Micro Simulation Study of Life Insurance Business

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This paper aims to investigate company policies and the way these interact together by measuring their effect on company's profitability and solvency. More precisely, the paper seeks to investigate what additional benefits micro-level simulation approach can bring to the modeling of the policy holder behavior, e.g. lapse risk, and what guidance the better information gives to the management.

This paper presents an individual simulation study of a typical (hypothetical) life insurance company where contract level (policy by policy) stochastic simulations are performed at every stage. In the implemented model economic scenarios are imported and joint simulations for the both sides of balance sheet are performed. This enables to define two market based key measures, Solvency II and MCEV. As these two measures form an important part of the information companies consider under decisions it is crucial to provide them for the company model's decision making side, i.e. the company policies. One is able to get more reliable and intuitive results out of the model by adjusting these policies.

Different types of computer intensive analysis are produced under several tasks for hypothetical individuals with various characteristics, average results and distribution for the company's business decisions and risk management (ERM, ORSA).

Keywords: Computational Insurance, Economic Capital, ERM, Individual Simulation, Lapse Risk, Management Actions, ORSA, Policyholder Behavior, Solvency II.

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1. Introduction

Much actuarial investigation now involves large simulation as well as theory and data analysis. Computing can often stimulate the insight and understanding that personal judgment, theory and data alone cannot achieve (cf. e.g. Pentikäinen et al. (1989) or Daykin et al. (1994)). Moreover, with modern computers, actuaries can study problems that previously would have been too difficult, time consuming or hazardous.

The increasing speed and memory of computers, the emergence of distributed processing, the explosion of financial information available through the internet, the maturing of the area of computational statistics and finance (cf. e.g. Springer Handbooks of Computational Statistics series (2013)), and the availability of reasonably priced computational tools all contribute to the increasing importance of computational insurance to actuaries.

Quoting England and Verrall (2002): "*It has to be borne in mind that traditional techniques were developed before the advent of desktop computers, using methods which could be evaluated using pencil and paper. With the continuing increase in computer power, it has to be questioned whether it would not be better to examine individual claims rather than use aggregate data.*"

A specific computational application that actuaries encounter nowadays is the use of economic scenario generator (ESG) since ESG simulations are a key element of market consistent valuation for life insurance businesses. Here instead the main aim is to utilize micro-level insurance data for better informed management by performing simulations.

Micro simulation models involve the generation of data on social or economic units (e.g., persons or contracts). The concept has been in existence since the 1950s, although for various reasons, including constraints of computing power, it only entered widespread usage much later. Now modern computing and programming tools offer several concepts to ease model building and help to speed-up computations. For more information on micro simulation see e.g. International Microsimulation Association (2013).

By taking the individual unit as the basis of the modeling work, micro-level simulation allows for the analysis of the distribution of resources across different groups (e.g., elderly vs. non-elderly people). This micro-level focus thus distinguishes micro-simulation models from other modeling work that operates with groups or cells, or aims to simulate the liabilities as a whole. Compared to traditional methods, they reflect real outcomes – at least in principle - in a more realistic and accurate way.

Unlike modeling where a typical or median case is the standard of analysis, micro-simulation models open up a much richer vein of possibilities by enabling the exploration of heterogeneity and diversity within the simulated population. For an excellent case study of micro–level stochastic loss reserving, see e.g. Antonio and Plat (2010). The paper shows that micro–level stochastic modeling in general insurance is feasible for real life portfolios with over a million data records. Predictive out-of-sample distributions obtained with the micro–level model reflect reality in a more realistic way: 'regular' outcomes are close to the median of the predictive distribution whereas pessimistic outcomes are in the very right tail. Hence, for their case study calculations based on the micro-level model are to be preferred.

The focus of this study is on contract level (policy by policy) stochastic simulations. The results demonstrate how micro simulation can be used as a tool for understanding life insurance business. Different types of computer intensive analysis are produced under several tasks for hypothetical individuals with various characteristics, average results and distribution for the company's business decisions and risk management e.g. for enterprise risk management (ERM) or own risk and solvency analysis (ORSA).

An ESG is needed for MCEV calibration and real world scenarios. For simplicity we propose an approximately calibrated ESG model that utilizes a well-known Markov process description of an economic business cycle (see Hamilton (1989)). The other variables inflation, yield curve, bond portfolio and stock return depend on the business cycle. The ESG is used for simulating purposes in order to study the effect of the economic cycle on the solvency of the company and individual policy holder behavior.

For the purposes of this micro simulation exercise we define a publicly listed life insurance company (hypothetical). We assume this to be a solo (no group) structure with policyholders and investors as the main interest groups. This company is assumed to practice business in Euro-area so all liabilities are euro denominated, Solvency II plays important part in decision making and the movements in MCEV is closely followed as being of shareholders interest. For background information we have used Achmea (2011), Allianz (2011), CFO Forum (2009 a,b), Fang and Kung (2005) and Sigma (2012).

As the main goal this paper seeks to investigate what additional benefits micro-level simulation approach can bring to the modeling of the policy holder behavior, e.g. lapse or surrender risk, and what guidance the better information gives to the management.

The paper is organized as follows. In Section 2 the micro simulation model and the ESG is described. Section 3 introduces the company model components model and Section 4 presents the model structure. Model simulation results are presented in Section 5.

2. Modeling framework

2.1 Technical model

The used micro simulation model was implemented in a generic simulation engine mSII® that has been built on the top of MATLAB®[1]. mSII software has been built to support high performance computing and its flexible, object-oriented implementation allows modeler to use of a wide range of simulation designs. It provides interactive graphical user interfaces for managing model definition modules and data sources and analyzing results.

In the developed model risk sources were modeled by using contract level (policy-by-policy) simulation at any stage. When developing the model, the relationship between an insured and the

[1] Model IT Ltd was founded in 2007 and is a partner of MathWorks, the developer of MATLAB®.

undertaking was assumed to be defined in applicable contract terms and contracts details of the insured contracts were defined as cash flow agreements where cash flows depend on stochastic events and processes (see chart 1).

The implemented model offers the modeler detailed view of each calculation step. Further, the model allows for finding non-simplified probability distributions of relevant variables, like cash-flows, premiums, profit/loss, and financial ratios.

In more detailed, the implemented model simulates probability distributions of desired variables over the time-period chosen for the analysis. The model offers tools to predict probability levels for cash-flows and cumulative cash-flows that can be used to measure liquidity and insolvency risks of the company. Accordingly, in one aspect, running simulations on contract level with non-simplified contract terms is provided.

The model allows external Economic Scenario Generator (ESG) data (see section 2.2) to be included in the analysis. The ESG data affects asset values and when combined with risk simulation it is possible to have both sides of the balance sheet simultaneously in analysis. As a result the model generates yearly or quarterly balance sheets during simulation. Economic scenarios can also affect contract-level cash flows (e.g. unit link life insurance) and customer behavior.

