulative = temp.PXCUMULATIVE;
623 SIMULATION
624 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
625 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
626 fundEvolution = equityEvolution + propertyEvolution;
627 PROBABILITIES
628 lapse = zeros(T+1,1);
629 lapse(1) = px(1)*lapseShocked;
630 lapse(2:end) = pxCumulative(1:end-1).*px(2:end).*(1-pLapse).^(years(2:end)-1).*
    pLapse.*(1-lapseShocked);
631
632 death = zeros(51,1);
633 death(1) = qx(1);
634 death(2:end) = pxCumulative(1:end-1).*qx(2:end).*(1-pLapse).^(years(2:end)-1).*(1-
    lapseShocked);
635
636 in = zeros(T+1,1);
637 in(1) = (1-qx(1))*(1-lapseShocked);
638 for i = 2:T+1
639     in(i) = in(i-1)*(1-qx(i))*(1-pLapse);
640 end
641 BENEFITS
642 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
643 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
644 OTHER
645 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
646 LIABILITIES
647 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
648 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
649 totalLiabilities = sum(BEL)
650 BOF
651 BOF_LAPSE_MASS = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
652 dBOF_LAPSE_MASS = max(BOF_BASE_CASE - BOF_LAPSE_MASS, 0)
653 DURATION_LAPSE_MASS = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)

```

```

654
655 CATASTROPHE
656 TERM STRUCTURE
657 fileName = 'PROGETTO';
658 opts = spreadsheetImportOptions('NumVariables',5);
659 opts.Sheet = 2;
660 opts.DataRange = 'A4:E54';
661 opts.VariableNames(1) = {'YEAR'};
662 opts.VariableNames(2) = {'RATES'};
663 opts.VariableNames(3) = {'SPOTRATES'};
664 opts.VariableNames(4) = {'DISCOUNTS'};
665 opts.VariableNames(5) = {'FORWARD'};
666 opts = setvartype(opts,'YEAR',{'double'});
667 opts = setvartype(opts,'RATES',{'double'});
668 opts = setvartype(opts,'SPOTRATES',{'double'});
669 opts = setvartype(opts,'DISCOUNTS',{'double'});
670 opts = setvartype(opts,'FORWARD',{'double'});
671
672 temp = readtable(fileName, opts);
673 years = temp.YEAR;
674 rates = temp.RATES;
675 spotRates = temp.SPOTRATES;
676 discounts = temp.DISCOUNTS;
677 forward = temp.FORWARD;
678 LIFE TABLE
679 opts = spreadsheetImportOptions('NumVariables',5);
680 opts.Sheet = 4;
681 opts.DataRange = 'N3:R53';
682 opts.VariableNames(1) = {'AGE'};
683 opts.VariableNames(2) = {'QXTHOUSEND'};
684 opts.VariableNames(3) = {'QX'};
685 opts.VariableNames(4) = {'PX'};
686 opts.VariableNames(5) = {'PXCUMULATIVE'};
687 opts = setvartype(opts,'AGE',{'double'});
688 opts = setvartype(opts,'QXTHOUSEND',{'double'});
689 opts = setvartype(opts,'QX',{'double'});
690 opts = setvartype(opts,'PX',{'double'});
691 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
692
693 temp = readtable(fileName, opts);
694 age = temp.AGE;
695 qx = temp.QX;
696 px = temp.PX;
697 pxCumulative = temp.PXCUMULATIVE;
698 SIMULATION
699 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);

```

