# What's Wrong with Annuity Markets?

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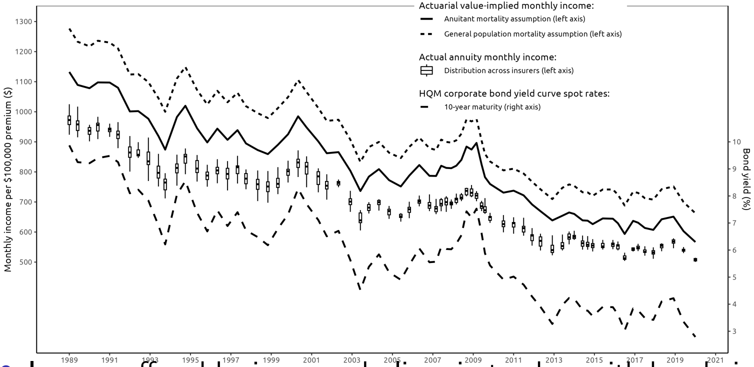
**JEEA Teaching Materials**

# What drives high annuity markups?

- Life annuities are useful to insure against late consumption risk
- Annuity prices are higher than what actuarial values suggest
- High markups often attributed to adverse selection
- But adverse selection only accounts for about half of markups

# A large fraction of single premium immediate annuities markups cannot be explained by adverse selection




- Income offered by insurers declines in tandem with bond yields
- Industry's average adverse selection pricing is stable/declining
- Substantial variation in AS-adjusted markups across insurers

# We show that insurer risk management drives the variation in markup that is not explained by adverse selection

- **Theory:** Three period economy with an interest rate shock
  - Limited liability life insurers (insolvency risk)
  - Constrained supply of long-term bonds (endogenous)
  - ⇒ Insurers manage interest rate risk with net worth
- **Evidence:** 30 years of annuity price data from 100 insurers
  - Over 600 prices from about 20 insurers per period
- **Identification:** Shocks that differentially affect the average cost curve (liability) and average bond demand curve (asset) for **different** annuity contracts offered by the **same** insurer

# Why should you care?

- There is a gap in the literature
  - Finance literature studies financial institution risk management
  - Insurers in macro/public finance models abstract from it
- Difficult to disentangle supply- and demand-side frictions
- Macro environment and monetary policy may have a dramatic impact on individuals' ability to transfer longevity risk
  - QE programs may distort the set of financial contracts
  - Revisit the welfare implications of retirement reforms

# Outline

1. Background on the life annuity business
2. Annuity pricing with adverse selection and interest rate risk
3. Identification of the interest risk management channel
4. Main empirical results
5. Interaction of adverse selection and interest rate risk
6. Cross-sectional evidence using swaps

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# Life insurers earn the spread between the yield on their assets and the rate they credit on their liabilities

- Life annuities are long-term fixed rate liabilities that are illiquid
- Insurers invest in fixed-income securities to match cash flow
- Illiquidity of liabilities lets insurers invest in illiquid assets
- Industry is the largest corporate bonds investor since the 1930s
- **Key issue:** Corporate debt maturity tends to be short

$\Rightarrow$ Life insurers are exposed to interest rate risk

# Life insurers manage interest rate risk with net worth

Life insurer's balance sheet

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

- Duration $D$ of an Asset or Liability: $D = -\frac{\partial PV}{\partial R}\frac{R}{PV}$
- $D_L > D_A$: Liabilities PV changes faster than asset PV
- Net worth cushions unbalanced changes in asset-liability PV
  - What is the optimal level of net worth?
  - How do insurers finance their net worth?
  - What is the effect of risk management on annuity prices?

