Workshop on the Financial Economics of Insurance

Pricing of Insurance Liabilities[1]

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Theories of insurance markets

- Traditional theories: Market equilibrium determined by the demand side.
  - Life-cycle demand (Yaari 1965).
  - Informational frictions (Rothschild and Stiglitz 1976).
  - Assumes efficient capital markets on the supply side.
- Modern view: Insurers are financial institutions.
  - Rated and regulated because of the potential for excessive risk taking (e.g., state guaranty funds or agency problems).
  - Pricing of liabilities depend on financial and regulatory frictions.
  - Market dominated by a few large insurers.

Evidence on individual annuities and life insurance

1. Fire sale of policies from November 2008 to February 2009.
   - Average markup on annuities: -19%
   - Average markup on life insurance: -57%
2. Larger price reductions for
   - Policies with lower statutory reserve requirements.
   - Insurance companies with worse balance sheet shocks (especially from variable annuities).
3. More constrained companies also received capital from their holding companies and reduced dividends.
   - Evidence of frictions in both external and internal capital markets.
4. Exploit exogenous variation in statutory reserves across policies to identify the shadow cost of capital.
   - \$0.96 per dollar of statutory capital.

Example: MetLife Investors USA Insurance Company

- 10-year term annuity: Guaranteed payment of \$1 for 10 years.
- MetLife priced it at
  - \$8.16 in November 2007.
  - \$7.74 in November 2008.
  - \$8.60 in May 2009.
- Replicating portfolio of Treasuries cost \$8.48 in November 2008.
- Economic profit: $\$7.74 - \$8.48 = -\$0.74$
- Liabilities recorded at accounting value.

A	L
\$7.74	\$7.54

- Sale creates statutory capital: $\$7.74 - \$7.54 = \$0.20$
- Cost of statutory capital: $\$0.74/\$0.20 = \$3.70$

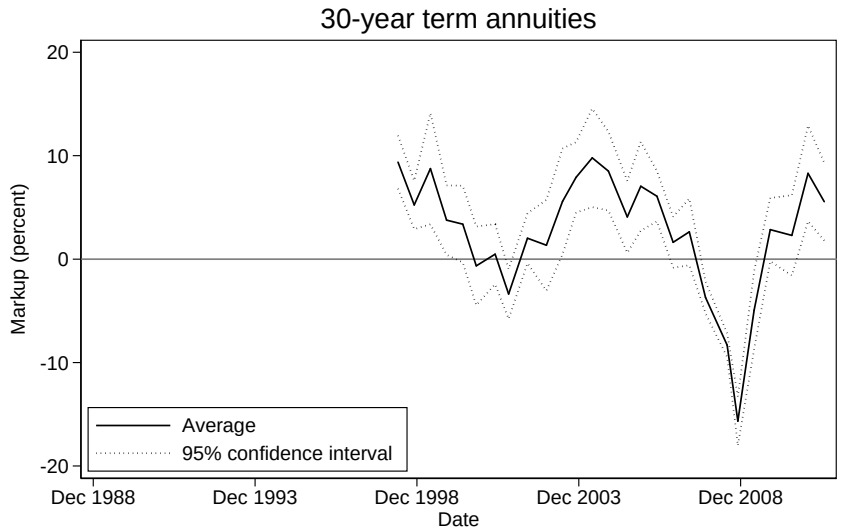
Data on annuity and life insurance prices

