Regulation-Induced Interest Rate Risk Exposure

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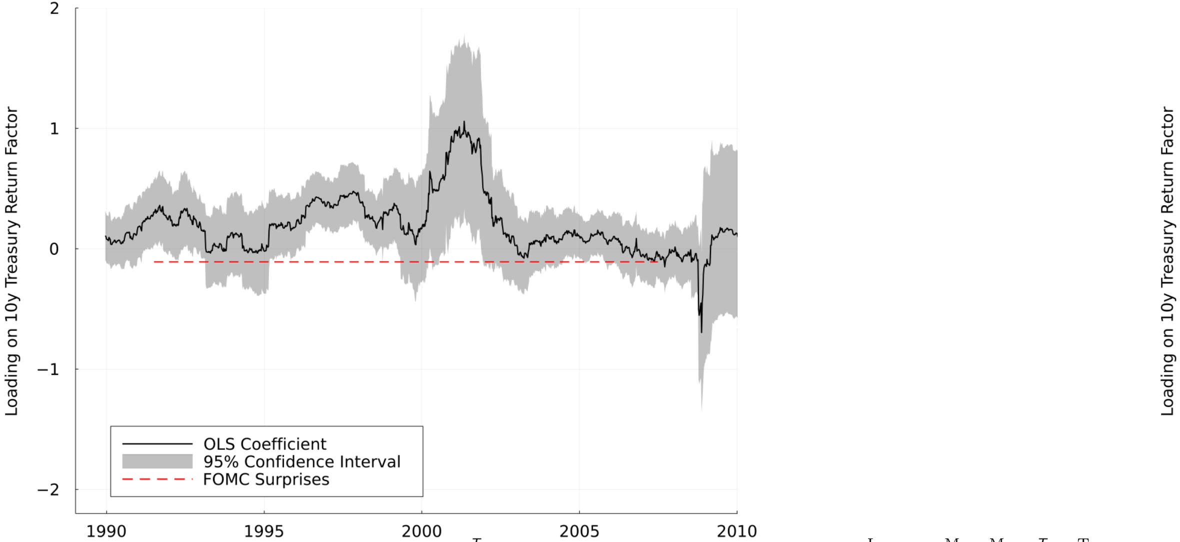


Interest rate sensitivity of life insurers' stock prices: β^T in 2-year rolling-window regression of weekly $rx_t^{\mathrm{L}} = \alpha + \beta^{\mathrm{M}} \cdot rx_t^{\mathrm{M}} + \beta^T \cdot rx_t^{\mathrm{T}} + \epsilon_t$

▸ Data ▸ FOMC Table ▸ FOMC w/o outliers ▸ FOMC timing ▸ FOMC Swanson ▸ Banks

Interest Rate Sensitivity

- Value of the equity E of a life insurer:

$$E = \underbrace{A - L}_{\text{net assets}} + \underbrace{F}_{\text{franchise}}$$

- Duration of equity:

$$D_E = -\frac{1}{E}\frac{\partial E}{\partial r} = \frac{A-L}{E} D_{A-L} + \frac{F}{E} D_F = \frac{A}{E} \underbrace{\left(D_A - \frac{L}{A} D_L \right)}_{G} + \frac{F}{E} D_F$$

- D_A: security-level holdings information
- D_L: opaque information $\Rightarrow$ statutory reserve regulation
- $D_F < 0$: indirect evidence on the profitability of the funding franchise

1. Net Assets $A - L$

Actuarial and Reserve Value of a Liability

- Actuarial (fair) V and reserve value $\hat{V}$ of a liability:

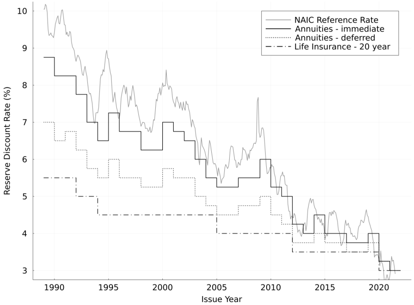
$$V_t = \sum_{h=1}^{\infty} e^{-h \cdot r_{t,h}} \cdot \mathbb{E}_t \left[b_{t+h} \right] \qquad \hat{V}_t = \sum_{h=1}^{\infty} \left(1 + \hat{r}_S\right)^{-h} \cdot \hat{b}_{t+h}$$

where $\hat{r}_s$ is the reserve discount rate and $\hat{b}$ are reserve cash flows specific to a valuation standard S prescribed by regulation.

- Pseudo-actuarial value:

$$\tilde{V}_t = \sum_{h=1}^{\infty} e^{-h \cdot r_{t,h}} \cdot \hat{b}_{t+h}$$

- Popular policies: $\tilde{V}_t \approx V_t$ and $\tilde{D}_t \approx D_t$! ▸ Examples



Data

- Need $\hat{b}$ for the pseudo-actuarial value and duration!
- Back out from reserve values $\hat{V}$:

$$\hat{V}_{i,t,S} = \left(1 + \hat{r}_S\right)^{-1} \hat{b}_{i,t+1,S} + \left(1 + \hat{r}_S\right)^{-1} \hat{V}_{i,t+1,S}$$

- "Exhibit 5 - Aggregate Reserves for Life Contracts":
  - at the end of year t from 2001 to 2020
  - for each life insurer i out of 900
  - aggregated to valuation standard S (mortality table, reserve discount rate $\hat{r}$, issue years)

