The Effects of a Low Interest Rate Environment on Life Insurers

Elia Berdin, Helmut Gründl

International Center for Insurance Regulation (ICIR)
and Center of Excellence SAFE

Goethe-Universität Frankfurt

berdin@finance.uni-frankfurt.de, gruendl@finance.uni-frankfurt.de

2014 Annual Conference
Asia-Pacific Risk and Insurance Association

Moscow, July 27-30, 2014

Financial support from the *Deutscher Verein für Versicherungswissenschaft e.V.* is gratefully acknowledged

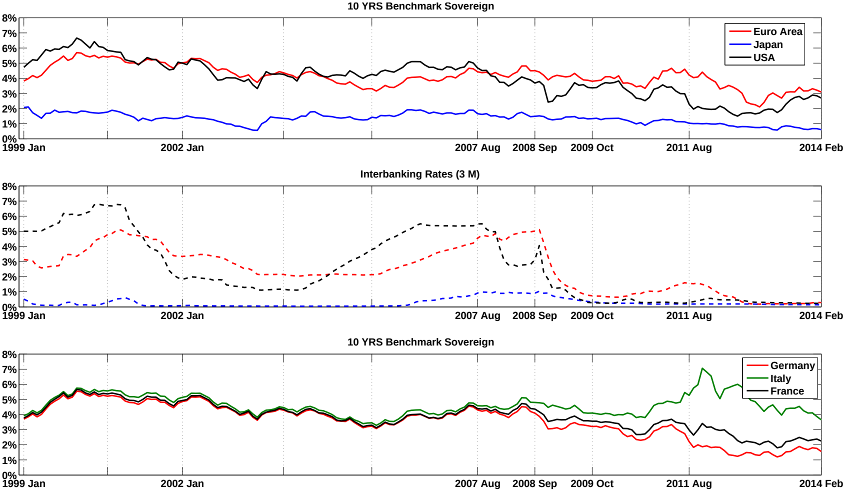
Table of content

The Current Market Interest Rate Level

- Decline of interest rates for the last decades in major economic areas
- US financial crisis induced a sharp loosening of monetary policies
- Sovereign debt crisis in Europe: increased risk aversion induced "flight-to-quality" towards some countries (e.g. Germany) with consequent increase in sovereign bond prices (decrease in yields) and further Central Banks interventions
- Monetary policy still very loose (forward guidance): similar scenario started in Japan towards the end of 1990s

The Current Market Interest Rate Level (cont'd)

Figure : Long Term Benchmark Interest Rates and Interbanking Rates (source: ECB)

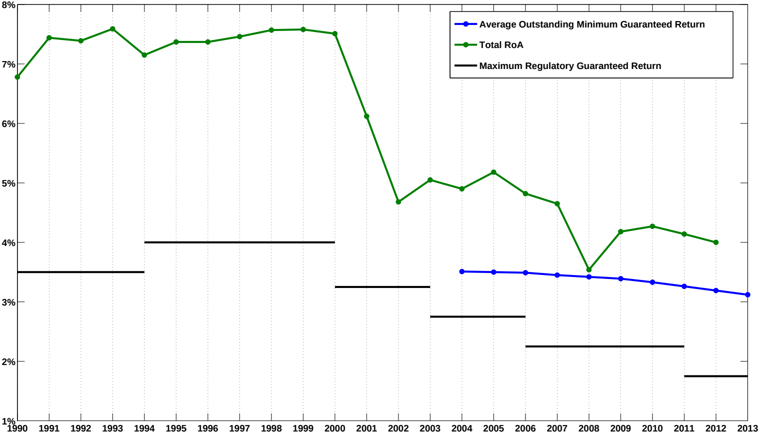


Challenges for Life Insurers

- Current market interest rate level: challenge for life insurers offering savings products with minimum guaranteed returns
- Swiss Re (2012): due to product characteristics, Germany, the U.S. and Italy report the highest exposure to interest rate risk among major insurance markets
- Germany special case: major insurance market with both **high exposure to interest rate risk** and **very low sovereign yields**
- Bundesbank Financial Stability Review (2013) reports results of stress tests on German Life Insurers: a very low interest rate scenario would affect solvency of a subset of companies (Solvency I regime)
- In the German market, the estimated average guaranteed return of life insurance contracts was 3.12% in 2013
- Products with a guaranteed return of 4% still account for ca. 24% of total outstanding contracts