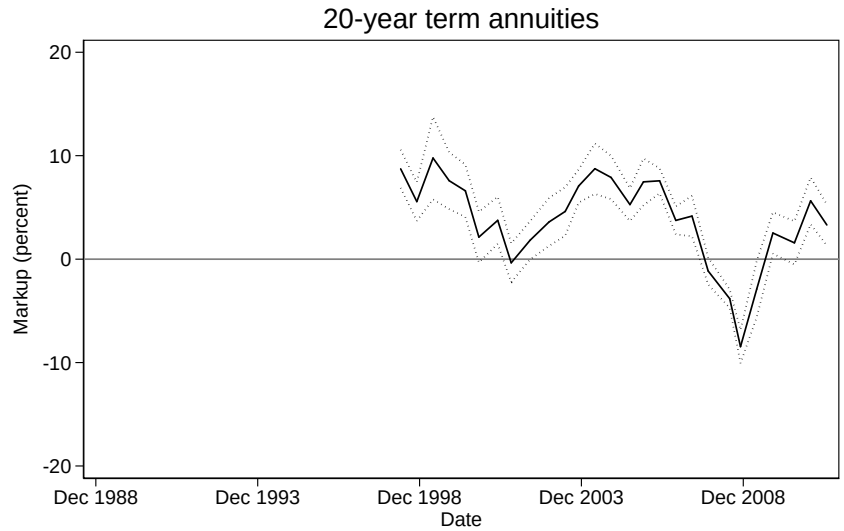
- Annuities: WebAnnuities, January 1989–July 2011 (semiannual/monthly).
  - 33,071 observations.
  - Covers 61% of market share in 2011.
  - Types of policies:
    1. Term annuities: 5- to 30-year maturities.
    2. Life annuities: Male and female, 50- to 85-years old, "life only" and 10- or 20-year guarantees.
- Life insurance: Compulife, January 2005–July 2011 (monthly).
  - 31,226 observations
  - Covers 42% of market share in 2011.
  - Universal life insurance: Male and female, 30- to 80-years old.
- Calculate the actuarial value for each type of policy.
  - Mortality tables from the American Society of Actuaries.
  - Zero-coupon Treasury yield curve.
- Merged with financial statements and A.M. Best ratings.

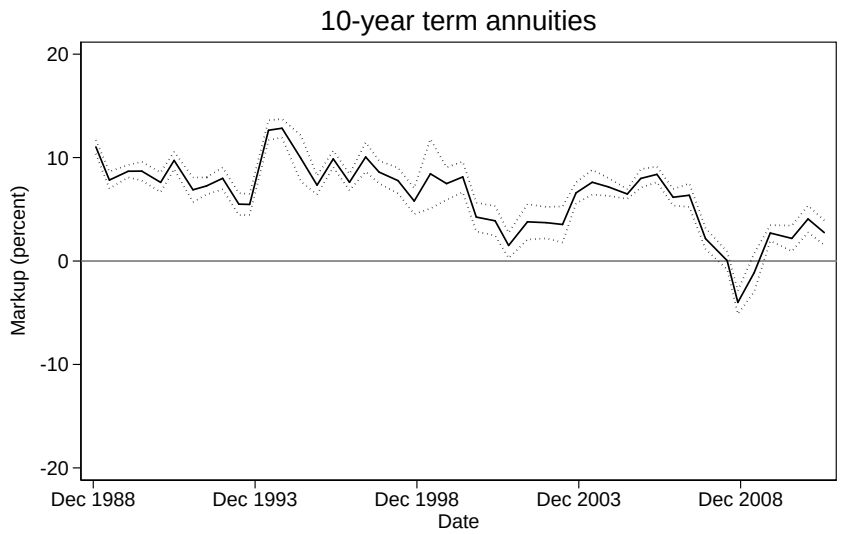
Summary statistics for annuity and life insurance prices