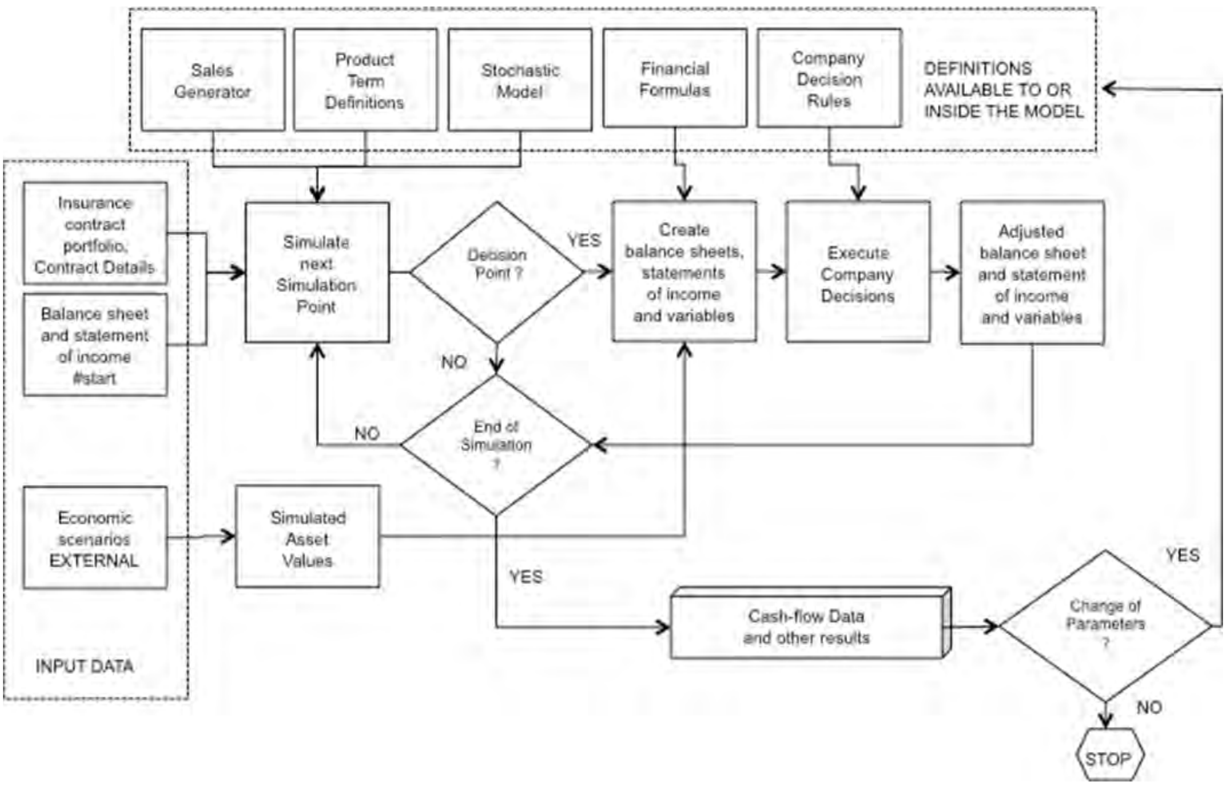

chart 1 The components and steps required to produce forecasts for financial statement distributions.

Management actions (Decision rules) are company specific rules that may change the course of the simulation, typically by changing dividend decisions or by altering investment allocation base on for example simulated financial indicators. It allows management to take independent action in each simulation after every generated balance sheet. Chart 2 presents the components and steps required to produce forecasts for balance sheet items.

In the developed model management actions can depend on all information in the current simulation path including balance sheets and cash flows. They can affect company's investment portfolios and balance sheet as well as contracts' future cash flows.

Traditionally, contract level Monte Carlo simulation has been considered computationally too slow for large portfolios. However, in practical applications desired performance can often be reached by combining two different technologies: distributed computing and advanced software design. The implemented model can utilize both these methods. Full 60 year simulation of the model of this paper takes less than an hour when distributed computing is utilized. A sample of 1000 individuals takes about one minute. For more information on the computational issues of the technical model see Jauri and Penttilä (2012).

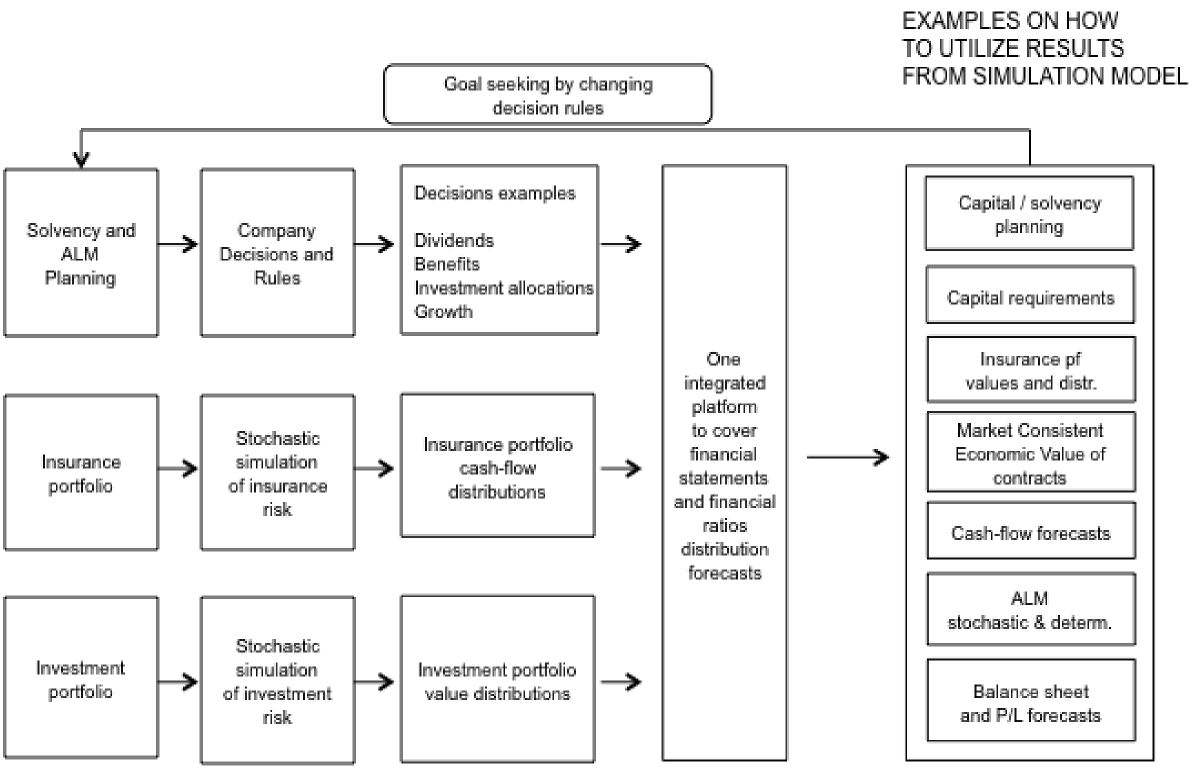

chart 2 The components and steps required to model management actions.

2.2. Economic Simulation Generator

The main focus of this paper is on contract level simulations. Hence, quite simple ESG is used and an exact statistical fitting of the model to historical and market data have not been attempted. A more sophisticated feature of the used ESG is its dependence on business cycle. The choice of parameters for the model is motivated by published research articles.

When a country experiences economic depression the losses in insurance may reach large dimensions. During that time the number of claims can be extraordinary large and, what is more important, the proportion of lapses can be much higher than usual and simultaneously invest return can be weak. Hence we assume that the primary process is that related to GDP development. This drives the other processes inflation and equity return. Inflation in turn drives nominal interest rates.

We propose a model that utilizes a modification of a well-known Markov process description of an economic business cycle (see Hamilton (1989)). The two states of the modeled homogenous Markov process $S(t)$ represent economic expansion and recession. When a simple description of the states of the Markov process is found, this approach leads to parsimonious modeling. More specifically, we choose the model of Puustelli et al. (2008) where the probability to stay in expansion regime $S(t) = 1$ is 0.97 and the probability to stay in recession regime $S(t) = 1$ is 0.40.