1 Valuation Standard	2 Total	
Life Insurance:		**Life Insu**
0100001. 58 CSO - NL 2.50% 1961-1969	243,737	0100001
⋮	⋮	
0100025. 80 CSO - CRVM 4.50% 1998-2004	306,242,662	0100025
⋮	⋮	
0100037. 01CSO CRVM - ANB 4.00% 2009	869,698	0100037
0199997. Totals (Gross)	466,142,285	0199997
0199998. Reinsurance ceded	339,424,855	0199998
0199999. Totals (Net)	126,717,430	0199999
Annuities (excluding supplementary contracts with life contingencies):		**Annuitie**
0200001. 71 IAM 6.00% 1975-1982 (Imm)	359,802	0200001
⋮	⋮	
0200028. 83 IAM 7.25% 1986 (Def)	188,675,689	0200028
⋮	⋮	
0200043. Annuity 2000 4.75% 2004 (Def)	206,817,839	0200043
⋮	⋮	
0200047. Annuity 2000 4.50% 2010 (Def)	1,731,459,797	0200047
0299997. Totals (Gross)	9,676,901,276	0299997
0299998. Reinsurance ceded	7,415,759	0299998
0299999. Totals (Net)	9,669,485,517	0299999
⋮	⋮	
9999999. Totals (Net) - Page 3, Line 1	9,804,893,998	9999999

Exhibit 5 of the Great American Life Insurance Company in 2010

Empirics of Reserve Decay

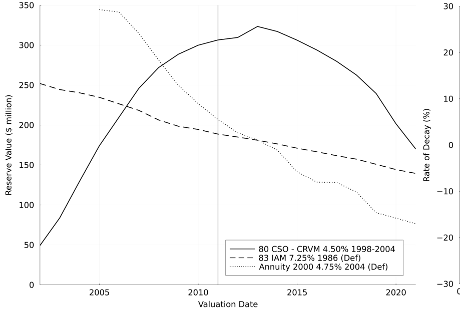
- Reserve decay has life-cycle pattern:

$$\frac{\hat{b}_{i,t,S}}{\hat{V}_{i,t-1,S}} = \Psi_{t-\tau,S} + \epsilon_{i,t,S}$$

estimated by least squares weighted by $\hat{V}_{i,t-1,S}$.

- Estimated model yields predictions for $\hat{b}$. Richer Models
- Calculate pseudo-actuarial duration D_L.
- Duration gap:

$$G = D_A - \frac{L}{A} D_L$$



Evolution of selected reserve positions

Estimated reserve decay

Duration of liabilities

Duration of assets

2. Funding Franchise

Incomplete Pass-Through: Annuity Rates

- How do the annuity interest rate react to a change of Treasury interest rates?

$$\Delta r^a_{t,h} = \alpha_h + \beta_h \cdot \Delta r^T_{t,h} + \epsilon_{t,h}$$

- How does the reserve discount rate react to a change of Treasury market interest rates?

$$\Delta \hat{r}^a_t = \alpha_h + \hat{\beta}_h \cdot \Delta r^T_{t,h} + \epsilon_{t,h}$$

Estimates $\hat{\beta} \approx 0.15$.

- Interest rates rise, economic spreads rise: $1 - \beta > 0$, statutory spreads falls: $\hat{\beta} - \beta < 0$.

Term Structure | Lower Rates | Cross-section | Concentration | Net Gain | More

3. Model

Model of a Life Insurer

- Exogenous stochastic bond market interest rate r

  $\Rightarrow$ correlated annuity interest rate r^A and statutory dicount rate $\hat{r}$
- Life insurer chooses the duration of the legacy capital D:

$$\max_{D} \quad \mathbb{E}\left[r - r^A - C\left(R_K\right) - \hat{C}\left(R_{\hat{K}}\right)\right]$$

  with reduced form costs $C(R_K) = \frac{\chi}{2} R_K^2$ and $\hat{C}(R_{\hat{K}}) = \frac{\hat{\chi}}{2} R_K^2$.
- Economic capital return:

$$R_K = \underbrace{-D\left(r - \mathbb{E}\left[r\right]\right)}_{\text{return on legacy capital}} + \underbrace{r - r^A}_{\text{economic earnings}}$$

- Statutory capital return:

$$R_{\hat{K}} = \underbrace{-\psi D\left(r - \mathbb{E}\left[r\right]\right)}_{\text{return on legacy statutory capital}} + \underbrace{\hat{r} - r^A}_{\text{statutory earnings}}$$

Duration of Net Assets

- First-order condition:

$$D = \frac{\chi(1-\beta) + \hat{\chi}\psi(\hat{\beta}-\beta)}{\chi + \psi^2\hat{\chi}}$$

- Without the regulatory friction $\hat{\chi} = 0$, the economic hedging motives prevail:

$$D = 1 - \beta > 0$$

- Without the economic friction $\chi = 0$, the statutory hedging motives prevail:

$$D = \frac{\hat{\beta}-\beta}{\psi} < 0$$

- The annuity interest rate reacts more to the bond market interest rate than the reserve discount rate does!

