Measuring Interest Rate Risk Management by Financial Institutions

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Financial intermediaries bear interest rate risk (IRR)

- Exposure to IRR comes from many sources
  - Cash flow differences across balance sheet components
  - Contractual or embedded options
- IRR managers have a wide range of asset and liability tools
- Nevertheless, intermediaries carry some *residual* exposure
  - Incomplete financial markets
  - Costly hedging
  - Contribution to earnings
- Implications for financial stability and macro outcomes

We measure insurers' residual exposure to IRR

- Dynamic pricing model with endogenous IRR management
  - Hedging IRR with long-term bonds and/or capital structure
  - Benchmark hedging implies stock prices insensitive to Δr
- Consistent estimator for time-varying stock price sensitivity
  - Exploit high-frequency data
  - Obtain the empirical distribution for statistical inference
- In general, stock prices are insensitive: insurers are hedged
- Ability to create net worth helps explain occasional sensitivity

Life insurer interest rate risk management problem

Life insurer's balance sheet

Assets	Liabilities
Corporate bonds	Annuities
Commercial real estate loans	Life insurance
Mortgage-backed securities	Net worth

- Duration of assets or liabilities PV: $D_i = -\frac{\partial PV_i}{\partial R} \frac{R}{PV_i}$
- $D_{IL} > D_A$: Insurance liabilities change more than assets
- Insurers prefer hedging IRR with LT bonds:
  - Exogenous constraint on LT bond supply
  - *NW* financed by insurance product markup
  - Competitive insurers prefer to keep prices low

IRR hedging involves LT bonds and/or capital structure

- Insurers manage IRR by matching asset-total liability duration
- D_{NW} means $D_{IL} > D_A$ isn't necessarily unhedged
  - More LT bonds increase asset duration
  - More NW decreases total liability duration
- Theoretical testable benchmark: insurers can always hedge
  - NW is generally unobservable, need proxies
  - Profitability/continuation value is insensitive to Δr

Key testable implications of the model

- Stock prices generally insensitive to Δr
  - Insurers that can fully hedge IRR $\rightarrow$ sensitivity $= 0$
- Sensitivity of stock prices to Δr reflects:
  - (i) LT bond returns; (ii) ability to create NW
- Insurers' efforts to manage IRR drives sensitivity towards zero
  - More variation within insurers than across insurers
- (What about balance sheet measures? See appendix.)

Estimating equity price sensitivity to interest rates

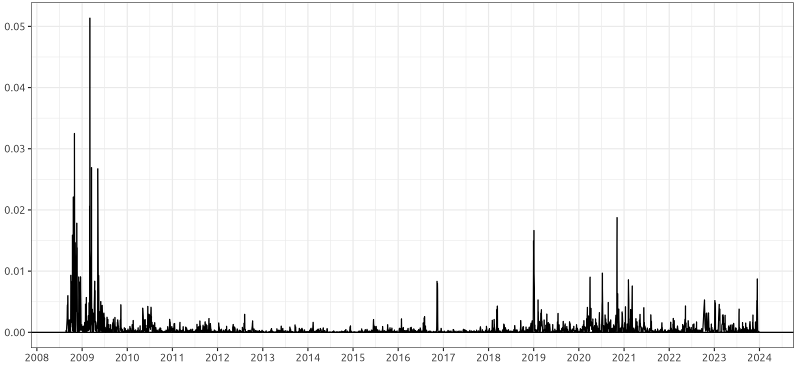
$$r_{i,t} = \alpha + \beta r_{m,t} + \gamma r_{y,t} + \epsilon_{i,t}$$

- $r_{.,t}$: return in t | i: insurer/index | m: S&P500 | y: Treasury
- Taking care to account for aggregate risks
- Shareholders of financial intermediaries bear residual IRR
- Fully hedged: no effect of interest rates on equity, $\gamma = 0$

Existing approach: low-frequency rolling-window OLS

- Weekly returns, two-year rolling window
- Potentially biased, inefficient, with incorrect inference explanation
- Other estimates in the literature are egregious example

Squared residuals suggest time-varying volatility



New method: Realized γ_t from high-frequency data

- High-frequency five-min returns data at one-min intervals
  - Market cap-weighted indexes and individual insurers list of names
- Thomson Reuters evaluated prices for 10yr Treasury
- AR(1) filter to address market microstructure noise: $\tilde{r}_{i,j,t}$
  - Anderson, Bollerslev, Diebold, Wu (2006), ...
- Index minutes with j, to get estimate of realized γ_t:

$$\tilde{r}_{i,j,t} = \alpha_t + \beta_t \tilde{r}_{m,j,t} + \gamma_t \tilde{r}_{y,j,t} + \epsilon_{i,j,t}$$