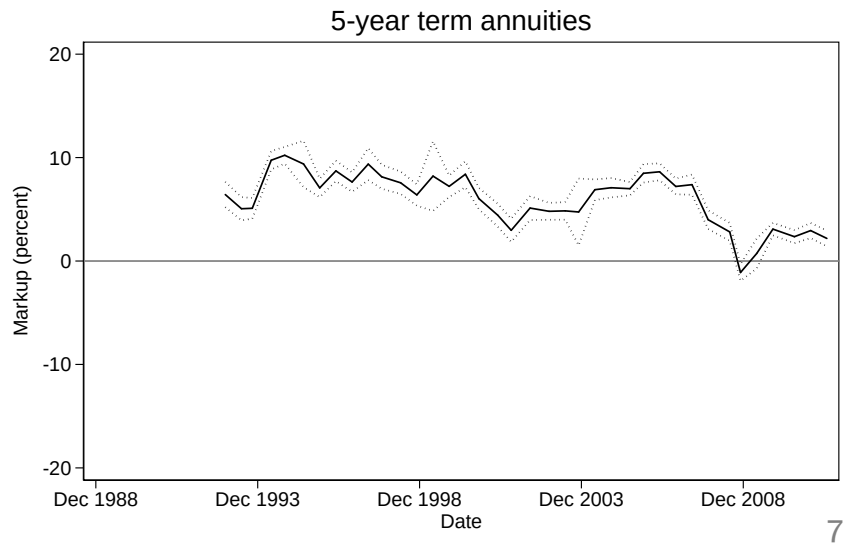
				Markup (percent)		
Type of policy	Sample begins	Frequency	Observations	Mean	Median	Standard deviation
Term annuities:						
5 years	December 1992	Semiannual	646	6.5	6.7	3.7
10 years	January 1989	Semiannual	870	7.0	7.2	4.2
15 years	May 1998	Semiannual	394	4.4	4.5	4.7
20 years	May 1998	Semiannual	390	4.1	4.0	5.7
25 years	May 1998	Semiannual	318	3.7	3.7	6.7
30 years	May 1998	Semiannual	309	3.1	3.2	7.9
Life annuities:						
Life only	January 1989	Monthly	13,675	7.9	8.4	7.6
10-year guarantee	May 1998	Monthly	10,221	4.2	4.9	6.7
20-year guarantee	May 1998	Semiannual	6,248	4.5	4.9	6.5
Universal life insurance	January 2005	Monthly	31,226	-5.8	-6.5	16.0