Evidence: Ex-ante Exposure to $\hat{\beta}$

- Reserve discount varies by policy type: $\hat{\beta}^{\text{life}} < \hat{\beta}^{\text{annuity}}$:

$$FL_{i,t} = \frac{(\text{Liabilities in Life Insurance Policies})_{i,t}}{(\text{Liabilities})_{i,t}}$$

- What explains the dynamics of the duration gaps?

$$G_{i,t} = \alpha_i + \alpha_t + \gamma_{FL} FL_{i,2008} \times Post_t + \gamma \cdot X_t + \epsilon_{i,t}$$

where $Post_t = 1$ after 2010.

	(1)
$FL \times Post$	-3.670**
Controls	Yes
Life Insurer FE	Yes
Year FE	Yes
N	3,839
R^2	0.751

Findings

- Quantification: when interest rates fall by one-percentage-point...
  1. life insurers realize a capital loss of \$121 billion or 26% of capital in 2019.

     Regulatory micro data ⇒ how long-term are the liabilities compared to assets?
  2. life insurers earn a half percentage point lower spread on newly issued policies.

     Incomplete pass-through from bond market interest rates to annuity interest rates
- Two exposures do not offset each other! Explanation:
  3. Model of a life insurer featuring statutory regulation ⇒ statutory hedging motives overpower economic hedging motives!

     Empirical evidence, policy recommendations, learnings

Literature Review

- Interest rate risk in banking: Begenau, Piazzesi, and Schneider (2020), Drechsler, Savov, and Schnabl (2017, 2021), Di Tella and Kurlat (forthcoming)
- Financial frictions and risk taking of life insurers: Becker and Ivashina (2015), Koijen and Yogo (2021)
- Risk management and accounting: DeMarzo and Duffie (1992), Heaton, Lucas, and McDonald (2010), Sen (2019)
- Overcoming balance sheet opacity: Gomez, Landier, Srear, and Thesmar (2021), Möhlmann (2021), Tsai (2009)
- Stability of life insurance liabilities: Chodorow-Reich, Ghent, and Haddad (2020), Ozdagli and Wang (2019)

Thank you!

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Background

- Life insurers provide insurance against mortality and retirement saving vehicles.
- Assets: transparent!
  - Life insurance companies own assets of about \$7 trillion
  - 37% of life insurer's assets are invested in corporate and foreign bonds
  - Corporate and foreign bond debt \$15 trillion of which 22% are held by life insurers
- Liabilities: opaque!
  - Household financial assets of \$105 trillion: 13% deposits, 43% securities, 30% pension entitlements and life insurance
  - Guaranteed by state guaranty funds in the case of default
- Equity: many public/private stock companies, few large mutual companies

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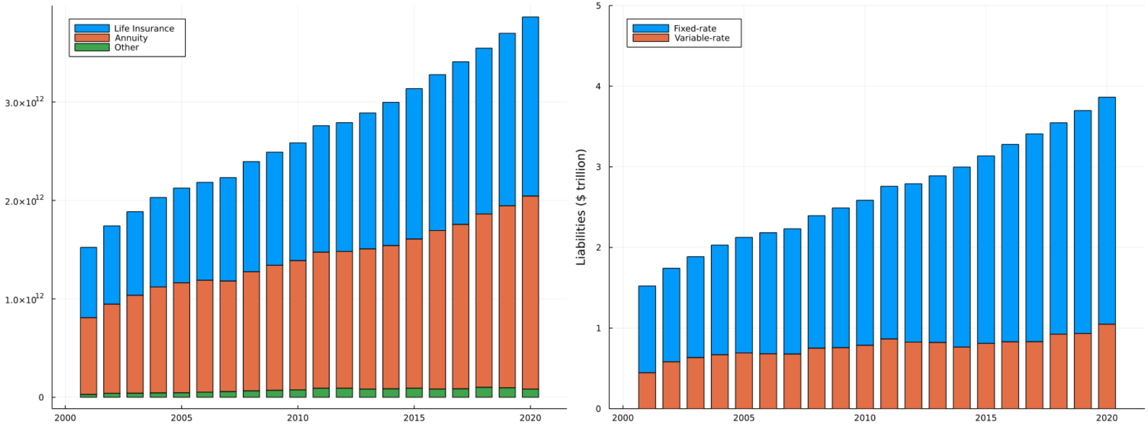
Reserves



Composition of reserves

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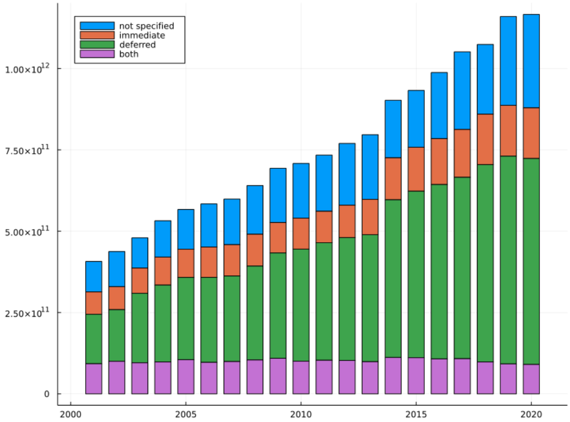
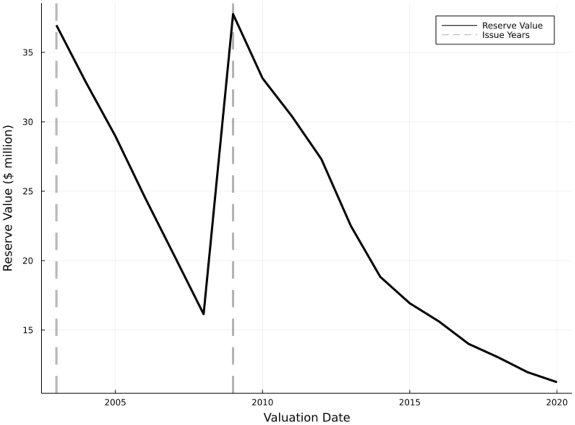
Reserves