```

700 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
701 fundEvolution = equityEvolution + propertyEvolution;
702 PROBABILITIES
703 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
704 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
705 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
706 BENEFITS
707 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
708 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
709 OTHER
710 expensesYearEvolution = computeExpenses(T, expensesYear, inflationRate);
711 LIABILITIES
712 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
        fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
713 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
714 totalLiabilities = sum(BEL)
715 BOF
716 BOF_CATASTROPHE = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
717 dBOF_CATASTROPHE = max(BOF_BASE_CASE - BOF_CATASTROPHE, 0)
718 DURATION_CATASTROPHE = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
719
720 EXPENSES
721 expensesShock = 0.1;
722 expensesYearShocked = expensesYear*(1+expensesShock);
723 inflationShock = 0.01;
724 inflationRateShocked = inflationRate + inflationShock;
725 TERM STRUCTURE
726 fileName = 'PROGETTO';
727 opts = spreadsheetImportOptions('NumVariables',5);
728 opts.Sheet = 2;
729 opts.DataRange = 'A4:E54';
730 opts.VariableNames(1) = {'YEAR'};
731 opts.VariableNames(2) = {'RATES'};
732 opts.VariableNames(3) = {'SPOTRATES'};
733 opts.VariableNames(4) = {'DISCOUNTS'};
734 opts.VariableNames(5) = {'FORWARD'};
735 opts = setvartype(opts,'YEAR',{'double'});
736 opts = setvartype(opts,'RATES',{'double'});
737 opts = setvartype(opts,'SPOTRATES',{'double'});
738 opts = setvartype(opts,'DISCOUNTS',{'double'});
739 opts = setvartype(opts,'FORWARD',{'double'});
740
741 temp = readtable(fileName, opts);

```

```

742 years = temp.YEAR;
743 rates = temp.RATES;
744 spotRates = temp.SPOTRATES;
745 discounts = temp.DISCOUNTS;
746 forward = temp.FORWARD;
747 LIFE TABLE
748 opts = spreadsheetImportOptions('NumVariables',5);
749 opts.Sheet = 4;
750 opts.DataRange = 'A3:E53';
751 opts.VariableNames(1) = {'AGE'};
752 opts.VariableNames(2) = {'QXTHOUSEND'};
753 opts.VariableNames(3) = {'QX'};
754 opts.VariableNames(4) = {'PX'};
755 opts.VariableNames(5) = {'PXCUMULATIVE'};
756 opts = setvartype(opts,'AGE',{'double'});
757 opts = setvartype(opts,'QXTHOUSEND',{'double'});
758 opts = setvartype(opts,'QX',{'double'});
759 opts = setvartype(opts,'PX',{'double'});
760 opts = setvartype(opts,'PXCUMULATIVE',{'double'});
761
762 temp = readtable(fileName, opts);
763 age = temp.AGE;
764 qx = temp.QX;
765 px = temp.PX;
766 pxCumulative = temp.PXCUMULATIVE;
767 SIMULATION
768 equityEvolution = computeEquity(T, equityValue, forward, RD, numSimulation,
    sigmaEquity);
769 propertyEvolution = computeEquity(T, propertyValue, forward, RD, numSimulation,
    sigmaProperty);
770 fundEvolution = equityEvolution + propertyEvolution;
771 PROBABILITIES
772 lapse = lapseProbabilities(T, px, pLapse, pxCumulative, years);
773 death = deathProbabilities(T, qx, pLapse, pxCumulative, years);
774 in = inProbabilities(T, qx, pLapse, pxCumulative, years);
775 BENEFITS
776 benefitsLapse = lapseBenefits(lapse, fundEvolution, penaltyLapse, discounts);
777 benefitsDeath = deathBenefits(death, fundEvolution, investedPremium, discounts);
778 OTHER
779 expensesYearEvolution = computeExpenses(T, expensesYearShocked,
    inflationRateShocked);
780 LIABILITIES
781 [lapseLiabilities, deathLiabilities, commLiabilities, expensesLiabilities] =
    computeLiabilities(T, numSimulation, benefitsLapse, benefitsDeath,
    fundEvolution, RD, COMM, in, discounts, expensesYearEvolution);
782 BEL = sum([lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities]);
783 totalLiabilities = sum(BEL)

```