The German Case

Figure : RoA and Guaranteed Returns, German Life Insurance Market (source: GDV, BaFin and Assekurata)



Goal and Methodology

- **Goal of the study**: assess the solvency situation of a stylized German life insurer in a protracted low interest rate environment
- **Methodology**: simplified balance sheet with *initial pre-existing asset allocation and liability portfolio*, projected 10 years ahead with stochastic capital markets developments
- **Regulatory framework**: German Insurance Regulation and Solvency II capital requirement
- **Calibration**: initial situation and balance sheet yearly adjustments as close as possible to reality

Book Values vs Market Values

- Book Value (BV) and Market Value (MV) Balance Sheets
- BVs basis for profit participation whereas MVs basis for solvency assessment
- **A**(ssets), **L**(iabilities), **E**(quity)
  - CB_t= capital buffer (*freie RfB*)
  - $OF_t = A_t^{MV} - L_t^{MV} = A_t^{MV} - (L_t^{BE} + RM_t)$

Assets	Liabilities
	E_t
	CB_t
A_t^{BV}	L_t^{BV}

Assets	Liabilities
	OF_t
	RM_t
A_t^{MV}	L_t^{BE}

The Asset Allocation

- 6 asset classes:
  - 4 bond-like asset classes:
    - Sovereign Debt
    - Mortgage Covered Bonds (Pfandbriefe)
    - Credit Institutions Bonds (Bank Bonds)
    - Corporate Bonds

    No credit risk of bond portfolio
  - 2 stock-like asset classes:
    - Stocks
    - Real Estate
- Every year a share of the bond portfolio comes due and needs to be reinvested
- Asset allocation remains fixed over time

The Asset Allocation (cont'd)

- Initial asset allocation:
  - 25 cohorts of Sovereign Bonds each with 25 yrs time to maturity (TTM): oldest cohort with 1 year residual TTM, newest 25 yrs TTM
  - 15 cohorts of Mortgage Pfandbriefe with 15 yrs TTM, 10 cohorts of Bank and Corporate Bonds each with 10 yrs TTM: same structure as Sovereign
- Average initial TTM 9.25 yrs, modified duration $\cong$ 7.4
- Historical coupons based on Bundesbank Database

Asset Classes	**share***
Sovereign Debt	34.4%
Mortgage Pfandbriefe	34.0%
Bank Bonds	13.4%
Corporate Bonds	9.2%
Stocks	5.3%
Real Estate	3.8%

Source: Statistical Yearbook of German Insurance 2013 (GDV) and authors' calculations.

Capital Markets Developments

- Term structure of risk free interest rates simulated using the Cox-Ingersoll-Ross model
  - each bond-like asset class pays a (liquidity) premium/spread over the Sovereign (and the risk free term structure)
  - spreads assumed to be different per maturity but constant over time
- Stock-like asset classes developments simulated using a Geometric Brownian Motion

The Liability Portfolio

- Life Insurer sells a *homogeneous savings product* with minimum guaranteed return
  - fixed TTM (25 years) with annual net premium payments
  - lump-sum final benefit payment
  - no mortality risk
  - no surrender option
  - no transactions costs
- 25 contracts simultaneously held in portfolio in every year (i.e. 1 enters and 1 gets liquidated)
- Each contract represents a cohort with the minimum guaranteed return at the inception moment (oldest sold at the end of 1989, residual TTM in 2013 = 1 year)
- initial TTM=13 yrs, initial modified duration$\cong$ 11.1
- New contract after 2013 s.t. regulatory decision on maximally allowed guarantee (we model a regulator's reaction function based on past behaviour)