Average markup on term annuities

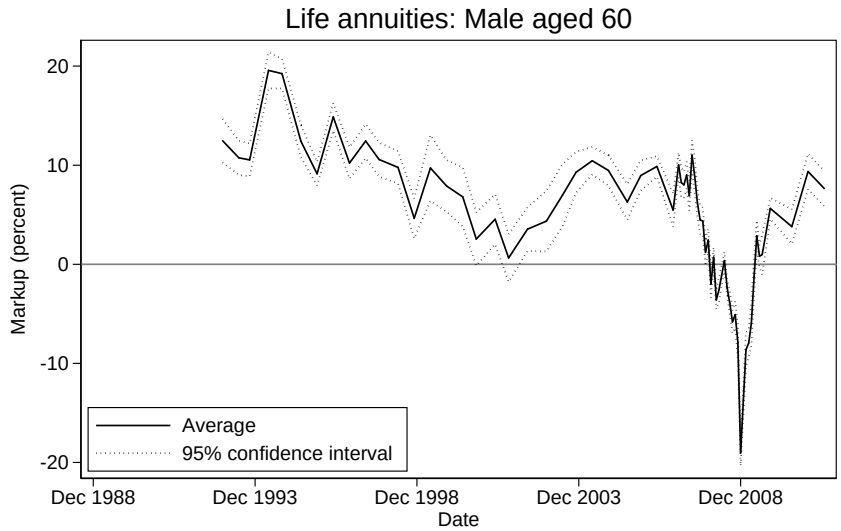


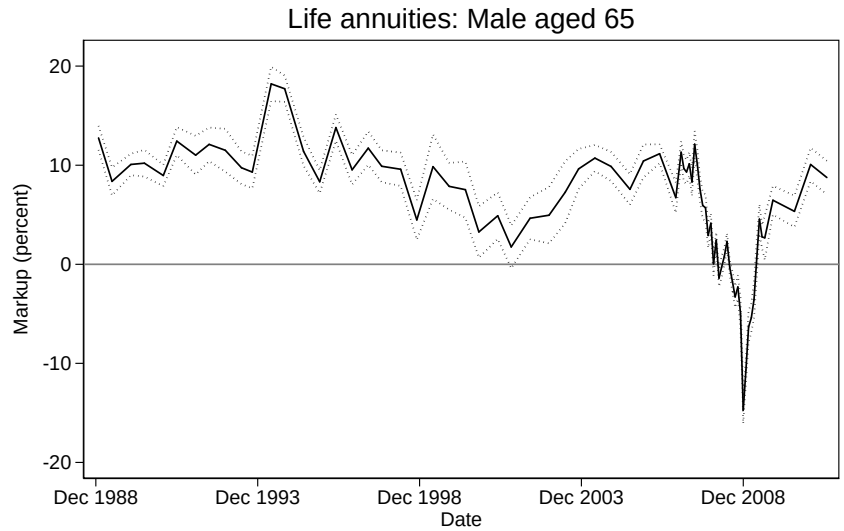


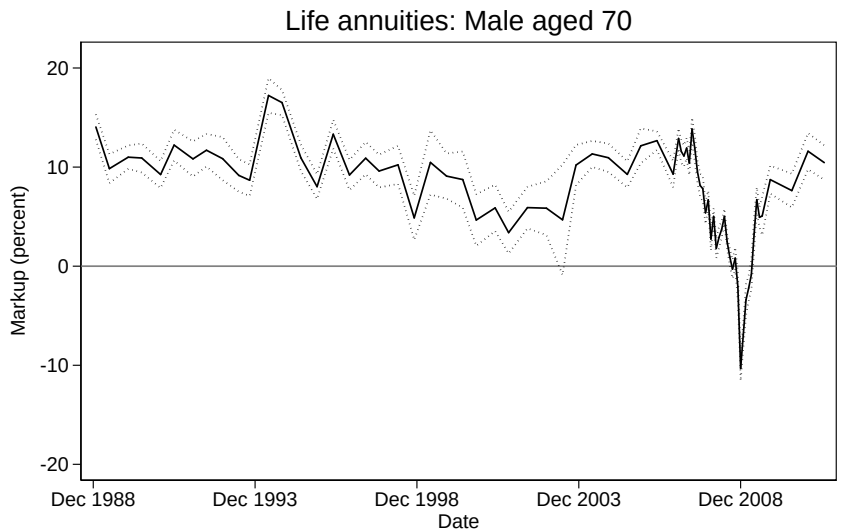