Composition of annuity reserves and the evolution of the A2000 6% Immediate reserve position of the Delaware Life Insurance Company

return

Empirics of Reserve Decay

- Insurer-specific weighted-average decay $\hat{\lambda}_{i,t,S} = \frac{\hat{b}_{i,t,S}}{\hat{V}_{i,t-1,S}}$:

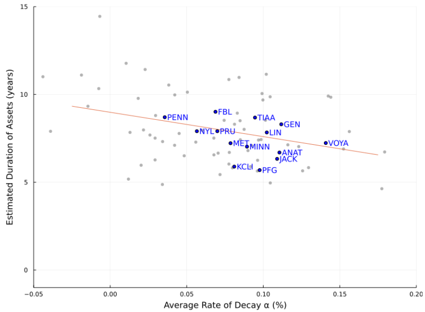
$$\hat{\lambda}_{i,t,S} = \alpha_i + \epsilon_{i,t,S}$$

weighted by the previous size of the reserve position.

- Life-cycle model of average reserve decay:

$$\hat{\lambda}_{i,t,S} = \Psi(t-\tau, S) + \epsilon_{i,t,S}$$

where Ψ is as fixed effect which captures the average decay of a $t-\tau$ year old reserve position of type S.



Asset duration and average decay across life insurance companies

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Life-Cycle Reserve Decay

	Rate of Decay $\lambda_{i,t,S,\tau}$					
Decade		0.000	-0.001	-0.010***	-0.000	-0.007***
$\Delta r^{T}_{t,\tau,10}$			0.171***	0.227***		
$\Delta r^{T}_{t,t-1,10}$					-0.147***	-0.113***
Life-cycle FE	Yes	Yes	Yes		Yes	
Finer Life-cycle FE				Yes		Yes
N	97,712	97,712	94,707	94,227	97,712	97,120
R^2	0.286	0.286	0.286	0.350	0.286	0.349

Decay

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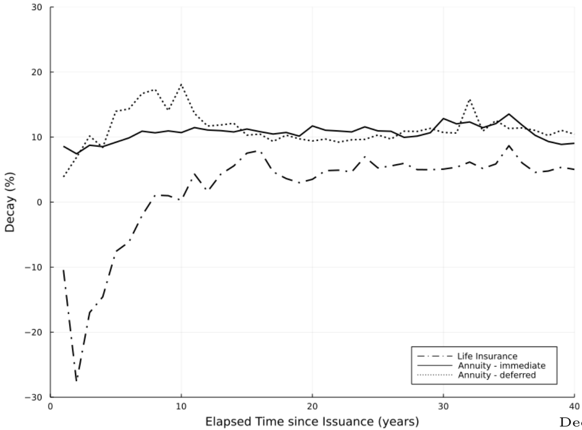
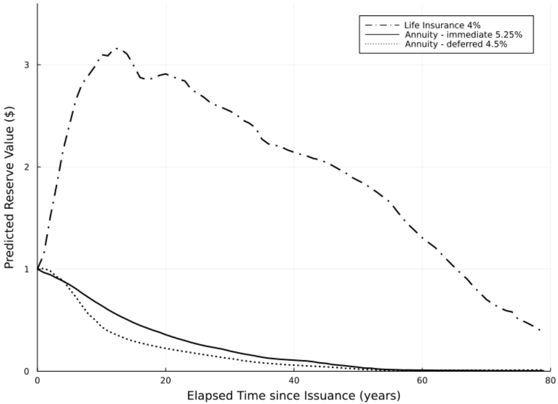
Life-Cycle Reserve Decay



Decay



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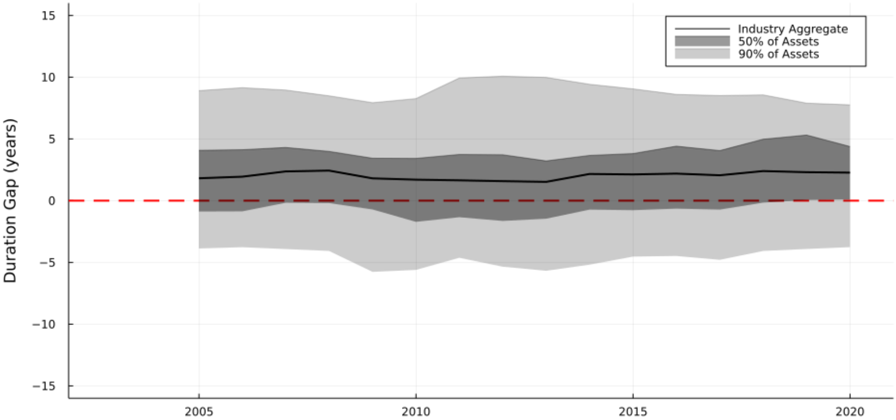
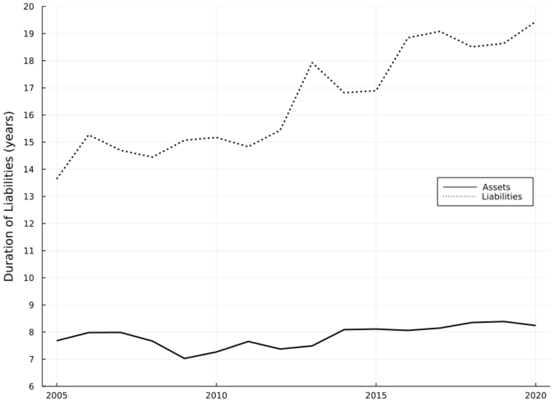
Duration Gap under constant Interest Rates