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# A model of adverse selection and interest rate risk

| | $\mathbf{t=0}$ | $\mathbf{t=1}$ | $\mathbf{t=2}$ |
|---|---|---|---|
| **Insurers** | Post price $q$; Choose asset portfolio + capital structure | Interest rate shock $R_2$ realized; Rebalance portfolio | |
| **Annuitants of type $\alpha$** | Purchase annuity $a(\alpha, q)$ | Survive with probability $\alpha$ | Survive with probability $\alpha$ |

- Financial instruments: One- and two-period bonds, annuities
- Demand-side frictions: Adverse selection, $\alpha \in A$ is private info
- Supply-side frictions:
  1. Insurers operate under limited liability
  2. Two-period bond supply is inefficient, $\psi = \frac{1}{R_l} - \frac{1}{R_1}\mathbb{E}\left(\frac{1}{R_2}\right) > 0$

# Assumptions on annuity demand

- Individual annuity demand $a(\alpha, q)$ satisfies:

  i. $a(\alpha, q)$ is differentiable in $\alpha$ and $q$, with $\frac{\partial a}{\partial \alpha} > 0$ and $\frac{\partial a}{\partial q} < 0$

  ii. $\exists \alpha \in (\underline{\alpha}, \overline{\alpha})$ such that $a(\alpha, q) > 0$ when $q = \frac{\overline{\alpha}}{R_1}(1 + \overline{\alpha})$

  iii. $a(\alpha, q) = 0 \forall \alpha$ and $q$ if there is a positive probability that the insurer is insolvent in period $t \geq 1$ and $a(\alpha, q) \geq 0$ otherwise

- For any annuity price $q$, individuals with higher longevity risk are less responsive to annuity price changes:

$$\operatorname{cov}\left(\alpha^2, \frac{\partial a(\alpha, q)}{\partial q}\right) \leq 0$$

# Optimal interest rate risk management strategy given $q$

**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 $= \frac{1}{R_2}\int_A \alpha^2 a(\alpha,q)\,dG(\alpha)$ |
| $b_2(R_2)$ | $NW_1(R_2) = 0$ |

$$b_1 = \frac{1}{R_1}\int_A \alpha a(\alpha,q)\,dG(\alpha)\ ; l_2 = \frac{1}{R_l}\int_A \alpha^2 a(\alpha,q)\,dG(\alpha)\,; b_2(R_2) = \frac{1}{R_2}\int_A \alpha^2 a(\alpha,q)\,dG(\alpha)$$

- Insurer prefers hedging the IRR with long-term bonds
- $\psi$ shapes the relative cost of hedging with $NW$

# Bertrand competition drives the annuity price $q^*$ down subject to maintaining the interest rate hedge

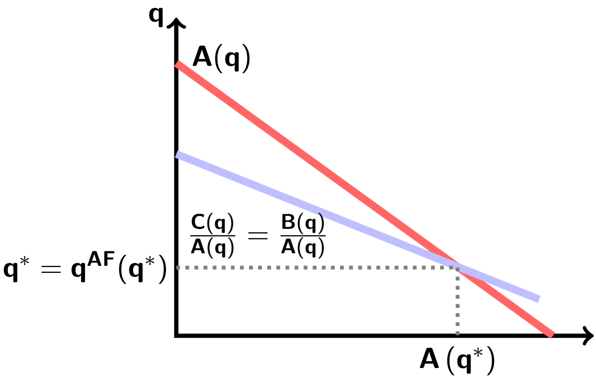
Equilibrium annuity price:

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

Actuarially fair price:

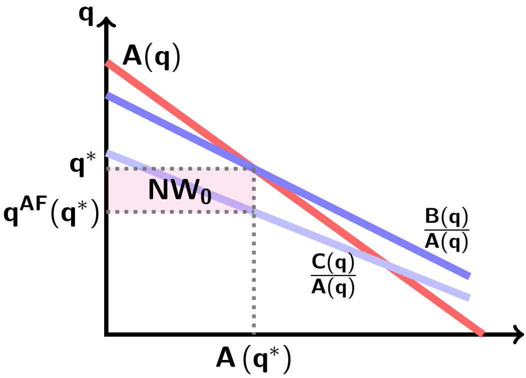
$$q^{AF} = \underbrace{\frac{\frac{1}{R_1} \int_{\underline{\alpha}}^{\overline{\alpha}} \alpha \left[1 + \alpha \mathbb{E}\left(\frac{1}{R_2}\right)\right] a\left(\alpha, q^*\right) dG\left(\alpha\right)}{\int_{\underline{\alpha}}^{\overline{\alpha}} a\left(\alpha, q^*\right) dG\left(\alpha\right)}}_{\text{Insurer's average cost } C(q^*)/A(q^*)}$$