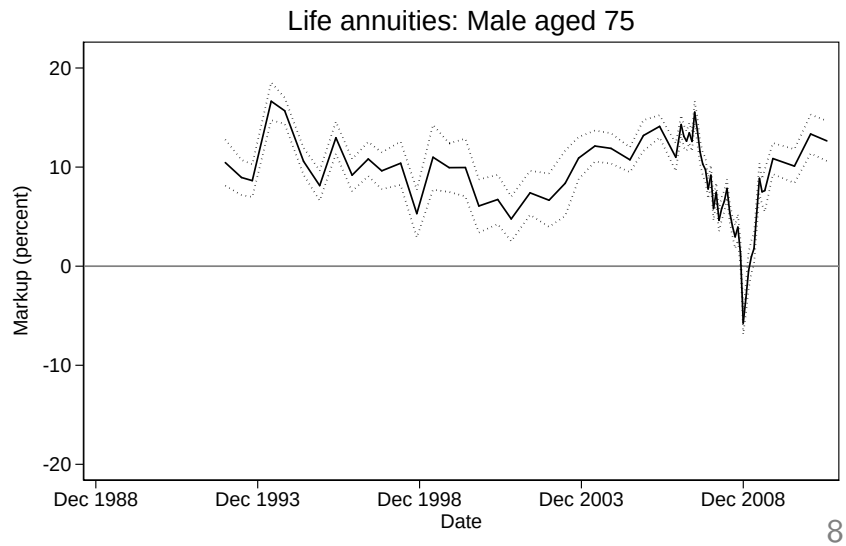


Average markup on life annuities

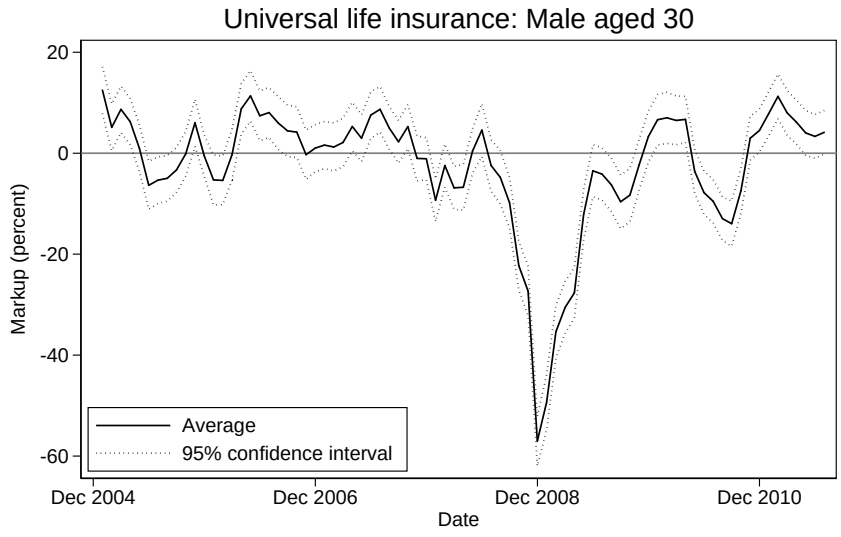


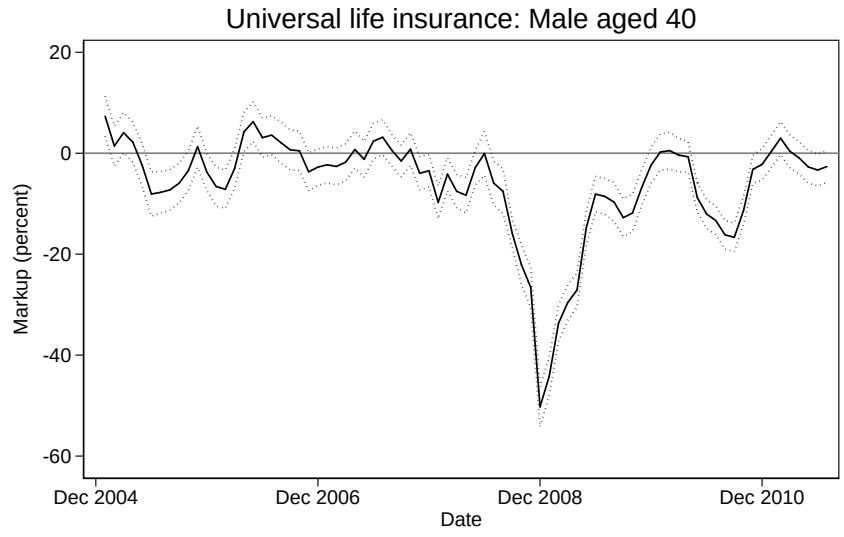


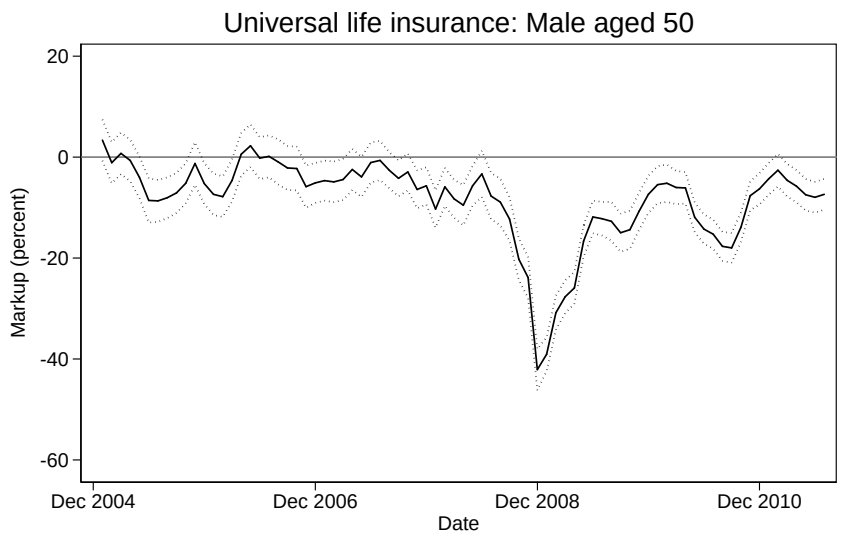