The Liability Portfolio Initial Composition

- Outstanding portfolio at $t = 2013$ has an average guaranteed return of 3.11% (Assekurata reports an average of 3.12% for the entire German Market)

inception period	guaranteed return	relative weight in portfolio
1/1989 – 6/1994	3.50%	22%
7/1994 – 6/2000	4.00%	24%
7/2000 – 12/2003	3.25%	14%
1/2004 – 12/2006	2.75%	12%
1/2007 – 12/2011	2.25%	20%
1/2012 – 12/2013	1.75%	8%
average in portfolio	3.11%	

The Liability Portfolio Evolution Over Time

- Typical feature of German life insurance products is the minimum profit participation and the additional return on top of the guarantee
- Each cohort's liability evolves according to (1)

$$l_t^{i,p,BV} = l_{t-1}^{i,p,BV} \cdot \left[1 + max\left(r_t^{i,g}, r_t^p\right)\right] + \pi_t^i \tag{1}$$

  - $r_t^{i,g}$: minimum guaranteed profit for cohort i that includes minimum profit participation
    - $max(0.9 \cdot RoA^i, r^i)$ with r^i the guaranteed return for cohort i
    - although we neglect mortality developments, we insert mortality returns as they are a stable source of income for the industry: i.e. deterministic share (empirically calibrated) of l: $0.75 \cdot r^q \cdot l_t^{i,p,BV}$
  - r_t^p includes additional returns if RoA in t is sufficiently high

- $l_t^{i,p,BV}$ is the BV of each cohort, sum of 25 gives L_t^{BV}
- L_t^{BE} is obtained discounting (using the risk free term structure) to present value t the final minimum guaranteed payment

The Balance Sheet Adjustment Over Time

- German Insurance Regulation
  - Interest Rate Reserve (*Zinszusatzreserve*) built on top of L^{BV} if (*reference interest rate*) $MA(10)^{10YTM\ Govie} < r^i$
  - Hidden Reserve Participation (50%) if $A_t^{MV} > A_t^{BV}$ (of assets belonging to PHs) at the liquidation date
  - BV adjusted according to prudential accounting principles (*Niederstwertprinzip*)
- Dividends to SHs and extra return to PHs distributed if RoA_t is sufficiently high (very prudent modeling: limited use of profit smoothing via CB_t)
- Balance Sheet adjustment occurs at the end of the year

Interplay Between A^{MV} and L^{MV}

- RM obtained as fixed markup on top of L^{BE} (data from QIS 5)
- OF compared in every period with SCR (*solvency ratio*)
- SCR determined with a $VaR_{0.995}$ via additional simulation on top of the capital market simulation
  - we simulate a 1 year forward asset and liability developments at the end of every period
  - 1 year CIR and GBM developments using same calibration but starting point dependent on underlying capital market simulation
- if $OF_t < 0$: recapitalization or transfer of liability portfolio (our model: default)

Capital Markets Simulation

- CIR calibration based on German overnight rate 1973-2013 (following Brigo et al. (2009))

Geometric Brownian Motion

Stocks	$\mu = 0.072$	$\sigma = 0.22$	$S_0 = 9552.16^*$
Real Estate	$\mu = 0.052$	$\sigma = 0.19$	$S_0 = 838.26^*$

CIR model

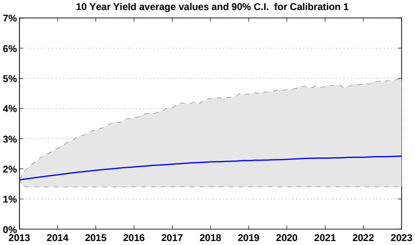
parameters	calibration 1	calibration 2	calibration 3
θ	**0.02**	**0.01**	**0.03**
k	0.201	0.201	0.201
σ	0.114	0.114	0.114
λ	-0.10	-0.10	-0.10
r_0	0.0045*	0.0045*	0.0045*