# When the supply of long-term bonds is **efficient** ($\psi = 0$), the insurer invests in a portfolio of bonds that perfectly hedge the interest rate risk




- Non-contingent bond portfolio “replicates” AD securities

# When the supply of long-term bonds is **inefficient** ($\psi > 0$), the insurer charges a markup to build net worth




- Low long-term bond returns increase the cost of hedging IRR

# Relative cost of hedging IRR with long-term bonds holdings increases when long-term bond returns decreases

- Unique level of average net worth financed by annuity markup:

$$\underbrace{q^* - q^{AF}}_{\text{AS-adjusted markup}} = \underbrace{\frac{NW_0(q^*)}{A(q^*)}}_{\text{Insurer's average net worth}}$$

- More constrained bond market means higher markup

$$\frac{\partial q^*}{\partial \psi} - \frac{\partial q^{AF}(q^*)}{\partial \psi} > 0$$

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# We collect annuity price data from the 1989-2019 issues of the *Annuity Shopper Buyer's Guide*


Summer 2021 — Immediate Annuities Update

**Table 5. Single Life Annuities - Age 65**

Column Headings: Life Only: Pays for the annuitant's lifetime. Life with 3% COLA: Pays for the annuitant's lifetime, payments increasing by 3% every policy anniversary date. Life with 10 Years Guaranteed: Pays for the annuitant's lifetime; if the annuitant dies within the first 10 years payments continue to beneficiaries until the end of the 10th year. Life with 20 Years Guaranteed: Pays for the annuitant's lifetime; if the annuitant dies within the first 20 years payments continue to beneficiaries until the end of the 20th year. Life with Cash Refund: Pays for the annuitant's lifetime; if the annuitant dies before receiving an amount equal to the premium, a lump sum equal to the remainder of the premium is paid to beneficiaries. Rates shown are per $100,000 of non-qualified money with monthly income beginning 30 days after purchase.

| | MALE | | | | | FEMALE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Insurance Company | Life Only | Life with 3% COLA | Life w/ 10 years Guar. | Life w/ 20 years Guar. | Life w/ Cash Refund | Life Only | Life with 3% COLA | Life w/ 10 years Guar. | Life w/ 20 years Guar. | Life w/ Cash Refund |
| American General | $501 | $357 | $489 | $444 | $445 | $477 | $334 | $465 | $431 | $429 |
| American National | $474 | $335 | $471 | $435 | $432 | $453 | $314 | $451 | $424 | $419 |
| Guardian Life | $489 | $339 | $480 | $453 | $446 | $467 | $318 | $461 | $441 | $431 |
| Integrity Life | $487 | $351 | $483 | $440 | $443 | $464 | $329 | $462 | $435 | $431 |
| Jackson National | $458 | $322 | $447 | $411 | $401 | $430 | $295 | $423 | $396 | $384 |
| Lincoln National | N/A | N/A | $450 | $414 | $405 | N/A | N/A | $425 | $400 | $390 |
| Mass Mutual | $494 | $352 | $482 | $448 | $451 | $469 | $329 | $461 | $436 | $437 |
| Minnesota Life | $503 | N/A | $489 | $446 | $448 | $472 | N/A | $462 | $431 | $429 |
| Mutual of Omaha | $476 | $337 | $465 | $434 | N/A | $455 | $315 | $446 | $421 | N/A |
| Nationwide | $476 | $329 | $483 | $437 | $439 | $446 | $302 | $455 | $422 | $422 |
| New York Life | $487 | $343 | $484 | $441 | $438 | $454 | $310 | $452 | $423 | $417 |
| North American | $460 | N/A | $450 | $421 | $414 | $435 | N/A | $428 | $407 | $398 |
| Pacific Life | $502 | $362 | $490 | $452 | $454 | $474 | $330 | $465 | $439 | $437 |
| Penn Mutual | $493 | $352 | $485 | $452 | N/A | $471 | $330 | $465 | $440 | N/A |
| Principal | $464 | $326 | $459 | $426 | $425 | $439 | $301 | $435 | $414 | $412 |
| Protective Life | N/A | N/A | $443 | $410 | $402 | N/A | N/A | $417 | $393 | $383 |
| Symetra Financial | $479 | $343 | $469 | $425 | $424 | $451 | $315 | $445 | $415 | $412 |
| **Average** | **$483** | **$342** | **$472** | **$435** | **$431** | **$457** | **$317** | **$448** | **$422** | **$415** |