Monthly inflation follows autoregressive process (Koskinen and Pukkila (1996)) where a high inflation period occurs during recession ($e(t)$ follows *i.i.d.* $N(0,1)$):

$$y(t) - 0.01 = 0.63 \times [\, y(t-1) - 0.01 \,] + 0.013 \times e(t), \text{ when } S(t) = 1 \text{ (expansion regime)}$$

$$y(t) - 0.08 = 0.4 \times [\, y(t-1) - 0.08 \,] + 0.038 \times e(t), \text{ when } S(t) = 2 \text{ (recession regime)}$$

We model monthly stock returns $p(t)$ by a simplified modification of the two-regime mixture model (see Kaliva and Koskinen (2003, 2009)) in which the process behaves like a random walk in one regime (expansion) while it is like an error-correcting process in the other (recession) . The model has a useful interpretation- regime one produces bubble periods and regime two periods which bring prices back to fundamentals. The model dynamics is

$$p(t) = 0.027 + 0.027 \times e(t) \text{ when } S(t) = 1 \text{ (expansion regime)}$$

$$p(t) = -0.3 + 0.059 \times e(t) \text{ when } S(t) = 2 \text{ (recession regime)}$$

For yield-curve modeling Bernadell et al. (2005) introduced a methodology relies on a stochastic state space formulation of the Nelson-Siegel (1987) parsimonious description of the shape and location of nominal yields. Here we assume a simpler approach where the parameters of Nelson-Siegel model follow autoregressive processes (Saraste (2009)). Interest rates incorporate regime-switching behavior in the time-series evolution through the above inflation process.

3. Defining the hypothetical company

3.1 The Company

For the purposes of this simulation exercise we start up by defining a publicly listed life insurance company. We assume this to have a solo (no group) structure with policyholders and investors as the main interest groups. This company is assumed to practice business in Euro-area so all liabilities are euro denominated, Solvency II plays important part in decision making and the movements in MCEV is closely followed as being of shareholders interest. Our aim is to define of a typical life insurance company. For more information on parameters and products we have used Achmea (2011), Allianz (2011), Fang and Kung (2005) and Sigma (2012) .

The history for the company is the following. There has been quite large amount of 4% guaranteed rate savings product with all life pension payment (based on the savings in the start of the retirement). After financial crisis and the beginning of low interest rate period this product line has been ended and new 0% guaranteed product have taken place. Other products that the company provides are pure risk based products and unit linked products. The unit linked savings product is linked into the guaranteed rate product so that there can been made changes between these funds on these products (so called switches). So the product can be understood as a savings product with α% in guarantee fund and (1- α)% in unit linked fund, switches allowed and for life pension from retirement.

In chart 3 some data is presented regarding the policies, breakdowns by age and savings (or risk amounts) and by age and amount of policyholders. All policy groups (0% savings with UL, 4% savings with UL and pure risk policies) are assumed to have 100 000 policyholders. The estimated year premium from the insurance portfolio including new sales is around 500 million euro.

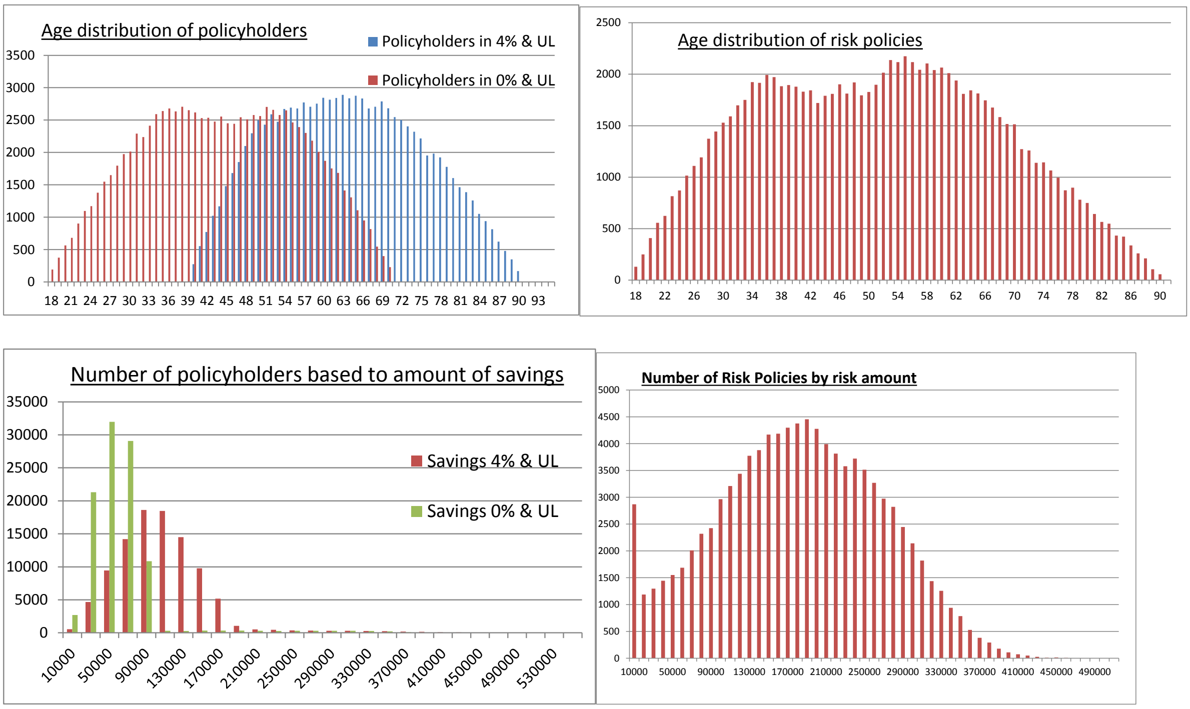

chart 3 Data related to the policies, breakdowns by age and savings and by age and amount of policyholders.

The balance sheet in the end of 2012 is presented in chart 4. This balance sheet is not based to IFRS or any certain member state regulation. The main assumptions here are that assets are valued in market value and liabilities based to book value meaning basically the savings amount at the end of the year. As noticed from the balance sheet unit linked funds makes some 40% of the total assets and the rest of its funds the company has invested mainly in bonds, loan type investments and equities. The three main product lines make the liabilities, but risk business considering its feature is rather small (by book value). Equity capital consists from share capital and retained. As company is publicly listed it follows closely the movements on its share value.

Solvency II (in chart 4 also) is first of the key measures company follows as in case of week solvency company has to come public with this. Also as the default event is based to Solvency II MCR it's crucial to be safely above this limit. Solvency II is based to last EIOPA specs of how it will possibly be like (Long Term Guarantees Assessment 2012 – 2013). In these Pillar I calculations of Eligible Own Funds (EOF) and Solvency Capital Ratio (SCR) no adjustments are made. The risk free interest rate curve is took from ESG data, with no adjustments and with no converge to UFR so the results differentiate bit from SII.

The main risks forming the SCR are in market- and life risks modules. In market risk module there is interest rate risk remaining from what has not been able to minimize by ALM. Also spread risk makes a considerable amount as there is need for return over risk free rates in bond portfolio also. The third considerable market risk element is equity risk as the company aims to take equity risk with all the capital over liabilities plus 2/3 SCR (now little over balanced).

31.12.2012 Million €	Life Company
Assets	
Investments	
Equities	784
Bonds	6 045
Loans	536
Cash	160
Investment backing unit-linked liabilities	6 218
TOTAL	**13 743**
Equity	
Core equity	
Share capital	350
Retained earnings	936
Sub-Ordinated loans	100
Liabilities	
Insurance liabilities	
Profit sharing business	6 125
Pure risk policies	42
From policies where policyholder bears the investment risk	6 190
TOTAL	**13 743**

Solvency position	**Life Company**
Eligible Own Funds (Solvency II)	**810**
SCR	**919**
MCR	**306**
Solvency rate	**88 %**
SCR (31.12.2012 Million €)	**919**
Adjustments	**-245**
Operational risk	**69**
Basic Solvency Capital Requirement	**1 096**
Diversification benefits	**-297**
Sum of risk components	**1 393**
Market risk	**843**
Interest rate	350
Equity	280
Property	0
Spread	356
Concentration	60
Currency	38
CCP	-
Counterparty default risk	**60**
Life Underwriting risks	**490**
Mortality	122
Longevity	244
Disability	121
Expense	119
Revision	-
Lapse	207
Life catastrophe	48
Health underwriting risk	-
Non-Life underwriting risk	-

chart 4 The balance sheet in the end of 2012.

Life risks arrive from liabilities were quite obviously longevity (from for life pensions) and lapse (from profitable risk policies) risks make the most of this risk module. Also expense risk stemming from the risk of unit linked fund losses makes a considerable amount on this life risk module.