```

784 BOF
785 BOF_EXPENSES = computeBOF(lapseLiabilities, deathLiabilities, commLiabilities,
    expensesLiabilities, investedPremium)
786 dBOF_EXPENSES = max(BOF_BASE_CASE - BOF_EXPENSES, 0)
787 DURATION_EXPENSES = computeDuration(years, lapseLiabilities, deathLiabilities,
    commLiabilities, expensesLiabilities, totalLiabilities)
788
789 BASIC SOLVENCY CAPITAL REQUIREMENT
790 MARKET
791 if dBOF_SHOCK_UP > dBOF_SHOCK_DOWN
792     a = 0;
793 else
794     a = 0.5;
795 end
796 marketCorrelationMatrix = [1 a a; a 1 0.75; a 0.75 1];
797 dBOF_MARKET = max(dBOF_SHOCK_UP, dBOF_SHOCK_DOWN);
798 marketSCR = [dBOF_MARKET; dBOF_EQUITY; dBOF_PROPERTY];
799 totalMarket = sqrt(marketSCR'*marketCorrelationMatrix*marketSCR)
800 LIFE
801 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];
802 dBOF_LAPSE = max([dBOF_LAPSE_UP; dBOF_LAPSE_DOWN; dBOF_LAPSE_MASS]);
803 lifeSCR = [dBOF_MORTALITY; dBOF_LAPSE; dBOF_EXPENSES; dBOF_CATASTROPHE];
804 totalLife = sqrt(lifeSCR'*lifeCorrelationMatrix*lifeSCR)
805 TOTAL
806 totalCorrelationMatrix = [1 0.25; 0.25 1];
807 totalSCR = [totalMarket; totalLife];
808 BSCR = sqrt(totalSCR'*totalCorrelationMatrix*totalSCR)
809
810 MARTINGALE TEST
811 equityEvolutionTest = computeEquity(T, equityValue, forward, 0, numSimulation,
    sigmaEquity);
812 propertyEvolutionTest = computeProperty(T, propertyValue, forward, 0,
    numSimulation, sigmaProperty);
813 fundEvolutionTest = equityEvolutionTest + propertyEvolutionTest;
814
815 meanFundFinal = mean(fundEvolutionTest(T+1, :));
816 discountsTest = discounts(T+1)./discounts;
817 meanFundFinalDiscounted = meanFundFinal*discountsTest;
818
819 fg = figure(2);
820 clf(fg)
821 hold off
822 plot(years, meanFundFinalDiscounted, 'or')
823 hold on
824 plot(years, investedPremium*ones(T+1), '*b')
825 grid on
826 title('MARTINGALE TEST')

```

```

827 legend('Invested Premium', 'Mean Final Value Discounted')
828 ylabel('Value')
829 xlabel('Years')
830
831 NUMBER OF SIMULATIONS
832 for i = 1:6
833     numSimulation = 10^i;
834     equityEvolutionTest = computeEquity(T, equityValue, forward, 0, numSimulation,
        sigmaEquity);
835     propertyEvolutionTest = computeProperty(T, propertyValue, forward, 0,
        numSimulation, sigmaProperty);
836     fundEvolutionTest = equityEvolutionTest + propertyEvolutionTest;
837
838     meanFundFinal = mean(fundEvolutionTest(T+1, :));
839     discountsTest = discounts(T+1)./discounts;
840     meanFundFinalDiscounted = meanFundFinal*discountsTest;
841     error(i) = 1 - meanFundFinalDiscounted(1)/investedPremium;
842 end
843
844 fg = figure(3);
845 clf(fg)
846 hold off
847 plot((1:6), error, 'x-')
848 grid on
849 hold on
850 plot(4, error(4), 'o', 'LineWidth', 2)
851 plot(5, error(5), 'o', 'LineWidth', 2)
852 title('ERROR VS NUMBER OF SIMULATIONS')
853 xlabel('Number of Simulations')
854 ylabel('Error')
855 legend('Error', 'Global Minimum', 'Number Chosen')

```