Duration gap under constant 2004 interest rates $G = D_A - \frac{L}{A} D_L$

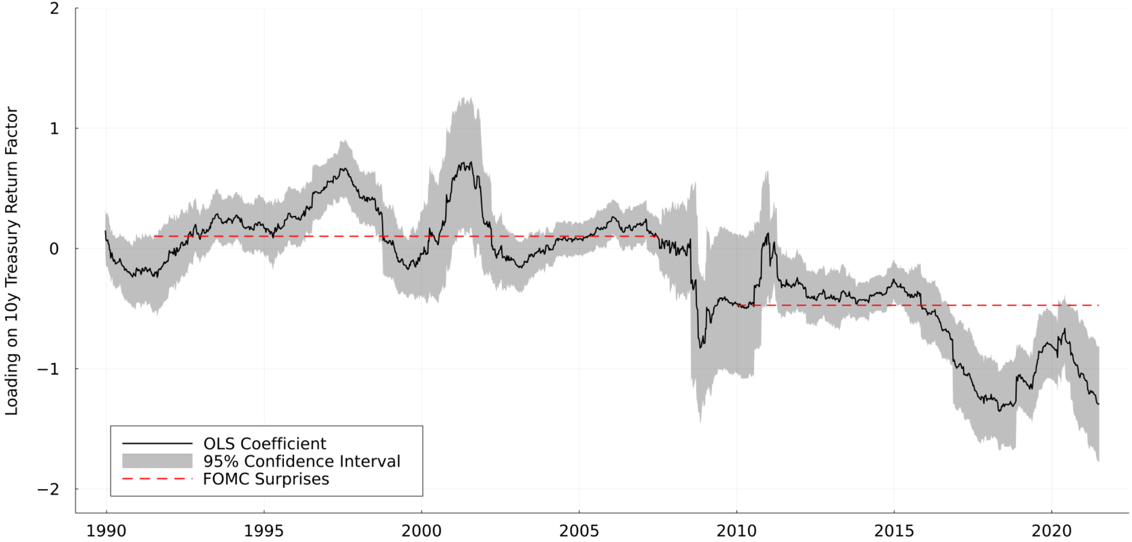
return

Net Assets of publicly-traded Life Insurers



Duration of assets and liabilities of a set of publicly-traded life insurers

▸ return



Interest rate sensitivity of life insurers' stock prices: β^T in 2-year rolling-window regression of weekly $rx_t^{\mathrm{L}} = \alpha + \beta^{\mathrm{M}} \cdot rx_t^{\mathrm{M}} + \beta^T \cdot rx_t^{\mathrm{T}} + \epsilon_t$

return

	rx_t^L					
	Full	Before	After	Full	Before	After
rx_t^{T}	0.492**	0.017	-0.672**	0.407**	-0.109	-0.658***
	(0.234)	(0.176)	(0.336)	(0.163)	(0.132)	(0.170)
rx_t^{M}				1.588***	0.751***	1.543***
				(0.096)	(0.071)	(0.095)
Intercept	0.004**	0.002**	0.001	-0.001	0.000	-0.000
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
N	257	140	92	257	140	92
R^2	0.017	0.000	0.042	0.525	0.447	0.757

Regressions on FOMC days

back

	rx_t^L					
	Full	Before	After	Full	Before	After
rx_t^{T}	-0.388**	0.293	-0.839**	-0.467***	-0.155	-0.677***
	(0.178)	(0.207)	(0.329)	(0.120)	(0.156)	(0.191)
rx_t^{M}				1.332***	0.836***	1.491***
				(0.063)	(0.078)	(0.096)
Intercept	0.003***	0.002**	0.003*	-0.000	0.000	0.000
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
N	243	133	78	249	134	83
R^2	0.019	0.015	0.079	0.660	0.467	0.787

Regressions on FOMC days excluding outliers

back

	rx_t^L					
	After 2009	After 2010	After 2011		After 2010	
		Until 2021		Until 2019	Until 2020	Until 2021
rx_t^{T}	0.307	-0.658***	-0.855***	-0.526***	-0.552***	-0.658***
	(0.256)	(0.170)	(0.186)	(0.165)	(0.165)	(0.170)
rx_t^{M}	2.127***	1.543***	1.547***	1.520***	1.478***	1.543***
	(0.177)	(0.095)	(0.095)	(0.107)	(0.105)	(0.095)
Intercept	0.001	-0.000	-0.001	-0.001	-0.001	-0.000
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
N	100	92	84	72	80	92
R^2	0.603	0.757	0.780	0.750	0.728	0.757