MCEV (market consistent embedded value) is the other of the key measures company follows. This is the primary way company is valuing the amount of its own funds and also what the investors are looking when valuing the share value. MCEV comprises of Value-in-force and adjusted net worth in which the latter is basically own funds from balance sheet. VIF in other hand need some calculation as future profits needs to be calculated trough future cash flows. What reduces VIF are time value of future guarantees (from future benefits in guarantee rate savings products), cost of capital (as in Solvency II) and cost of residual non-hedgeable risks. Two of the major parts that are different in MCEV vs. Solvency II are the ways future profits are understood (no contract boundaries for future premiums in MCEV) and no ultimate forward rate for discounting. In this exercise these do not make a difference because of the way Solvency II figures are produced. The breakdown of MCEV in end of 2012 is shown in chart 5. (More on MCEV is found e.g. CFO Forum (2009 a,b)).

MCEV (31.12.2012 Million €)	**Life Company**
Value in-force (VIF)	
Present value of future profits	-272
Time value of options & guarantees	-37
Cost of Capital (CoC)	-185
risks	-41
Adjusted net worth (ANW)	1 386
TOTAL	**851**

chart 5 The breakdown of MCEV in end of 2012.

3.2 Company policies

Main Strategy:

Overall strategy is that as the main business area is insurance, capital is primarily budgeted for it. Investments are seen as secondary business area getting the residual capital. As the strategy is also to grow new policies are all accepted and the capital they need allocated for these. As noticed from chart 4 the solvency II position is only 88% of SCR which needs to be noticed and followed closely. Company aims to get its solvency II position over 140% in the strategy period (5 years) else risk mitigation will continue and finally also new capital. For the company it is extremely important to give benefits for the policyholders and to be competitive player in the field. Also from investor perspective it is crucial to increase the share value and pay dividends which company aims to do.

Sub Strategies – The company policies:

Capital management policy

The policy for capital management consists from two main areas; the way capital has been allocated inside company and the way how risks will be minimized or hedged and new capital raised in case of week solvency. The way company aims to act in case of over capitalization is handled in the profit sharing policy.

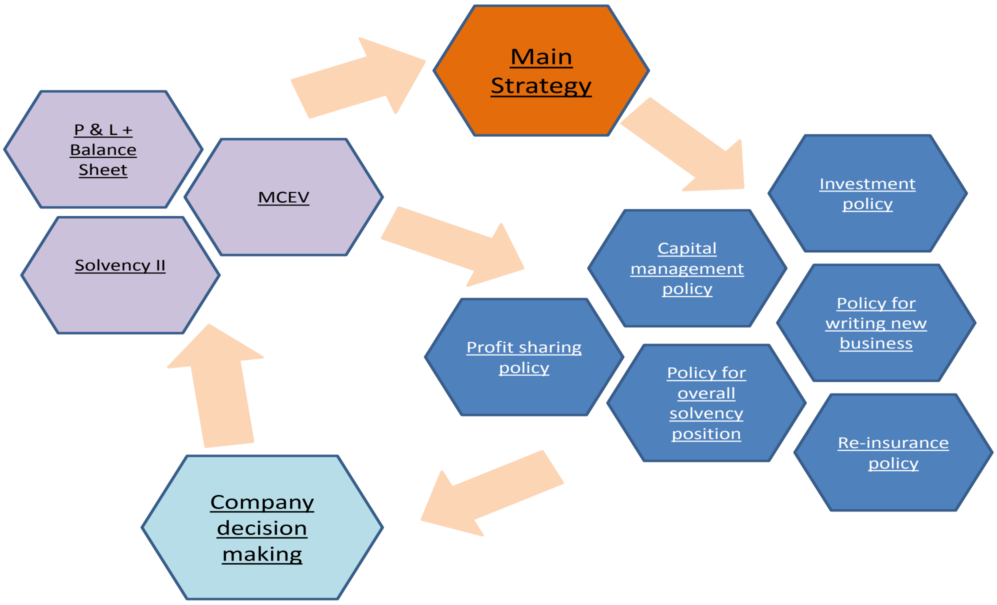

chart 6 Company strategy, policies and decisions.

Capital allocation is done using Euler method (chart 7) which divides the diversification benefits for each risk group. As said in the main strategy insurance business and therefore new business will get all the capital it needs and capital for investments are considered as the residual amount.

Investment policy

Investment strategy is to allocate investments into bonds and equities. Since there is no group structure, strategic investments are excluded. Also real estate investments are considered to be something not in the interest of the company. The proportion of equities is maximized to the amount of the risk budget they hold and if overstepped then reallocation will be done. The overall strategy for equities is to allocate all free capital (over 2/3 SCR) to equities but this might not always be in balance. With Bonds and other loan type investments ALM is the main driver since there is two goals to achieve. Firstly as the guaranteed rate plus the yearly extra benefit (by the plan) is over 4% this is something to be tried to achieve every year to meet the goals of the liability best estimates. Also as the liabilities are measured market based, the rates used in discounting must be earned. If not, this will be seen as a loss in BOF (and MCEV). The second point about bond investments considers the interest rate risk and how to control it. This is taken account in the investment policy by trying to keep the asset and liability cash flows matched. As the market in the ultra-long end (over 30 years) is quite thin the shorter periods must be weighted more to achieve this ALM need with duration. In case of week solvency the most risky assets in bond portfolio are re-allocated into less risky ones.

Policy for writing new business

Following the strategy capital is allocated for the new business. New insurance policies can only be pure risk policies or savings type policies with 0% guaranteed rate with switch-option to unit linked funds. In savings products after the savings period pension benefit for life is granted based on the amount of the savings. Extra benefits will be granted both in savings period and in pension period.

For the old 4% guarantee fund new premiums are accepted (before pension time) but considering the high age of the policy holders these are diminishing quite fast.

Since writing new policies is extremely important for this company there will be no changes in the way new policies are sold before solvency position gets week. After falling under SCR there will be reduction in new sales but total stop will take place only when solvency position drops under 2/3 SCR.

Capital allocation to Risk components (Euler) incl. Adjustments & Op. risk

	Allocating SCR	Allocating EOF	Free capital over SCR	Free capital over 140% SCR
TOTAL	**919**	**810**	**-110**	**-478**
Market	633	557	-76	-329
Default	18	16	-2	-9
Life	269	237	-32	-140
Heath	0	0	0	0
Nonlife	0	0	0	0
Market risk SCR	**633**	**557**	**-76**	**-329**
Interest rate	211	186	-25	-110
Equity	182	161	-22	-95
Property	0	0	0	0
Spread	232	204	-28	-121
Concentration	3	3	0	-2
Currency	4	3	0	-2
CCP	0	0	0	0
Life risk SCR	**269**	**237**	**-32**	**-140**
Mortality	18	16	-2	-9
Longevity	80	71	-10	-42
Disability	30	27	-4	-16
Expense	51	45	-6	-27
Revision	0	0	0	0
Lapse	79	69	-9	-41
Life catastrophe	10	9	-1	-5

chart 7 Capital allocation to risk components.

Re-insurance policy

Re-insurance policy do not form major part of the strategy as only top of the risk amounts could be re-insured in states of week solvency. This limit has not been set yet.

Company realizes that there lies a risk of having for life pension promises on liabilities but has not done anything to reduce this risk. If the market for so called longevity bonds would grow more then there could be actions towards this type of hedging.

Policy for overall solvency position

The main strategy states that the Solvency II based solvency ratio (EOF/SCR) must be over 140%. When this requirement is fulfilled the company is defined to be in a normal stage and the main measure for steering the company is MCEV based information. If fallen below this ratio Solvency II based measures are taken place with increasing importance. The steering procedure is such that below 140% SCR profit sharing is limited and below SCR risk mitigation and capital management procedures will take place. MCR is the default limit for the company.