Another framing: Highly flexible nonparametric estimates

- Two auxiliary regressions (Frisch-Waugh-Lovell Theorem):

$$r_{ijt} = \hat{\alpha}_t^1 + \hat{\beta}_t^1 r_{mjt} + \hat{\epsilon}_{ijt}$$
$$r_{yjt} = \hat{\alpha}_t^2 + \hat{\beta}_t^2 r_{mjt} + \hat{\epsilon}_{yjt}$$

- Realized covariance: $\hat{\nu}_{i,y,t} = \sum_j \hat{\epsilon}_{ijt} \cdot \hat{\epsilon}_{yjt}$
- Realized variance: $\hat{\nu}_{y,t} = \sum_j \hat{\epsilon}_{yjt}^2$
- Realized $\gamma_t = \frac{\hat{\nu}_{i,y,t}}{\hat{\nu}_{y,t}}$
  - Zhang, Mykland and Aït-Sahalia (2005) – Two Time Scale
- Applies to any sampling frequency and estimation method

Inference with subsampling (Politis, Romano, Wolf 1999)

- **Goal:** Keep time-series properties & avoid DGP assumptions
  - Bootstrap inappropriate and requires showing it does not fail
  - Within-day block subsamples provide consistent γ_{it}
  - Each within-day block drawn from the true DGP
- Obtain empirical distribution of γ_{it}
  - Does not rely on asymptotic approximation
  - Extremely weak assumptions for convergence
  - **Challenge:** Very computationally intensive

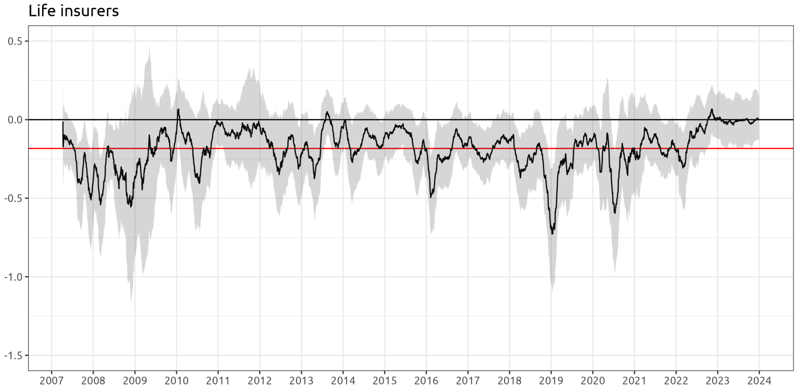
Time-series and cross-sectional analysis of γ_{it}

1. Is γ_{it} variation in time-series or cross-section more important?
2. How hedged are life insurers according to markets?
3. How does life insurers' hedging compare to P&C?
4. What macrovariables correlate with significant γ_{it}?
5. How does γ_{it} relate to an insurer's ability to create NW?
6. Does interest rate volatility determine γ_{it}?

How does γ_{it} vary across life insurers?

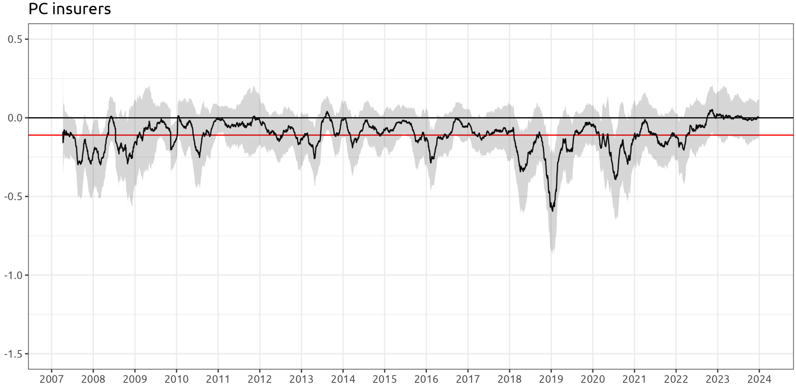
- Most life insurers' γ_{it} comove with the index
- Overall SD: 0.55; Between SD: 0.09; Within SD: 0.54
- Time-series variation is far larger than cross-sectional variation

How hedged are life insurers according to markets?



- Negative sign: insurers benefit from higher long-term rates
- Insurers are perceived as hedged most of the time

How does life insurers' hedging compare to P&C?