Regressions on FOMC days with different cut-off dates

back

	rx_t^L					
	Full	Before	After	Full	Before	After
rx_t^{T}	1.044***	0.842**	-0.782*	0.869***	0.262	-1.048***
	(0.349)	(0.347)	(0.463)	(0.329)	(0.286)	(0.302)
rx_t^{M}				0.504	0.689***	1.051***
				(0.400)	(0.169)	(0.395)
Intercept	0.003*	0.001	0.001	0.002	-0.000	-0.000
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
N	241	139	76	241	139	76
R^2	0.008	0.016	0.011	0.277	0.414	0.630

Regressions on FOMC days with different cut-off dates

back

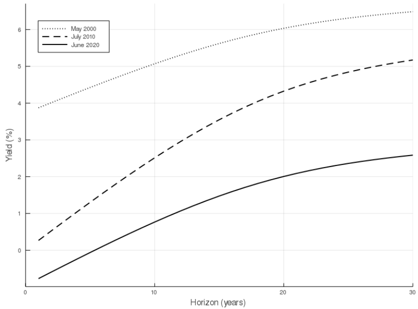
Calculating the Yield Curve

- What term structure of interest rates r rationalizes the observed prices of a menu of policies?

$$V_n^{term} = \sum_{h=1}^{n} e^{-h \cdot r_{t,h}} \cdot 1 \quad V_{age}^{life} = \sum_{h=1}^{\infty} e^{-h \cdot r_{t,h}} \cdot b_{age,h}$$

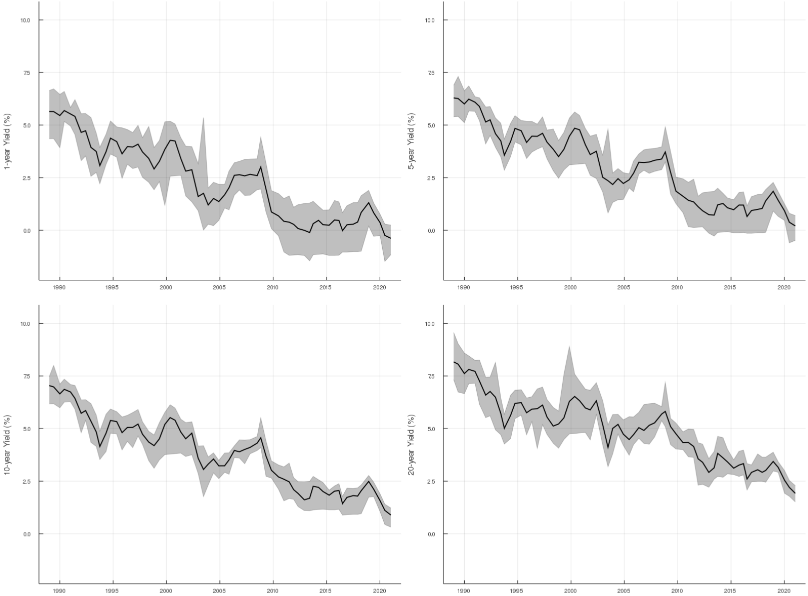
- Parametrize $r_{i,t,h}$ by imposing a B-spline on the forward rates for every insurer i, time t, and policy j:

$$P_{i,j,t} = V_{i,j,t} + \epsilon_{i,j,t}$$



Annuity yield curves

back



10.0
7.5
5.0
2.5
0.0
1-year Yield (%)
1990
1995
2000
2005
2010
2015
2020
5-year Yield (%)
10-year Yield (%)
20-year Yield (%)

return

Incomplete Pass-Through: Reserve Interest Rate

- How does the reserve discount rate react to a change of bond market interest rates?

$$\hat{r}_t = 0.03 + 0.8 \cdot \left(\bar{r}^{\mathrm{NAIC}}_{June(t)-12, June(t)} - 0.03\right)$$

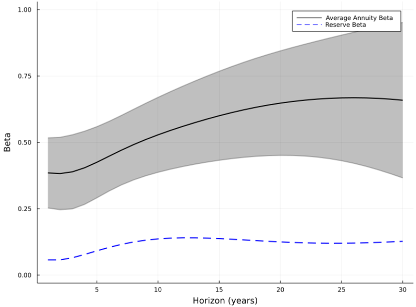
- Changes over the 1-year time interval:

$$\Delta r^a_{t,h} = \alpha_h + \beta_h \cdot \Delta r^b_{t,h} + \epsilon_{h,t}$$

$$\Delta \hat{r}_t = \alpha_h + \hat{\beta}_h \cdot \Delta r^b_{t,h} + \epsilon_{h,t}$$

- Annuities:

$$0.5 = \beta > \hat{\beta} = 0.13$$



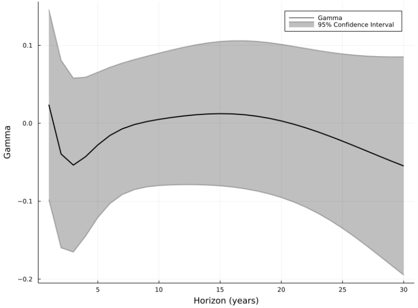
Pass-through to reserve discount rates

return

Incomplete Pass-Through: lower at lower rates?