Profit sharing policy

The profit sharing policy tries to find a harmony inside the triangle of policyholder's benefits, investors' expectations and the company's capital position (solvency position). As stated also in the main strategy profit sharing somehow defines the reason for existence for the company. Still without enough capital to buffer risks this is not possible.

Profit sharing is in action when the yearly profit is positive. Then both policyholders and investors are rewarded with some 30% of this profit for each group. Since MCEV is considered to be an important driver for the company (and its share value) investors are paid an extra 20% of the profit if MCEV growth exceeds 10%. If Solvency II ratio crosses 300% the excess amount will be split for shareholders benefit.

Company decision making

After defining all the policies the way how these are being followed is stated in the decision making part and basically how this changes company's profit and loss statement and balance sheet. This is illustrated in the chart 8.

Company decision making - binding together all the policies

No	Solvency & business trigger	Profit sharing	Risk tolerance	Capital management
1.	(EOF/SCR > 300%)	Benefits are granted amount of 30% of positive profit. Shares are payed amount that cuts the over capitalization into 300%	Since the amount of (Assets - liabilities - 2/3*SCR) is invested in equitys, this increases the company risk position quite much	Over capitalization is taken care in profit sharing part
2.	(140% < EOF/SCR) && dMCEV > 1.1	Benefits are granted 30% of the positive profit. Shares on the other hand are granted 50% of positive profit in case of substantial increase in MCEV	-	-
3.	(140% < EOF/SCR)	Benefits and Shares are granted both 30% of the positive profit	-	-
4.	100% < EOF/SCR < 140%	Benefits are halved (if positive profit) and shares are set at zero	Equity proportion is redused as EOF diminishes	-
5.	2/3 < EOF/SCR < 100%	-	Equity proportion of the portfolio is minimized now. Also worst rating class of bond holdings is lifted up into A or less risky.	Sub-ordinated loan is raised with spread equal to A + alpha. This amounts up to (1.1xSCR - EOF) but makes only Tier 2 type of capital (and max is 50% of Tier 1 EOF)
6.	MCR < EOF/SCR < 2/3	-	No new policies will be accepted. All assets are re-allocated into A or less risky bonds.	New share capital will be collected, total value an amount up to (SCR - EOF)
7.	EOF/SCR < MCR	Bankruptcy	Bankruptcy	Bankruptcy

chart 8 Company decisions.

4. Model structure

4.1 Policy-By-Policy structure

Individually modeled policies lead to better accuracy and also enable to include indicators (1 or 0) to drive these events (e.g. deaths, future premiums, surrenders or lapses). For surrenders and lapses the actual probability for such an event is included as part of the ESG data. As it is important to use the characteristics of the insurance portfolio of the company in these particular events these are taken into account by the following distribution how the event varies over the policyholders.

The distibution of Lapse Probabilities for risk policies

100% means the same lapse probability as in ESG for a individual

Policy Duration	Age					
	18 - 30	30 - 40	40 - 50	50 - 60	60 - 65	Over 65
0 - 2	403.20 %	352.80 %	138.60 %	113.40 %	189.00 %	63.00 %
3 - 5	215.04 %	188.16 %	73.92 %	60.48 %	100.80 %	33.60 %
6 - 10	188.16 %	164.64 %	64.68 %	52.92 %	88.20 %	29.40 %
11 - 15	147.84 %	129.36 %	50.82 %	41.58 %	69.30 %	23.10 %
16 - 20	120.96 %	105.84 %	41.58 %	34.02 %	56.70 %	18.90 %
21 - 30	107.52 %	94.08 %	36.96 %	30.24 %	50.40 %	16.80 %
Over 30	161.28 %	141.12 %	55.44 %	45.36 %	75.60 %	25.20 %

The distibution of Lapse Probabilities for Savings policies

100% means the same lapse probability as in ESG for a individual

Policy Duration	Age					
	18 - 30	30 - 40	40 - 50	50 - 60	60 - 65	Over 65
0 - 2	537.60 %	470.40 %	184.80 %	151.20 %	252.00 %	84.00 %
3 - 5	403.20 %	352.80 %	138.60 %	113.40 %	189.00 %	63.00 %
6 - 10	107.52 %	94.08 %	36.96 %	30.24 %	50.40 %	16.80 %
11 - 15	94.08 %	82.32 %	32.34 %	26.46 %	44.10 %	14.70 %
16 - 20	40.32 %	35.28 %	13.86 %	11.34 %	18.90 %	6.30 %
21 - 30	53.76 %	47.04 %	18.48 %	15.12 %	25.20 %	8.40 %
Over 30	107.52 %	94.08 %	36.96 %	30.24 %	50.40 %	16.80 %

The distibution of Lapse Probabilities for Unit linked policies

100% means the same lapse probability as in ESG for a individual

Policy Duration	Age					
	18 - 30	30 - 40	40 - 50	50 - 60	60 - 65	Over 65
0 - 2	510.72 %	446.88 %	175.56 %	143.64 %	239.40 %	79.80 %
3 - 5	430.08 %	376.32 %	147.84 %	120.96 %	201.60 %	67.20 %
6 - 10	120.96 %	105.84 %	41.58 %	34.02 %	56.70 %	18.90 %
11 - 15	80.64 %	70.56 %	27.72 %	22.68 %	37.80 %	12.60 %
16 - 20	53.76 %	47.04 %	18.48 %	15.12 %	25.20 %	8.40 %
21 - 30	67.20 %	58.80 %	23.10 %	18.90 %	31.50 %	10.50 %
Over 30	80.64 %	70.56 %	27.72 %	22.68 %	37.80 %	12.60 %

chart 9 Used Lapse data.

The distributions (chart 9) are illustrational for the purpose of this study but it is noticed that for reaching good results the macro-economic influence which is taken into account in the actual lapse model should somehow be excluded from these above distributions.

In the police-by-policy modeling all events happen in individual policy level and thus have their own influence how cash flows are realized for the year. Also in this type of modeling there is more freedom to take into account interrelationships between different events. For example in ESG there is a model that estimates lapse and surrender probabilities using macro-economic data. By using policy-by-policy technique in simulation and the lapse and surrender distributions every single policy can be reached individually. And with policies having different characteristics (when pension starts, amount of future premiums, allocation into UL funds, etc.) these events will be taken into account properly.

4.2 The year-end part

Over the year different cash flows are being generated from insurance and investment portfolios. These are summed together for profit and loss account and to close the balance sheet. During the year no changes are made to the way cash flows are realized. This makes year-end more or less a time point reading in the results about how the chosen risk tolerance and policies for this certain year have driven the company. For balance sheet it's assumed that only asset side is at market value which makes also own funds fully volatile to market movements. In liability side for the book value the amount of year-end saving has been used and for risk policies this is assumed to be zero (Policy period assumed to be one full year).

After balance sheet has been closed the resulting information; Solvency II position and MCEV can be calculated. For approximating the Solvency II position throughout the ORSA period (or strategy period) following methodologies is being used:

1. Assets are calculated based to markets (ESG) and liabilities by using an approximation based to movements on risk free interest rate curve and a cash flow profile.
2. An estimate of the eligible own fund (EOF) value can be calculated using assets and liabilities. There is assumed to be no issues about eligibility of Tier classes (all BOF counts as EOF).
3. SCR market risk components are calculated separately. Both interest risk and spread risk are calculated more precisely as the cash flow structure and rating classes can't be ignored. For equity risk the risk dampener is set to zero. What comes to other market risks these are assumed to develop hand-in-hand with the overall asset fluctuations.
4. SCR life risks are estimated separately for risk-, guarantee rate savings- and unit linked policies. As life SCR risk components are calculated stressing the best estimate liabilities it is assumed that all SCR life risks follow the certain proportion (of market value liabilities) of what they are at the starting point. These are illustrated in chart 9.
5. Future benefits are assumed to hedge part of the total SCR and change following the balance sheet movements.