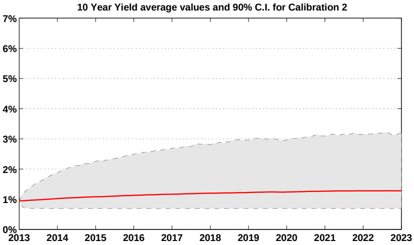
Correlation Matrix

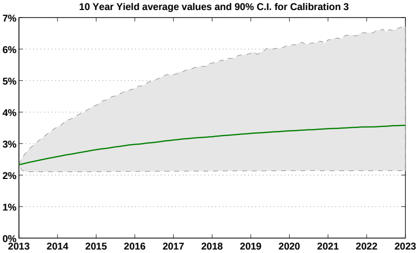
	DAX	DREITS	FIBOR/EONIA
DAX	1	0.93	-0.65
DREITS	-	1	-0.61
FIBOR/EONIA	-	-	1

Time series from January 1973 until December 2013 (end of month). Source: Datastream, Bundesbank. *) values as per December 2013 for DAX, DREITS and EONIA respectively

Capital Markets Simulation (cont'd)







Balance Sheet Calibration

- Initial Level of Capital Endowment exogeneously given:
  - $\frac{E+CB}{A}$ of top 40 Life Insurers in Germany in terms of premiums in 2012
  - $BS1 = 10^{th}$, $BS2 = 30^{th}$, $BS3 = 50^{th}$,$BS4 = 70^{th}$ and $BS5 = 90^{th}$ percentile respectively
  - Equity capital level average of industry in 2012 (BaFin)

Balance Sheet

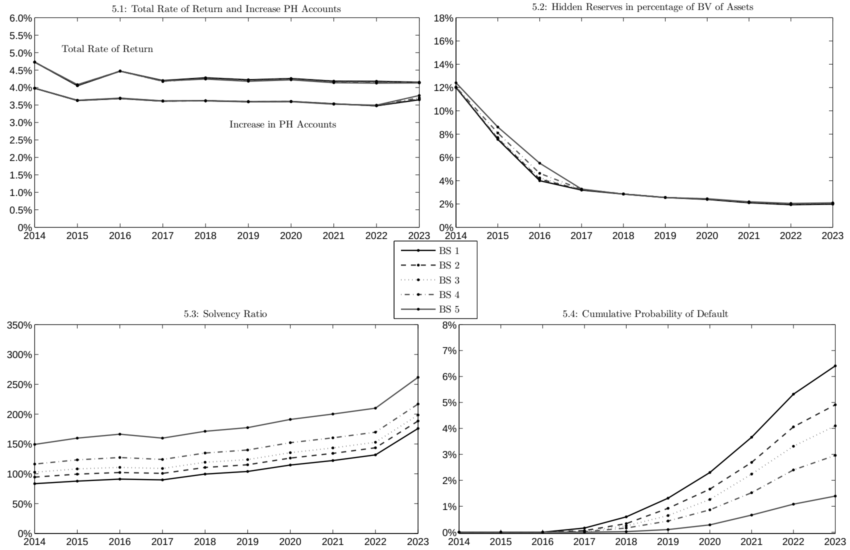
	BS 1	BS 2	BS 3	BS 4	BS 5
$\frac{CB_0}{L_0^{p,BV}}$	0.036	0.044	0.05	0.06	0.084
$\frac{E_0}{L_0^{p,BV}+CB_0}$			0.017		
$\frac{E_0+CB_0}{A_0^{BV}}$	$\cong 0.051$	$\cong 0.058$	$\cong 0.063$	$\cong 0.072$	$\cong 0.093$

Balance Sheet Calibration (cont'd)