- **Life** insurers are perceived as less hedged than **P&C** insurers
- Share of statistically significant days: **Life**: 31%; **P&C**: 18%

How does γ_t relate to an insurer's ability to create *NW*?

Dep. var.: $\mathbf{1}(\gamma_t < 0)$	Life	PC
$TermPremium_t$	-0.13^{***}	-0.04
	(0.03)	(0.03)
$BAA - AAA_t$	-0.58^{***}	-0.12
	(0.19)	(0.12)
$FundingCost_t$	0.30^{***}	0.07
	(0.09)	(0.06)
Observations	4,134	4,134

Note: Newey-West standard errors

- Life insurer γ_t is less likely to be significant when:
  - Long-term compensation (term premium) is higher
  - Credit risk compensation (BAA-AAA spread) is higher
  - Funding cost (single-A US corporate OAS) is lower
- Similar results across individual life insurers analysis

Does interest rate volatility determine γ_t?

On FOMC days, interest rate volatility is (exogenously) high

1. Add int. rate volatility in index regression ⇒ not significant
2. 2-SLS: FOMC as instrument and run 1. ⇒ not significant

	99% confidence interval		
	Life insurers	P&C insurers	10yr Treasury
FOMC days vs. 1 day before	[-0.081, 0.09]	[-0.037, 0.074]	[0.214, 0.575]
FOMC days vs. 7 days before	[-0.067, 0.083]	[-0.041, 0.063]	[0.21, 0.595]

Conclusion

- Dynamic pricing model with endogenous IRR management
  - Benchmark theory for (in)sensitivity of stock prices to Δr
- New consistent estimator for stock price sensitivity
- Our time-varying measure is timely and unbiased
  - Cannot extrapolate to large **hypothetical** interest rate changes
- In general, stock prices are insensitive: insurers are hedged
- Inability to create net worth helps explain occasional sensitivity

APPENDIX

Optimal interest rate risk management and insurance prices

$t = 0$

Assets	Liabilities
Bond holdings	Annuity liabilities $= \int_A \frac{\alpha}{R_1} \left[1 + \alpha \mathbb{E}\left(\frac{1}{R_2}\right)\right] a(\alpha, q)\, dG(\alpha)$
b_1 and l_2	$NW_0 = \int_{\underline{\alpha}}^{\overline{\alpha}} \alpha^2 \psi a(\alpha, q)\, g(\alpha)\, d\alpha$

$t = 1$: R_2 is realized

Assets	Liabilities
Bond holdings	Annuity liabilities $= \frac{1}{R_2} \int_A \alpha^2 a(\alpha, q)\, dG(\alpha)$
$b_2(R_2)$	$NW_1(R_2) = 0$

- Competition drives annuity price q^* down s.t. maintaining optimal IRR hedge return

$$q^* = \underbrace{\underbrace{\frac{\int_{\underline{\alpha}}^{\overline{\alpha}} \frac{\alpha}{R_1} \left[1 + \alpha \mathbb{E}\left(\frac{1}{R_2}\right)\right] a(\alpha, q^*)\, dG(\alpha)}{\int_{\underline{\alpha}}^{\overline{\alpha}} a(\alpha, q^*)\, dG(\alpha)}}_{\text{Insurer average insurance cost } C(q^*)/A(q^*)} + \psi \overbrace{\frac{\int_{\underline{\alpha}}^{\overline{\alpha}} \alpha^2 a(\alpha, q^*)\, dG(\alpha)}{\int_{\underline{\alpha}}^{\overline{\alpha}} a(\alpha, q^*)\, dG(\alpha)}}^{\text{Insurance price markup}}}_{\text{Insurer average bond demand } B(q^*)/A(q^*)}$$

Insurers in our sample

- Alleghany Group
- American Financial Group
- American Intl Group, Inc.
- Assurant, Inc.
- The Allstate Corporation
- Ameriprise Financial, Inc.
- American National Financial Group
- Apollo Global Management, Inc.
- Brighthouse Financial, Inc.
- Berkshire Hathaway Inc.
- Chubb Ltd.
- Cigna Health Group
- Cincinnati Financial Corporation
- CNA Financial Corporation
- CNO Financial Group
- Erie Insurance Group
- Equitable Holdings, Inc.
- FBL Financial Group Inc.
- Fidelity and Guaranty Life
- Fidelity National Financial, Inc.
- Genworth Financial, Inc.
- Hanover Insurance Group, Inc.
- The Hartford Fin. Svcs Group, Inc.
- Horace Mann Group
- Kansas City Life Insurance Group
- Kemper Corporation Group
- Lincoln National Corporation
- Mercury General Group
- Markel Corporation Group
- MetLife, Inc.
- Manulife Financial Corporation
- Nationwide Corporation Group
- The Phoenix Companies, Inc.
- Primerica Group
- Principal Financial Group, Inc.
- Protective Life Corporation
- The Progressive Corporation
- Prudential Financial, Inc.
- Selective Insurance Group
- Symetra Financial Corp.
- The Travelers Companies, Inc. Group
- Voya Financial, Inc.
- W. R. Berkley Corporation