6. Total SCR is calculated based to different modules and adjustments. For operational risk and default counterparty risk a proportional method looking the initial values and balance sheet movements is used.

MCEV will be tied into EOF as an approximation method. Though ANW will be automatically born in balance sheet and there is a picture how the other components move from year to year so this could be calculated more precisely.

SCR Life risk module - Assumptions on the risk proportional to market value liabilites

	Guaranteed rate	Unit Linked	Risk policies
Mortality	1.00 %	1.00 %	3.00 %
Longevity	3.00 %	1.50 %	0.00 %
Disability	1.00 %	0.50 %	3.00 %
Expense	1.30 %	3.00 %	0.50 %
Revision	0.00 %	0.00 %	0.00 %
Lapse	1.00 %	3.00 %	9.00 %
Life catastrophe	0.50 %	0.50 %	0.50 %

chart 10 SCR Life Risk Module.

4.3 The way company decisions are modeled

As the last task of models single year functions there is the decision making part. This is the point where all relevant information about profits & losses, balance sheet movements or Solvency position and MCEV is in use. The aim is to put in place a structure that implements the company policies introduced in last chapter. This has been done in a following way:

1. The relevant information is collected
2. Its sorted out in which stage (No 1 to 7) company is at the end of year
3. If the profit sharing procedures are possible these are executed
4. If risk mitigation procedures are needed then re-allocation and/or new sales cuts are executed. It's important to note that this is done following the initial information (in 1. step)
5. If there are capital management procedures in this stage those are also executed
6. Stage 7 is considered to be final (no return).

Well informed decisions require analysis to capture interactions between complex entities: economy, policyholder behavior and management actions. Ai et al (2011) presents a sophisticated conceptual framework for operationalizing strategic enterprise risk management in a general firm. Here a strait forward policy adjustment approach is adopted.

Company decision making - Algorithmic approach

No	Solvency & business trigger	Profit sharing	Risk tolerance	Capital management
1.	(EOF/SCR > 300%)	As in No 2 or No 3 depending of dMCEV but after the payments an extra dividend amounting EOF - 3SCR (if positive) will be payed.	This will automaticly work through re-allocation processes	Overcapitalization is taken care in profit sharing part
2.	(140% < EOF/SCR) && dMCEV > 1.1	As in No 3 but with extra 20% into dividends	Normal stage - no changes	Normal stage - no changes
3.	(140% < EOF/SCR)	If profit before benefits & taxes is positive, 30% from this will be for benefits and 30% into dividends. Benefits increases the guaranteed funds and shares will be payed (and will be taken into account when measuring the company)	Normal stage - no changes	Normal stage - no changes
4.	100% < EOF/SCR < 140%	As in 3. but benefits are only 15% and dividends zero	Re-allocation (by Euler) takes care of reducement of market risk as there will not be any changes into the amount of Life risk	No changes at this stage
5.	2/3 < EOF/SCR < 100%	No benefits or shares	The proportion invested into B rated bonds are allocated into less risky (A rated) bonds. The proportion in equities is reduced automatically towards zero as EOF reaches 2/3 SCR.	Sub-ordinated loans will grow and amount of (EOF - 1.1 SCR) assuming that there has not been any other new loan in current simulation (one time event in strategy period 5 years).
6.	MCR < EOF/SCR < 2/3	No benefits or shares	The parameter controling the maximum amount of new policies will stop all sales of new policies. Proportion invested into A rated bonds will be allocated into AAA class .	Share capital will increase by an amount of (EOF - SCR) assuming that there has not been any other new share capital in current simulation (one time event in strategy period 5 years).
7.	EOF/SCR < MCR	Bankruptcy	Bankruptcy	Bankruptcy

chart 11 Company decision rules – traffic lights.

5. Simulation results

The model was set up to run 1000 simulations for 60 years with changing time steps, starting with one month steps and later moving to 12 month steps. Beforehand generated economic scenarios were read from a separate source.

The initial solvency position 88% SCR was quite low and therefore it is interesting to see how company can survive from such a state and whether there is a strategy that keeps the business running with highest probabilities.

Chart 12 illustrates the 5 year development of the solvency II position which stays over 50% SCR and nearly touches 200% SCR in best scenarios at the end of the strategy period 5 years. The distribution for year 1 (2013) end from different solvency ratios is also shown. As it can be seen the mean value for solvency ratio is lifted nearly to 100% SCR.

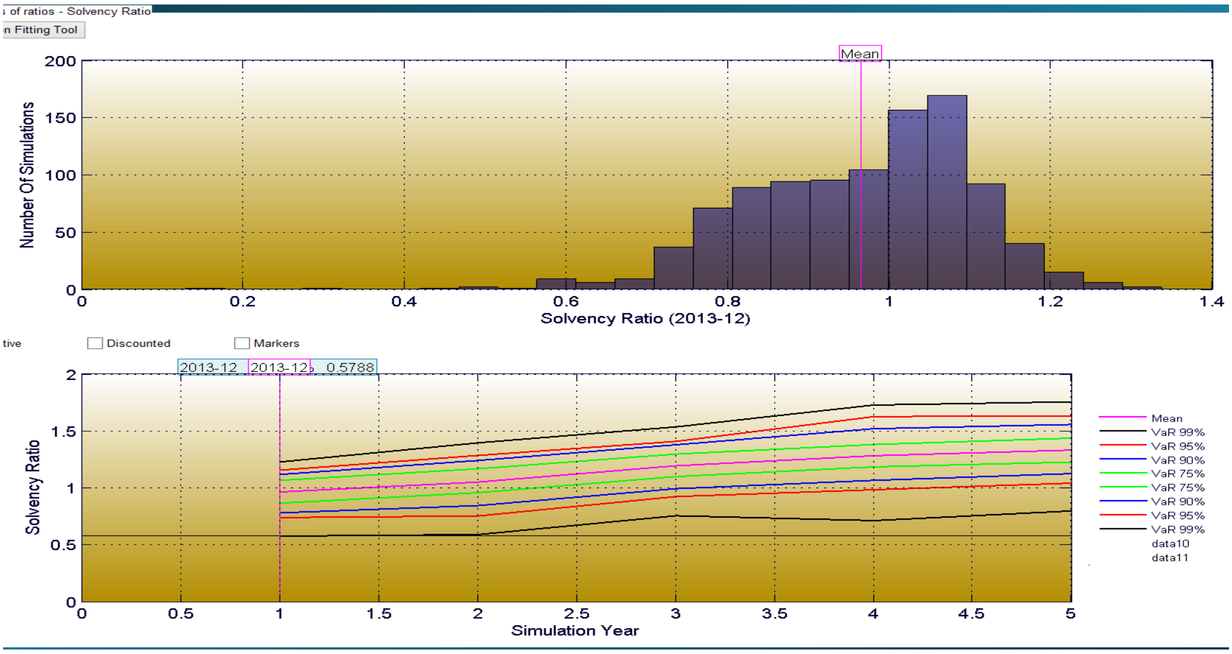

chart 12 Solvency ratio: a) Distribution of in 2013 (upper figure); b) The 5 year development of quantiles.

SCR was at the end of 2012 some 920 million € and from chart 13 it can be seen how this starts to evolve in the 5 year period. The overall SCR volatility seems to increase slightly and also a type of two peak distribution seems to illustrate this. In the distribution of the 4th year SCR there seems to be quite much variety in the results. Obviously when risk mitigation (or increases of risk) takes place in some of the simulations this balances the portfolios differently and moves SCR components.