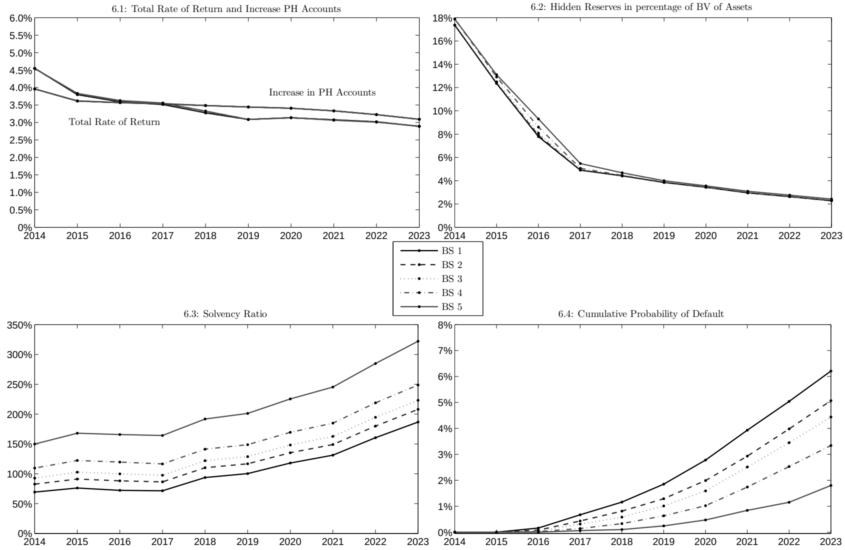
Other Parameters

ω	0.005	marginal change technical rate
ϑ	0.5	share of market value increase cashed in as dividends and rents
δ	0.05	shareholder dividends constraint
π_t^i	1	premium paid by cohort i
N^l	25	cohorts of contracts simultaneously held in portfolio
N^b	4	bond-like asset classes
N^k	2	stock-like asset classes
r^q	0.01	mortality return as share of book value of liabilities
v	0.8	lowest bound for additional return distributions
u	1.2	lowest bound for additional return distributions
α	0.995	confidence interval for the VaR
ρ	0.0183	fixed markup to calculate the RM

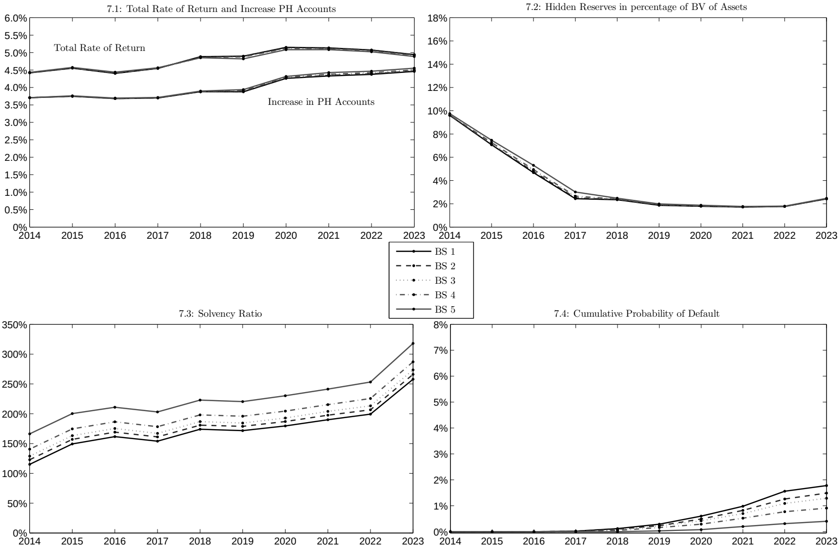
Calibration 1



Calibration 2



Calibration 3



Conclusion and Discussion (cont'd)

Discussion of Results

⇒ Each initial capital endowement represents the average of ca. 20% of the German LI. Thus we can calculate an expected *PD* by 2023:

- under calibration 1 the $\mathbb{PD}^1 = 3.95\%$
- under calibration 2 the $\mathbb{PD}^2 = 4.17\%$
- under calibration 3 the $\mathbb{PD}^3 = 1.17\%$

Moreover...

- under calibration 1 we observe financial distress already in 2017
- under calibration 2 we observe financial distress already in 2016!
- under calibration 3 still situations of financial distress in the lower part of the capital endowement distribution

Conclusion and Discussion (cont'd)

Conclusions

- The current low interest rate environment might have severe consequences for German life insurers
  - particularly exposed are less capitalized companies (not a surprise): under calibration 2, Solvency Ratio of median insurer close/below 100%
- Adjustment of liability portfolio slower than asset portfolio: current source of major solvency problems
- Product innovation would affect new business, however problems remain on old contracts
- RM pretty high: does it have OF character?