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# Annuity markups measurement

- $M$-year guaranteed single premium immediate annuity value

$$V_t^i(\text{age}, \text{sex}, M, r) = \underbrace{\sum_{m=1}^{M} \frac{1}{R_t(m,r)^m}}_{\text{M-year term certain annuity}} + \underbrace{\sum_{m=M+1}^{N^i_{\text{sex}}-\text{age}} \frac{\Pi_{l=0}^{m-1} p^i_{\text{sex},\text{age}+l}}{R_t(m,r)^m}}_{\text{Life annuity from year } M+1}$$

- $r$ : Discount rate of the marginal investor in the insurer
- $i$ : Mortality assumption (**annuitants** or **general** population)

$$P_t(\text{age}, \text{sex}) - V_t^{\text{general}}(\text{age}, \text{sex}, r) = \underbrace{P_t(\text{age}, \text{sex}) - V_t^{\text{annuitant}}(\text{age}, \text{sex}, r)}_{\text{Adverse selection adjusted markup}} + \underbrace{\left(V_t^{\text{annuitant}}(\text{age}, \text{sex}, r) - V_t^{\text{general}}(\text{age}, \text{sex}, r)\right)}_{\text{Average adverse selection pricing}}$$

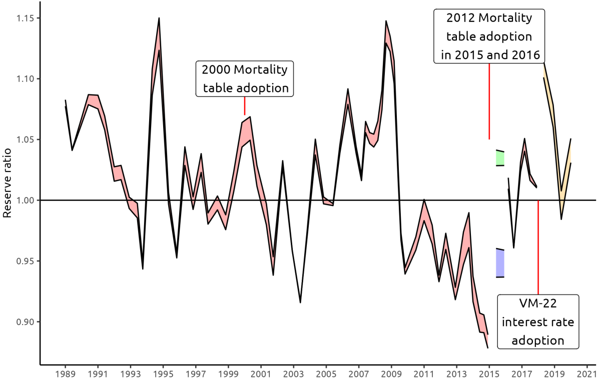
# **Identification:** Shocks that differentially affect the average cost curve and average bond demand curve

1. Contract-level reserve requirement shocks
   - Regulatory interest rate is fixed and resets infrequently
   - Contract maturities create exogenous variation in relative cost

   → Exogenous shifter of average cost and bond demand curve
2. Long-term investment grade bond spread shock
   - Wider spreads mean higher average coupon rates
   - Shocks the tradeoff between long-term bonds and *NW*

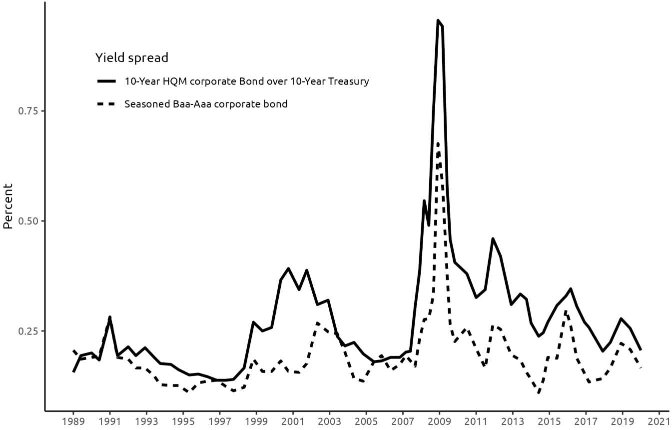
   → Exogenous shifter of average bond demand curve