return

Comparing to balance sheet measures of insurers IRR

- Balance sheet measures are hard to calculate
  - Sparse information about liability duration, derivatives...
  - Special thanks to Huber (2022) for sharing his data
- Static model: asset duration comoves with liabilities duration
  - Dynamic model with NW breaks this codependence

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How does γ_{it} relate to net asset duration and NW?

Dependent variable:	$Assets\_Duration_{it}$	γ_{it}
	(1)	(2)
$Liabilities\_Duration_{it}$	-0.01	
	(0.02)	
$Small\_Duration\_Gap_{it}$		-0.06^{***}
		(0.02)
Big_NW_{it}		-0.06^{***}
		(0.02)
$Big\_NW_{it} \times Small\_Duration\_Gap_{it}$		0.10^{***}
		(0.03)
Constant		-0.14^{***}
		(0.01)
Std. Err.	Robust	Robust
Year FE	Y	Y
Observations	228	228
R^2	0.04	0.05

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Other rolling gamma estimates

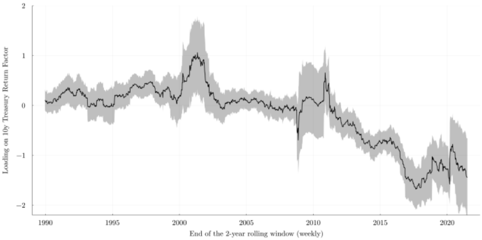

Figure 1: Interest rate sensitivity of life insurers' stock prices

Notes: The black solid line shows the OLS estimate of β^T in a 2-year rolling window regression of weekly excess returns of a stock portfolio of life insurers, rx_t^L, on the excess return of the stock market portfolio, rx_t^M, and the excess return of a 10-year Treasury note, rx_t^T: $rx_t^L = \alpha + \beta^M \cdot rx_t^M + \beta^T \cdot rx_t^T + \epsilon_t$. The heteroscedasticity-consistent 95% confidence interval is shown in gray.

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Intuition for rolling regression biases

- Without properly specified errors, parameter estimates are
  1. definitely inefficient
  2. likely biased
- Bias can exist even asymptotically with well-behaved errors
- When $\mathbf{xx}'$ is high, OLS puts more weight on those gammas
- One solution: long-run variance estimator
- This problem is well-known:
  - Cai & Juhl 2021; Robertson 2018; Hamilton 2008

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Empirical measurement exercise and CAPM

- We are not assuming $r_{m,t}$ and $r_{y,t}$ are orthogonal
  1. We are estimating GE effect of $r_{y,t}$
  2. Robustness exercise looks at exogenous shocks to $r_{y,t}$
- Bond pricing consistent with CAPM
  - $r_{y,t} = r_{m,t} + r_{f,t}$
  - Decompose bond return into systemic and idiosyncratic parts
- Insurer combines asset portfolio and ins. liabilities portfolio
  - Insurer stock return is combination of parts:

$$
\begin{aligned}
r_{i,t} &= \beta r_{m,t} + \gamma r_{f,t} \\
&= (\beta - \gamma) r_{m,t} + \gamma r_{y,t}
\end{aligned}
$$

  - Empirical exercise yields consistent estimate of γ

Analysis of individual life insurers

- $Low\_\gamma_{it} = 1$ if $\gamma_{it} < 15^{th}$ percentile, otherwise 0
- $FABS\_Spread_{it}$ is insurer-specific cost of funding
  - Funding agreement-backed security spread over zero curve
  - DGS10: market yield on constant maturity 10-year Treasuries
- α_t focus on cross section, but absorb macro time series

	Dependent variable:		
	Low_γ_{it}		
	(1)	(2)	(3)
$FABS\_Spread_{it}$	0.05***	0.05***	0.07***
	(0.02)	(0.02)	(0.02)
$FABS\_Spread_{it} \times DGS10_t$			−0.07***
			(0.02)
Std. Err.	Robust	Cluster	Robust
Date FE	Y	Y	Y
Observations	1,843	1,843	1,843
Adjusted R^2	0.60	0.60	0.60

return