Caveats

- Our results strongly dependent on
  - duration mismatch (our is $\cong$ 3.75 yrs $\rightarrow$ GDV non-official data): might be better/worse
  - liability portfolio pace of adjustment: in reality it might be quicker/slower
  - asset allocation: our proposal is very conservative, though there are trade offs with respect to more risky allocations

Thank you for your attention

Elia Berdin, M.Sc. (berdin@finance.uni-frankfurt.de)
Prof. Dr. Helmut Gründl (gruendl@finance.uni-frankfurt.de)

Backup

The CIR and GBM in continuous

CIR

$$dr(t) = [k\theta - (k + \lambda\sigma_r)r(t)]dt + \sigma_r\sqrt{r(t)}dW_r(t) \tag{2}$$

$W(t)$: standard Brownian motion; $r(t)$: instantaneous interest rate, k: speed of adjustment; θ: mean reversion level ; σ_r: volatility of the short rate dynamics; λ: MPR. The model allows the pricing of a ZCB B according to

$$B(t, T) = A(t, T)e^{-H(t,T)r(t)} \tag{3}$$

$$A(t, T) = \left[\frac{2\gamma e^{(k+\lambda+\gamma)(T-t)/2}}{(\gamma + k + \lambda)(e^{\gamma(T-t)} - 1) + 2\gamma}\right]^{\frac{2k\theta}{\sigma_r^2}}, \tag{4}$$

$$H(t, T) = \left[\frac{2(e^{\gamma(T-t)} - 1)}{(\gamma + k + \lambda)(e^{\gamma(T-t)} - 1) + 2\gamma}\right], \tag{5}$$

$$\gamma = \sqrt{(k + \lambda)^2 + 2\sigma_r^2}. \tag{6}$$

GBM

$$S(t) = S(0)e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma_s W_s(t)}. \tag{7}$$

The CIR and GBM in discrete

CIR The simulation of the continuous time first-order auto regressive process can be obtained by means of the following recursive equation with discretization time t_i:

$$r_{t_i} = k\theta\Delta t + (1 - k\Delta t)r_{t_{i-1}} + \sigma\sqrt{r_{t_{i-1}}\Delta t}\varepsilon_{t_i} \qquad (8)$$

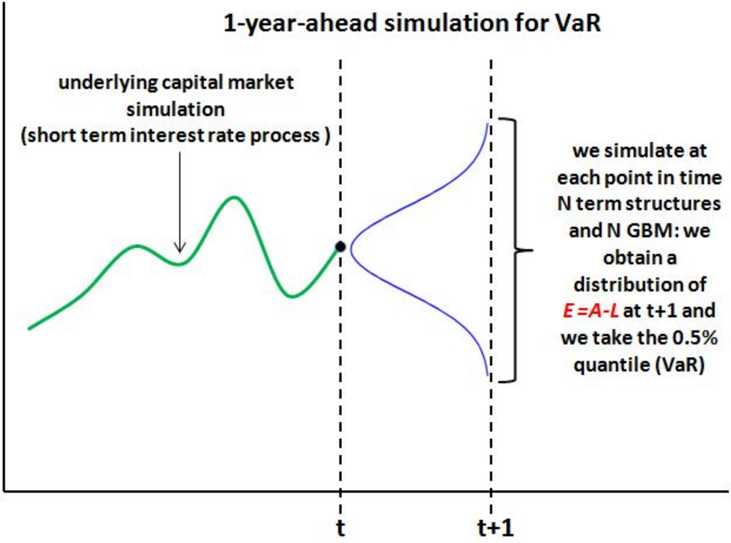
with $\varepsilon \sim \mathcal{N}(0,1)$ and $\Delta t = t_i - t_{i-1}$ (see Brigo et al. (2009)).

GBM The simulation of the process follows the recursive version of the continuous time equation with discretization time t_i:

$$S_{t_i} = S_{t_{i-1}} e^{\left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \sigma\sqrt{\Delta t}\varepsilon_{t_i}} \qquad (9)$$

with $\varepsilon \sim \mathcal{N}(0,1)$ and $\Delta t = t_i - t_{i-1}$ (see Brigo et al.(2009)).