# 1. Contract-level reserve requirement shocks




- $\dfrac{V_{jt}^{\text{regulator}}(r{=}\text{flat rate})}{V_{jt}^{\text{insurer}}(r{=}\text{yield curve})}$ for a 65 and 70 years old male
- Regulatory interest rate is fixed and resets infrequently
- Contract maturities create exogenous variation in relative cost
  - Insurer needs to create a larger liability and buy more bonds

# 2. Long-term investment grade bond spread shock




- Conditional on the insurer funding cost, wider spreads mean higher coupon for given credit risk and maturity
  - Insurer needs fewer bonds for hedge the same annuity liability

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**Test:** Looking at an insurer offering multiple contracts with exogenously varying reserve requirements, what is the effect of a widening of long-term bond spread on the AS-adjusted markup?

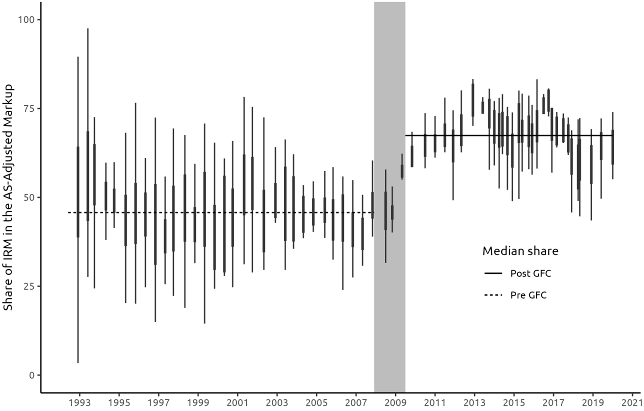
$$
\begin{aligned}
AS\_adj\_markup_{ijt} = & \beta_1 BaaAaa\_spread_t \times Reserve\_Ratio_{jt} \\
& + \beta_2 BaaAaa\_spread_t + \beta_3 Reserve\_Ratio_{jt} \\
& + \beta_4 10\_HQM\_spread_t + \mathbf{z}'_{it}\gamma \\
& + [\text{controls interacted with } BaaAaa\_spread_t] \\
& + \alpha_1^i + \alpha_2^j + \epsilon_{ijt}
\end{aligned}
$$

- $\alpha_1^i$ insurer fixed effect; $\alpha_2^j$ product fixed effects
- $\mathbf{z}'_{it}$ insurer-level time varying financial variables

# Insurers raise their AS-adjusted markup when the relative cost of hedging IRR with long-term bonds increase

| Dependent variable: | $AS\_adjusted\_markup_{ijt}$ | | |
|---|---|---|---|
| $Reserve\_Ratio_{jt} \times Baa\text{-}Aaa\_spread_t$ | -29.18*** | -22.53** | -22.05** |
| | (9.75) | (10.95) | (10.92) |
| $Reserve\_Ratio_{jt}$ | 41.98*** | 33.76*** | 32.70*** |
| | (9.95) | (10.85) | (10.81) |
| $Baa\text{-}Aaa\_spread_t$ | 25.61*** | 17.83* | 17.40* |
| | (8.71) | (9.74) | (9.68) |
| Additional controls | Y | Y | Y |
| Fixed effects: | | | |
| Contract charac. ($j$) | Y | Y | N |
| Insurer ($i$) | Y | Y | N |
| Insurer ($i$) × Contract charac. ($j$) | N | N | Y |
| SE Clustering | Insurer/Date | Insurer/Date | Insurer/Date |
| Observations | 40,790 | 29,462 | 29,462 |
| Adjusted $R^2$ | 0.54 | 0.57 | 0.64 |

# IRM could account for most of the AS-adjusted markup




- 5-year term certain annuities are similar to banks' CDs
  - No adverse selection and little interest rate risk
  - Markup largely reflect insurers' expenses and market structure
- Difference it out of the life annuity AS-adjusted markup