- How does the annuity interest rate react to a change of bond market interest rates?

$$\Delta r^a_{t,h} = \alpha_h + \beta_h \cdot \Delta r^b_{t,h} + \gamma_h \cdot \Delta r^b_{t,h} \cdot r^b_{t,h} + \epsilon_{h,t}$$



Pass-through to annuity rates at higher interest rates

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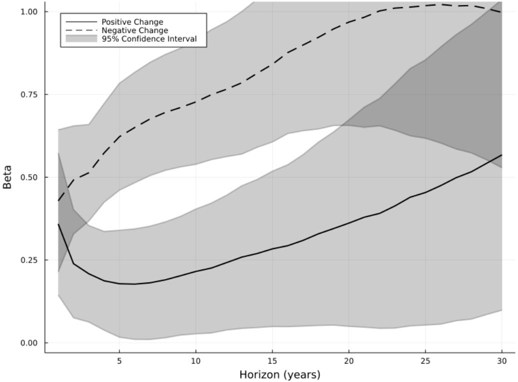
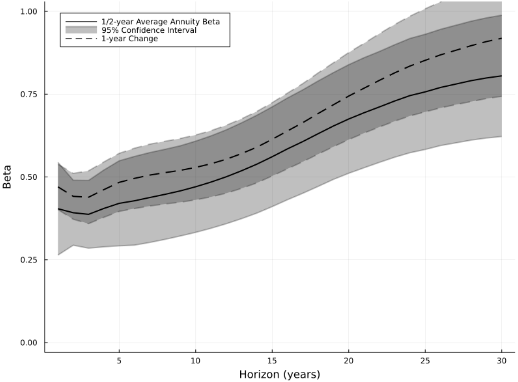
Incomplete Pass-Through





return

Market Concentration and Pass-Through

	Annuity Spread			
	Levels s		Changes Δs	
$r \cdot$ HHI	0.022***	0.033***		
	(0.001)	(0.001)		
$\Delta r \cdot$ HHI			0.060***	0.082***
			(0.006)	(0.006)
Horizon FE	Yes	Yes	Yes	Yes
Rating FE		Yes		Yes
N	13,290	13,290	13,290	13,290
R^2	0.916	0.931	0.319	0.333

Cross-sectional pass-through related to a proxy for the insurance company specific market power: the average of Herfindahl-Hirschman indices of U.S. states weighted by the share of the collected premiums from a state to overall premiums. The regression specification is: $s_{i,t,h} = \gamma \cdot r_{t,h}\text{HHI}_{i,t-1} + \beta_h \cdot r_{t,h} + Rating_{i,t} \cdot r_{t,h} + \epsilon_{i,t,h}$

return

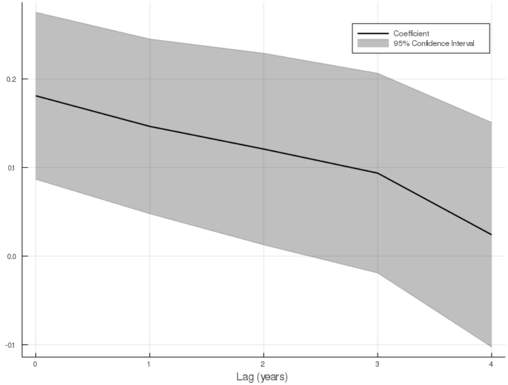
Spread affects future Net Gain from Operations

The annuity spreads $s_{i,t,h}$ predicts the future net gain of operations:

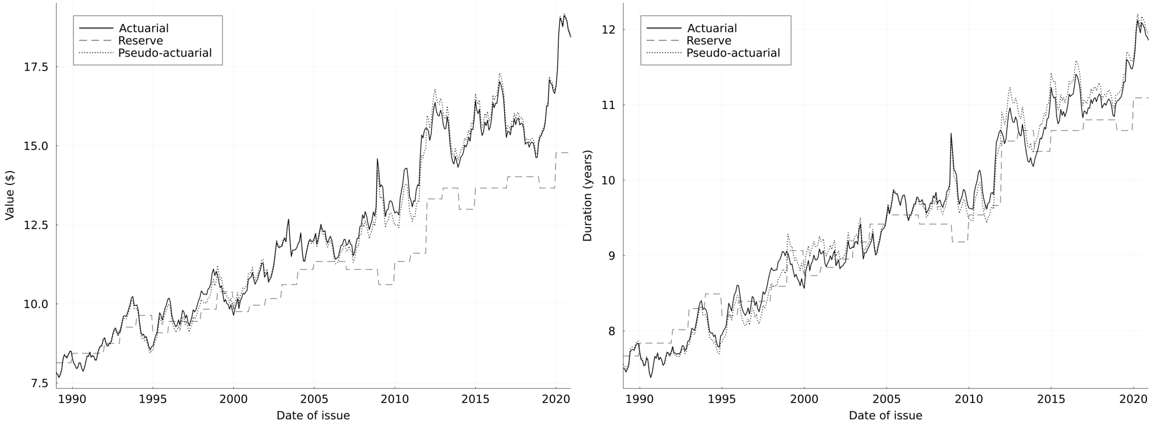
$$NetGain_{i,t+h} = Spread_{i,t} + \epsilon_{i,t}$$

A higher annuity spread implies larger future profits!