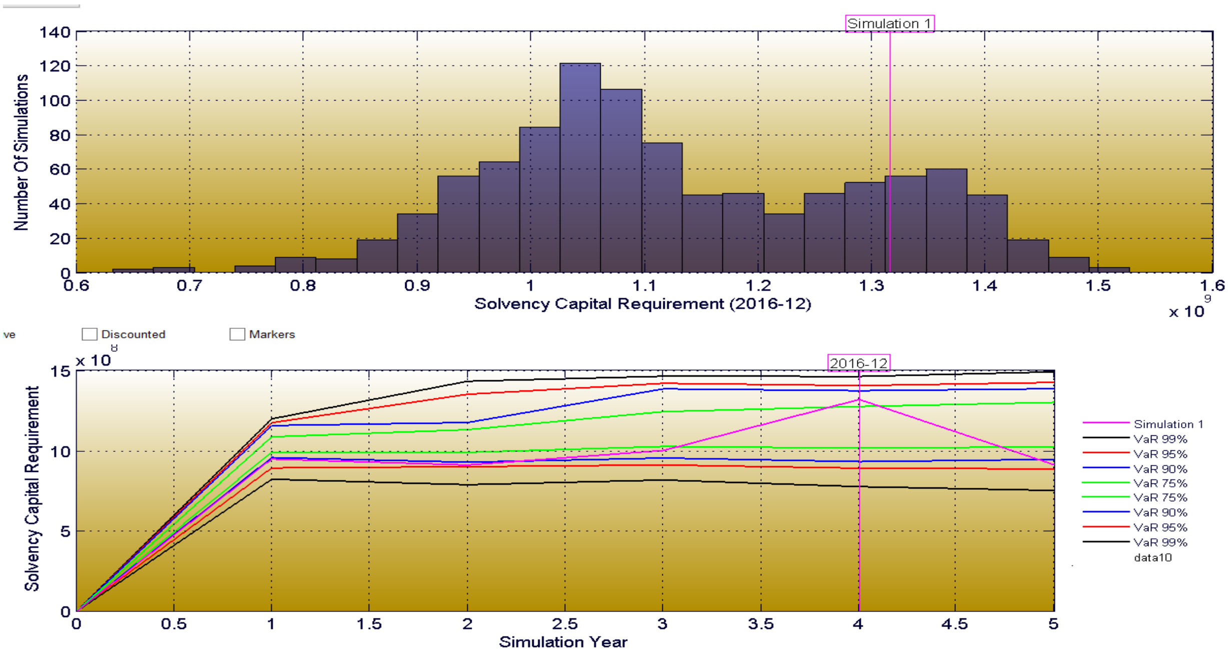

chart 13 Solvency capital requirement: a) Distribution in 2016 (upper figure); b) The 5 year development of quantiles and simulation 1.

As the company policies stated future benefits where ceased only if own funds going under 100% SCR. For dividends this limit was higher (140%). In charts 14 and 15 there are shown results describing how future benefits and dividends are granted in the simulations. Benefits are shown as percentage of savings and it can be seen that a number of the simulations make 0% benefit (end 2015 result) but around 1% benefits seems also to be common (for the 0% guarantee rate policies). Moderately rare event seems to be the benefit that reaches also the 4% guaranteed rate policies. As the starting position of the solvency position is low the probability of dividends to be paid to shareholders is only 0.7. In case of dividends to be paid (in year 2016) the conditional expected value for these are about 180 million €.

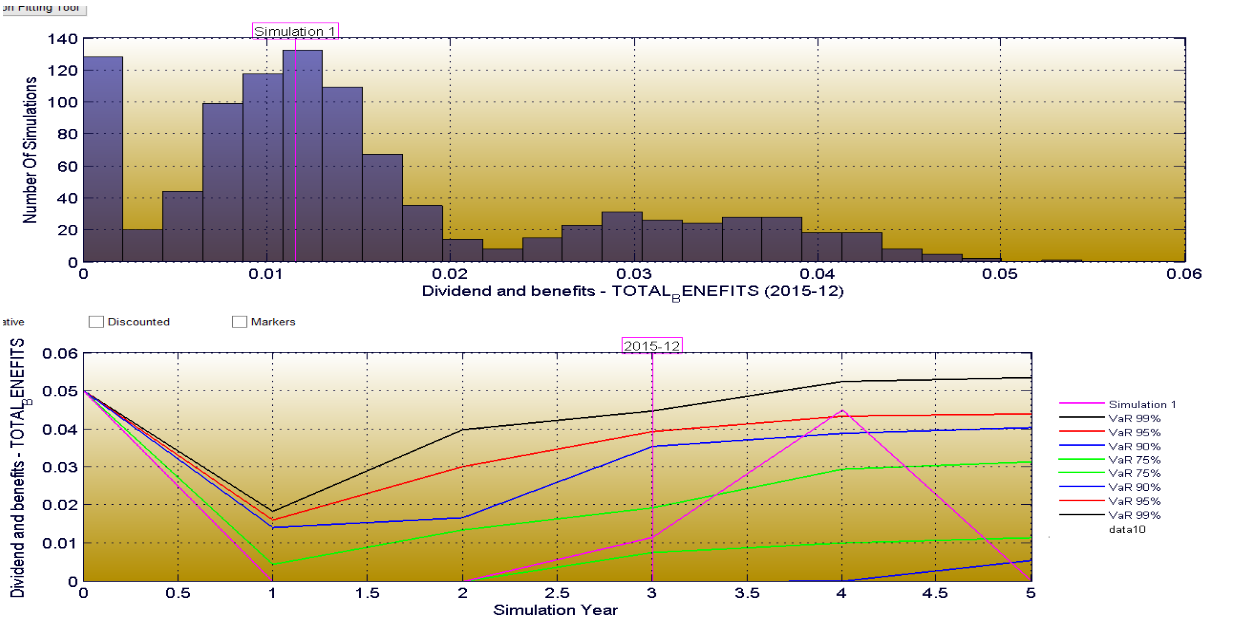

chart 14 Total benefits: a) Distribution in 2015 (upper figure); b) The 5 year development of quantiles and simulation 1.

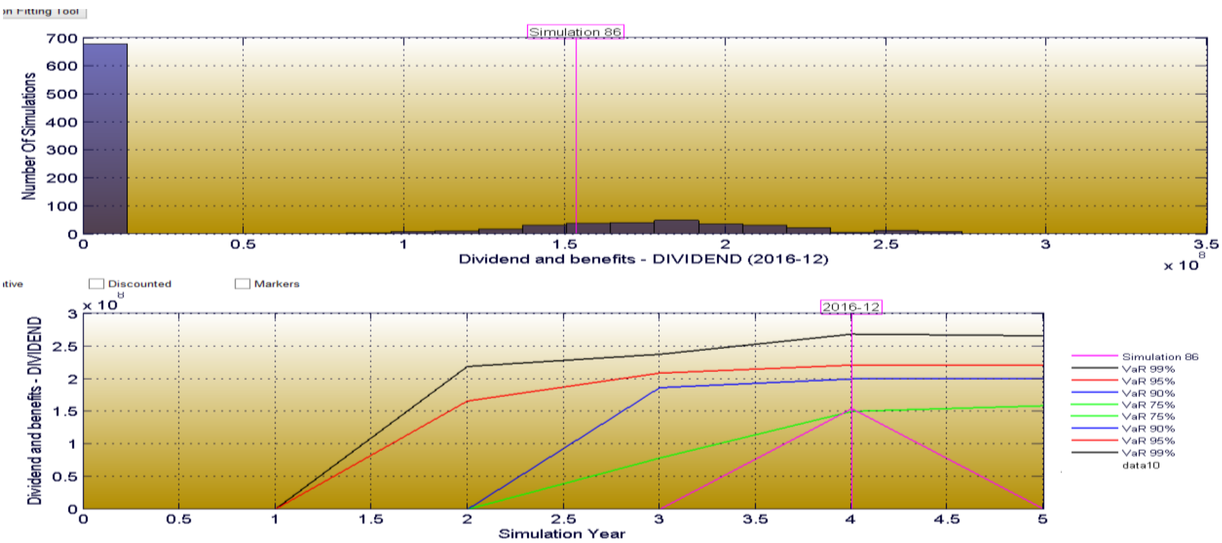

chart 15 Dividends : a) Distribution in 2016 (upper figure); b) The 5 year development of quantiles and simulation 1.