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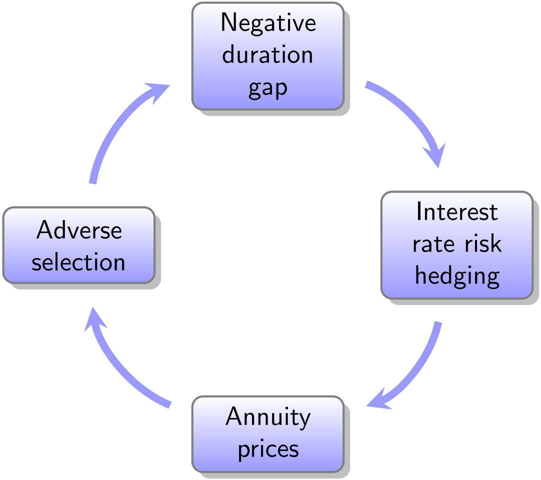
# Interaction of interest rate risk and adverse selection



# An increase in interest rate risk management cost amplifies adverse selection

- $z = R_1/R_l$: Higher $z$ means a more constrained bond market:

$$\frac{\partial q^*}{\partial z} = \underbrace{\frac{\frac{1}{R_1}\int_{\underline{\alpha}}^{\overline{\alpha}} \alpha^2 a(\alpha, q^*) g(\alpha) d\alpha}{\int_{\underline{\alpha}}^{\overline{\alpha}} a(\alpha, q^*) g(\alpha) d\alpha}}_{\text{Risk management effect}} + \underbrace{\frac{\partial q^*}{\partial z} \frac{\int_{\underline{\alpha}}^{\overline{\alpha}} e(\alpha, q^*) \left[1 - \frac{\frac{\alpha}{R_1}(1+\alpha z)}{q^*}\right] a(\alpha, q^*) g(\alpha) d\alpha}{\int_{\underline{\alpha}}^{\overline{\alpha}} a(\alpha, q^*) g(\alpha) d\alpha}}_{\text{Adverse selection effect}}$$

- $e(\alpha, q)$ is the price elasticity of demand for type $\alpha$

# Compare the change in AS pricing for contracts offered by the **same** insurer with **different** guarantee periods in response to the **same** reserve requirement shock

$$AS\_pricing_{ijt} = \frac{P_{ijt}}{V_{jt}^{\text{general}}(r = \text{insurer})} - \frac{P_{ijt}}{V_{jt}^{\text{annuitant}}(r = \text{insurer})}$$

$$\begin{aligned} AS\_pricing_{ijt} = & \beta_1 10yr\_guarantee\_period \times Reserve\_Ratio_{ijt} \\ & + \beta_2 20yr\_guarantee\_period \times Reserve\_Ratio_{ijt} \\ & + \beta_3 10yr\_guarantee\_period + \beta_4 20yr\_guarantee\_period \\ & + \beta_5 Reserve\_Ratio_{ijt} + \text{ [additional controls]} \\ & + \alpha_1^i + \alpha_2^j + \epsilon_{ijt} \end{aligned}$$

# Exogenous increases in reserve requirement disproportionately increase the AS pricing of life annuities with 10 and 20 year guarantees

| Dependent variable: | $AS\_pricing_{ijt}$ | |
|---|---|---|
| $Reserve\_Ratio_{jt}$ | -19.26*** | -21.10*** |
| | (3.26) | (4.22) |
| $10yr\_Guarantee$ | -29.97*** | -27.74*** |
| | (3.43) | (3.77) |
| $10yr\_Guarantee \times Reserve\_Ratio_{jt}$ | 25.25*** | 23.15*** |
| | (3.35) | (3.75) |
| $20yr\_Guarantee$ | -34.83*** | -34.33*** |
| | (3.69) | (4.45) |
| $20yr\_Guarantee \times Reserve\_Ratio_{jt}$ | 26.83*** | 26.49*** |
| | (3.59) | (4.43) |
| Additional controls | Y | Y |
| Insurer FE | Y | Y |
| Observations | 40,790 | 29,462 |
| Adjusted $R^2$ | 0.70 | 0.68 |

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# Cross-sectional evidence using interest rate derivatives