return



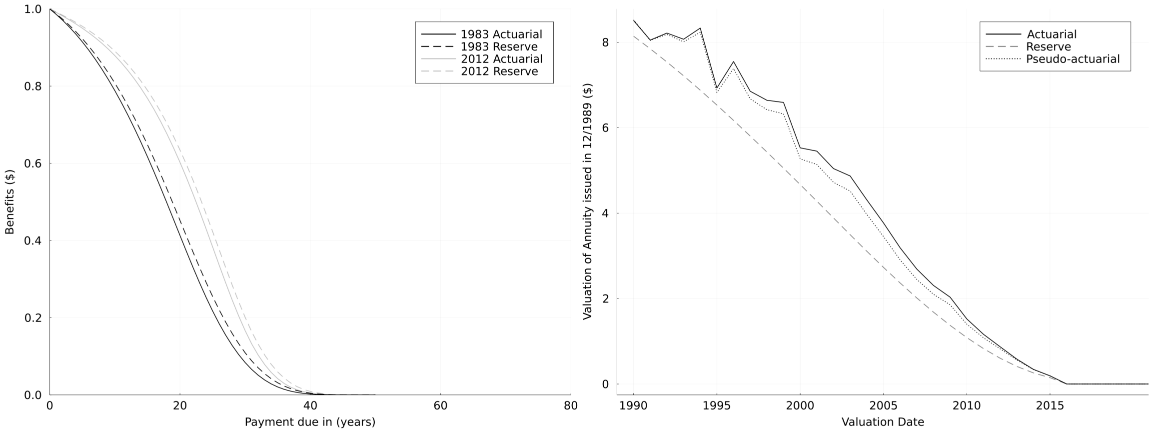
Actuarial vs. Reserve vs. Pseudo-Actuarial



Valuation and duration at issuance for a life annuity for a 65-year-old male

▸ Cash flows and Life-cylce

Actuarial vs. Reserve vs. Pseudo-Actuarial



Comparison of cash flows and and valuations after issuance in December 1989 for a life annuity for a 65-year-old male

return

Indirect Evidence: Supplemental Information

- New York-based life insurance companies have to file the “Analysis of Valuation Reserves” supplement to the annual statement
  - How well does the annual income align with the predicted cash flow?

VALUATION STANDARD	Location in last year's analysis of valuation reserves Line No.	Total	
		Annual Income(a) (000 Omitted)	Reserve
0200014. 83 Table 'A'; 9.50%; Imm.; 1981	200015	56	106,355
0200015. 83 Table 'A'; 7.65%; Imm.; 1984	200017	457	1,634,586
0200016. 83 Table 'A'; 7.65%; Imm.; 1985	200018	1,850	10,263,129
0200017. 83 Table 'A'; 7.65%; Imm.; 1986	200019	1,696	7,104,998
0200018. 83 Table 'A'; 7.65%; Imm.; 1987	200020	2,307	9,379,066
0200019. 83 Table 'A'; 7.65%; Imm.; 1988	200021	2,566	10,575,657
0200020. 83 Table 'A'; 7.65%; Imm.; 1989	200022	3,913	16,526,073
0200021. 83 Table 'A'; 7.65%; Imm.; 1990	200023	4,933	22,012,788
0200022. 83 Table 'A'; 7.50%; Imm.; 1991	200024	2,169	10,523,236
0200023. 83 Table 'A'; 7.00%; Imm.; 1992	200025	2,426	10,323,403
0200024. 83 Table 'A'; 6.00%; Imm.; 1993	200026	2,559	10,382,114
0200025. 83 Table 'A'; 6.50%; Imm.; 1994	200027	4,363	20,934,023
0200026. 83 Table 'A'; 6.50%; Imm.; 1995	200028	5,904	32,589,468
0200027. 83 Table 'A'; 6.00%; Imm.; 1996	200029	5,559	29,913,379

Supplement of the New York Life Insurance Company in 2011

return

Effect of Market Rates on Policyholder Behaviour

- Model with policyholder behaviour:

$$\bar{b}_{i,t,S} = \Psi(t - \tau, S) + \delta \cdot \Delta r_{t,\tau,10} + \epsilon_{i,t,S}$$

- The change in the market interest rate since the issuance of the policy may make the outside option more or less attractive.
- A one-percent increase leads to a 0.16 percent higher rate of decay.
- The policyholder behavior has a marginal effect on the duration of the liabilities!

	$\bar{b}$	
	(1)	(2)
t in decades	0.003***	0.003***
	(0.000)	(0.000)
$\Delta r^{Treasury}_{t,\tau,10}$	-0.008	
	(0.022)	
$\Delta r^{HQM}_{t,\tau,10}$		-0.017
		(0.024)
N	90,954	90,954
R^2	0.355	0.355

return

Evidence under Constant Interest Rates

- Omitted variable bias:
  falling interest rates mechanically increase the duration of life insurance policies!
- Evaluate all objects under constant 2004 interest rates.

$$G_{i,t} = \alpha_t + \gamma_{FL} FL_{i,t} + \gamma_{Lev} Lev_{i,t} + \gamma_{LogA} LogA_{i,t} + \gamma \cdot X_{i,t} + \epsilon_{i,t}$$

$$G_{i,t} = \alpha_i + \alpha_t + \gamma_{FL} FL_{i,2008} + \gamma_{Lev} Lev_{i,t} + \gamma_{LogA} LogA_{i,t} + \gamma \cdot X_{i,t} + \epsilon_{i,t}$$

	(1)	(2)
FL	-6.260***	-4.577**
Lev	-0.022***	-0.005
LogA	-0.057	1.002
mutual	-1.356***	
MktLev	-0.021**	-0.003
Year FE	Yes	Yes
Life Insurer FE		Yes
N	5,868	5,864
R^2	0.298	0.758

return