Internal Model



Internal Model (cont'd)

SCR is determined as follows

$$\mathcal{P}\left\{ \left(\widetilde{SCR}_t + (1+\rho)\cdot L_t^{BE}\right)\cdot(1+\tilde{r}_t) - (1+\rho)\cdot \widetilde{L_{t+1}^{BE}} \geq 0\right\} \geq 1-\alpha \quad (10)$$

$$\widetilde{L}_{t+1}^{BE} = \sum_{i=1}^{N^l} \tilde{l}_{t+1}^{i,BE} = \sum_{i=1}^{N^l} \frac{l_{(t+1,T-\tau-1)}^{i,g,BV}\cdot\left(1+max\left(0.9\cdot\tilde{r}_{t+1}, r^i\right)\right)^{(T-\tau-1)}}{\left(1+\tilde{i}_{d,(t+1,T-\tau-1)}\right)^{(T-\tau-1)}} \quad (11)$$

with $\tilde{i}_{d,(t+1,T-\tau-1)}$ being the simulated discount rate (i.e. the simulated term structure)

$$\tilde{r}_{t+1} = \frac{\widetilde{A}_{t+1}^{MV} - A_t^{MV}}{A_t^{MV}} \Longrightarrow \widetilde{A}_{t+1}^{MV} = \sum_{b=1}^{N^b}\sum_{\tau=1}^{T}\widetilde{B}_{(t+1,T-\tau-1)}^{b,MV} + \sum_{k=1}^{N^k}\tilde{S}_{t+1}^{k,MV} \quad (12)$$

The Regulator's Reaction Function

The Regulator in the model reacts to the changes in the reference interest rate (r_t^{ref}) according to the following rule:

$$\begin{cases} r_{t+1}^g = r_t^g - \omega, & \text{if} \quad r_t^{ref} \leq r_t^g \\ r_{t+1}^g = r_t^g + \omega, & \text{if} \quad r_t^{ref} \geq r_t^g + \omega \\ r_{t+1}^g = r_t^g, & \text{otherwise} \end{cases} \tag{13}$$

where r_t^g is the maximum allowed guaranteed return at time t and ω is the marginal change decided by the regulator. Consistently with the observed changes in the technical interest rate in recent years, we assume $\omega = 50$ basis points.

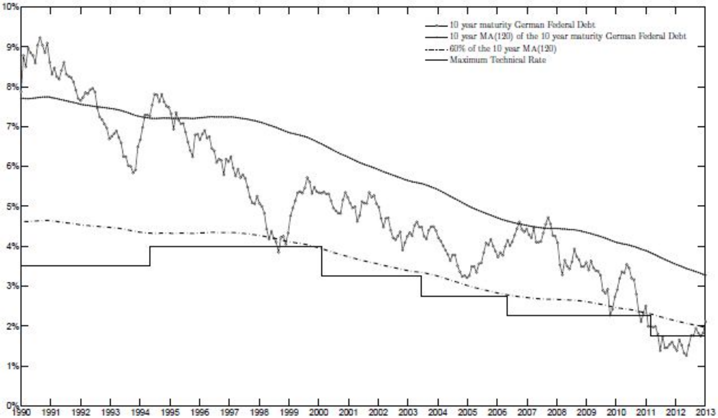
Assekurata Surveys

Table 5: Assekurata Market Surveys on Life Insurance Contracts in Germany

year	total weighted avg.	min. weighted avg.	max. weighted avg.	avg. total return	share of 4% g.r.
2004	3.51%	2.75%	3.80%	4.43%	28.56%
2005	3.50%	2.75%	3.69%	4.28%	29.15%
2006	3.49%	2.75%	3.77%	4.24%	29.55%
2007	3.45%	2.63%	3.76%	4.23%	30.17%
2008	3.42%	2.57%	3.67%	4.34%	26.69%
2009	3.39%	2.52%	3.62%	4.26%	29.44%
2010	3.33%	2.52%	3.56%	4.19%	27.17%
2011	3.26%	2.44%	3.52%	4.08%	26.00%*
2012	3.19%	2.41%	3.47%	3.94%	22.15%
2013	3.12%	2.38%	3.45%	3.68%	21.50%

Note: the total weighted average indicates the average of the guaranteed return among all survey's participants. The total average return indicates the return including the profit distribution and the share of 4% g.r. indicates the relative weight of highest guaranteed return in the underwriting portfolio.
* No precise value reported.