- Insurers add duration with *fixed-for-float* interest rate swaps
- Equivalent to financing fixed rate bonds with short-term debt
- Positive swap duration hedges against a flattening yield curve
- Insurers' NW is favorably/adversely affected by interest rate shocks *ex-post* through their *ex-ante* hedging program
- Focus on *zero lower bound* period 2009-2015:
  - All variation in the yield curve comes from the long end

# How would insurers on opposite ends of hedging performance change their AS-markups when the yield curve flattens?

$$\begin{aligned} AS\_adj\_markup_{ijt} = & \beta_1 10Y3M\_Treasury\_spread_t \times Net\_swap\_duration_{it} \\ & + \beta_2 Net\_swap\_duration_{it} + \text{[additional controls]} \\ & + \alpha_1^i + \alpha_2^j + \alpha_3^t + \epsilon_{ijt} \end{aligned}$$

- $Net\_swap\_duration_{it}$:
  - 82,000 individual swap contract positions from 44 insurers
  - Calculate aggregate net swap duration relative general account
- $\alpha_1^i$ insurer fixed effect
- $\alpha_2^j$ product fixed effects
- $\alpha_3^t$ date fixed effects

# Although their interest rate hedge is effective on average, insurers at the top of the $Net\_swap\_duration_{it}$ distribution cut their AS-adjusted markup when the yield curve flattens

| Dependent variable: | $AS\_adjusted\_markup_{ijt}$ |
|---|---|
| $Net\_swap\_duration_{it} \times 10Y\text{-}3M\_Treasury\_spread_t$ | 5.04** |
| | (2.32) |
| $Net\_swap\_duration_{it}$ | -8.85 |
| | (5.97) |
| | |
| Insurer financial/bond market controls | Y |
| Contract characteristics ($j$), Insurer ($i$), date ($t$) FE: | Y |
| SE Clustering | Insurer/Date |
| Observations | 9,149 |
| Adjusted $R^2$ | 0.67 |

## How would **different** insurers on opposite ends of hedging performance change their AS-markups when the yield curve flattens?

$$Q_{AS\_adj\_markup_{ijt}}(\tau|\mathbf{x}'_{ijt})$$
$$= \beta_3(\tau)10Y3M\_Treasury\_spread_t \times Net\_swap\_duration_{it}$$
$$+ \beta_1(\tau)Net\_swap\_duration_{it} + \beta_2(\tau)10Y3M\_Treasury\_spread_t$$
$$+ \text{additional controls} + \alpha_1^i + \alpha_2^j$$

- $\tau$ percentile of the distribution
- $\alpha_1^i$ insurer fixed effect
- $\alpha_2^j$ product fixed effects

# The least competitive insurers that are the most beneficially affected by the interest rate shocks disproportionately cut their AS-adjusted markup

| Dependent variable: $AS\_adjusted\_markup_{ijt}$ | $\tau = 0.25$ | $\tau = 0.5$ | $\tau = 0.75$ |
|---|---|---|---|
| $Net\_swap\_duration_{it} \times$ $10Y\text{-}3M\_Treasury\_spread_t$ | 6.78*** | 4.62*** | 3.94*** |
| | (0.56) | (0.35) | (0.35) |
| $Net\_swap\_duration_{it}$ | -14.98*** | -9.34*** | -8.46*** |
| | (1.59) | (1.09) | (1.03) |
| $10Y\text{-}3M\_Treasury\_spread_t$ | 7.79* | 9.34*** | 7.96** |
| | (3.07) | (2.81) | (2.61) |
| Other controls: $Reserve\_Ratio_{ijt}$, $Baa\text{-}Aaa\_spread_t$, $10\_HQM\_spread_t$ | | | |
| Fixed Effects: Contract ($j$), Insurer ($i$), date ($t$) | | | |
| Observations | | 9,149 | |
| $\chi^2_1$-test | | 26.3*** | |
| SE | | Clustered bootstrap | |

# Conclusion

- Interest rate risk management drives annuity markups
- Limits on fixed income duration/yield constrain supply
  - Life insurer invests in increasingly illiquid assets
- Ongoing work:
  - Measuring interest rate risk management by financial institutions
  - Estimating life insurers' cost of capital
  - Designing optimal retirement reforms with private annuities