In order to investigate what specific benefits micro-level simulation approach can bring to the modeling of benefits and surrender payments sample correlation graphs are shown in charts 16 - 18.

First observation is that there is large individual variation in each graph. In more detailed, Chart 16 indicates that there are two subgroups (the boundary is of course fuzzy): In one group (benefits 0 - 0.025) solvency ratio varies mainly between 0.8 and 1.5. In the other group (benefits > 0.025) solvency ratio is always above 1. Chart 17 reveals no clear pattern in dependence between equity and surrender payments, but large individual variation can be seen. Instead, the final chart reveals that during the high inflation period surrender payments are clearly large than during the normal inflation regime.

These kinds of phenomena are difficult to capture with aggregate level simulations. Further step in the analysis could be the tracking of specific individuals (e.g. outliers or representatives of interesting sub-groups) and analyzing their cash flows (see Appendix for a graphical analysis).

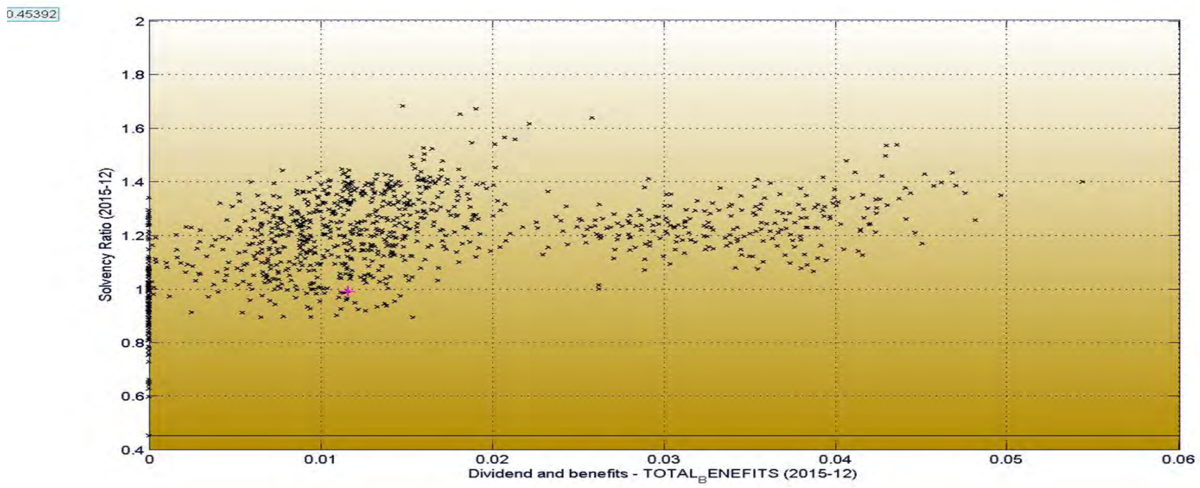

chart 16 Correlation plot between solvency ratio and total benefits (end of 2015).

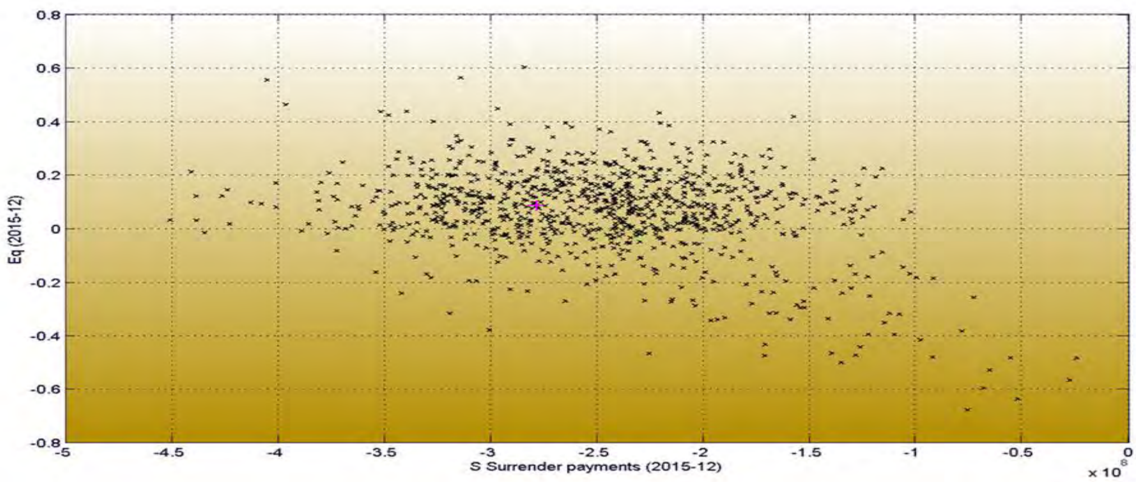

chart 17 Correlation plot between equity and surrender payment (end of 2015).

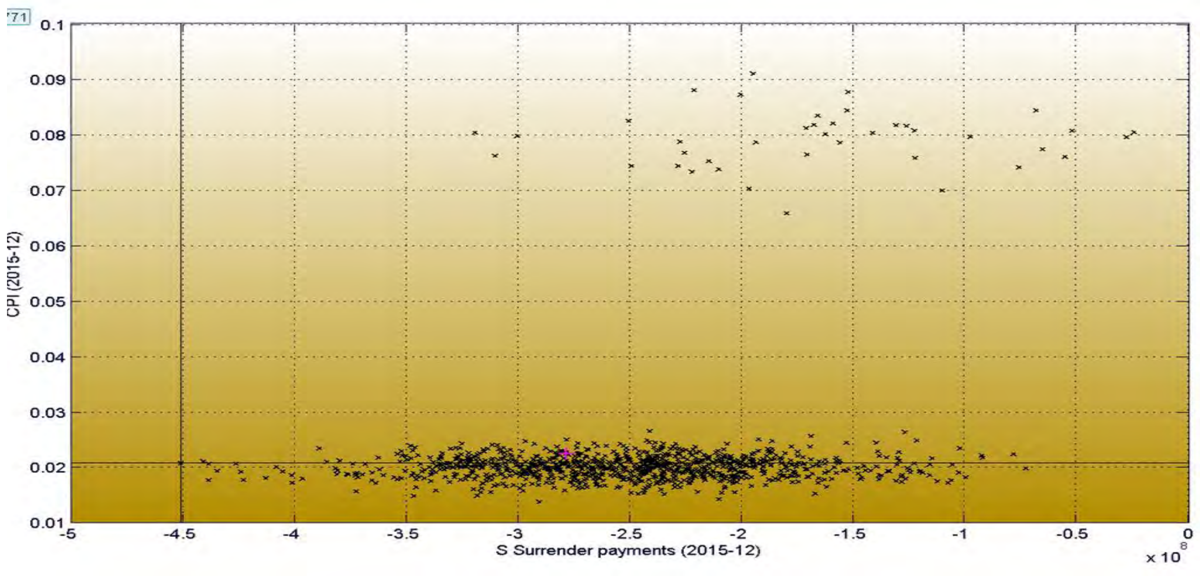

chart 18 Correlation plot between inflation and total benefits (end of 2015).

6. Conclusions

The measurement of future cash flows and their uncertainty becomes more and more important for life insurance business. However, with aggregate data, lots of useful information about the cash flows remains unused. For instance, individual variation and covariate information from policy, policy holder or the past development cannot be fully used in traditional actuarial models.

In this paper a micro simulation model for a hypothetical life insurance company has been developed. The performed simulation study has demonstrated that individual level simulation is feasible computational tool for life insurance modeling and that it gives the flexibility to model the future cash flows realistically. The obtained better information can potentially lead to better decisions.

Several aspects of the micro simulation model have been investigated in order to establish its suitability for business decisions and risk management. Analyzing the simulation results both at micro-level and at aggregate level has brought more insight in the insurance portfolio and greater sophistication in the view of in business.

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Appendix. A graphical analysis of an individual contract.