Maximum Allowed Guaranteed Return



source: Deutsche Bundesbank and BaFin

Mortality (and Risk) Returns

Table 4: Breakdown per source of Return net of the guaranteed Rate of Return (tsd. €)

year	liabilities	assets	mortality	costs & others	total	$\frac{mortality}{liabilities}$
2002	512,935	1,339	4,590	(697)	5,231	0.9%
2003	521,670	5,886	4,697	(1,502)	9,081	0.9%
2004	545,310	7,878	4,478	(2,218)	10,139	0.8%
2005	562,009	10,668	5,569	(1,796)	14,441	1.0%
2006	578,381	9,337	6,363	(1,477)	14,223	1.1%
2007	595,236	8,533	6,381	(1,161)	13,754	1.1%
2008	607,796	892	6,498	(575)	6,815	1.1%
2009	627,966	5,485	6,463	(130)	11,819	1.0%
2010	654,133	6,569	6,460	(871)	12,158	1.0%
2011	666,677	4,481	6,518	(717)	10,282	1.0%
2012	693,484	4,545	5,729	(600)	9,675	0.8%
					average	1.0%

Source: BaFin, Primary Life Insurer, 2002-2012.

ICIR International Center for Insurance Regulation

SAFE Center of Excellence

Spreads

Table 2: Interest Rate Differentials versus Term Structure of Listed German Federal Securities

Maturity	1999 – 2013*	1999 – 2008**	2008 – 2013***
Mortgage Pfandbriefe†			
1	0.55%	0.31%	0.94%
2	0.51%	0.30%	0.86%
3	0.51%	0.30%	0.84%
4	0.50%	0.30%	0.84%
5	0.50%	0.30%	0.82%
6	0.50%	0.31%	0.81%
7	0.50%	0.32%	0.79%
8	0.50%	0.32%	0.78%
9	0.50%	0.33%	0.77%
10	0.51%	0.34%	0.77%
11	0.52%	0.36%	0.78%
12	0.53%	0.37%	0.80%
13	0.55%	0.38%	0.83%
14	0.57%	0.39%	0.87%
15	0.60%	0.40%	0.91%
Credit Institutions Bonds			
1	0.49%	0.24%	0.93%
2	0.48%	0.24%	0.92%
3	0.47%	0.24%	0.90%
4	0.46%	0.23%	0.86%
5	0.46%	0.22%	0.88%
6	0.42%	0.23%	0.75%
7	0.41%	0.23%	0.75%
8	0.39%	0.23%	0.68%
9	0.33%	0.21%	0.57%
10	0.33%	0.21%	0.57%
Corporate Bonds‡			
1 – 10	1.63%	1.06%	2.67%

*) Monthly data from January 1999 to December 2013.
**) Monthly data from January 1999 to August 2008.
***) Monthly data from September 2008 to December 2012.
† Data for the term structure of Mortgage and Public Pfandbriefe available from January 2000.
‡ Due to the lack of data, differentials were calculated on the average maturity of the sample and assumed to be constant for all maturities (1 – 10).

The Balance Sheet Adjustment Over Time

- In every period the FCF_t determines the reinvested amount of funds s.t. minimum growth of L
  - if FCF_t below to the minimum amount of funds to be transferred to the PHs' accounts (*funding gap*), cash in of hidden reserves
    - straightforward trading strategy: sell assets with $MV > BV$ starting from the oldest and most liquid
  - if no hidden reserves at hand, reinvest FCF_t and move on

Timeline of Balance Sheet Adjustment