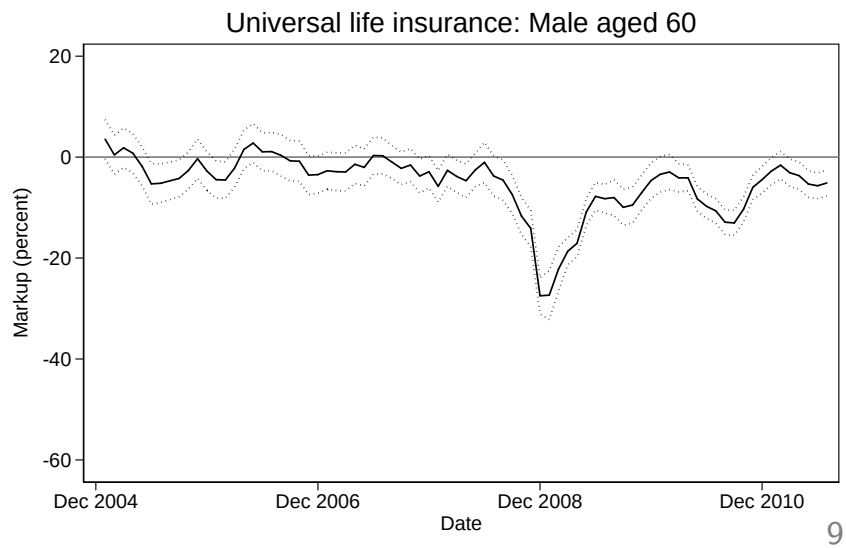


Average markup on life insurance

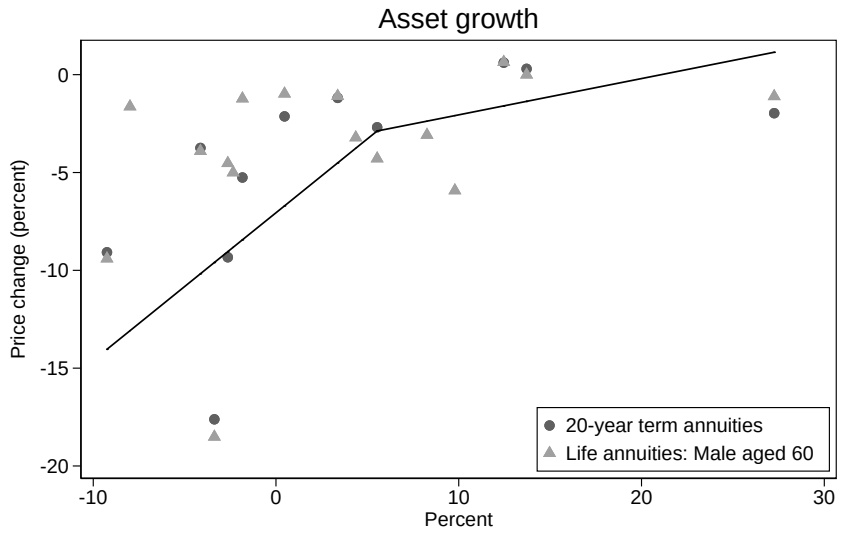


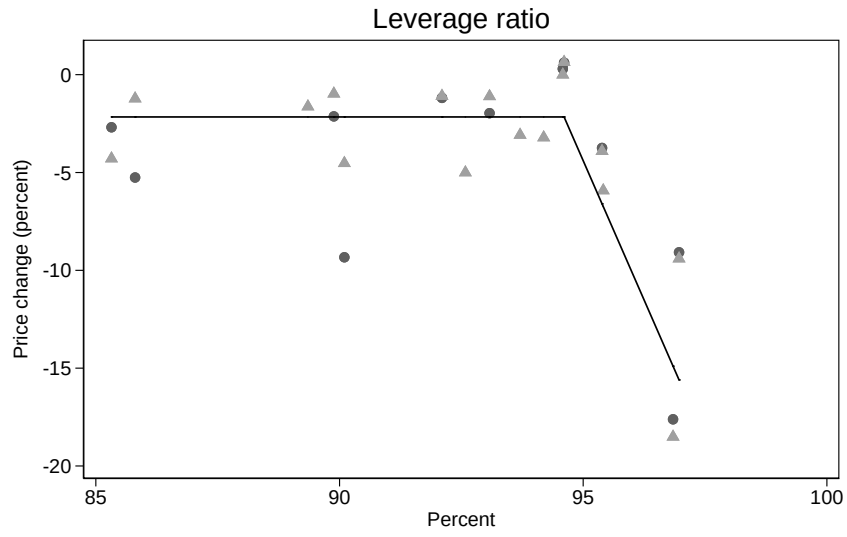


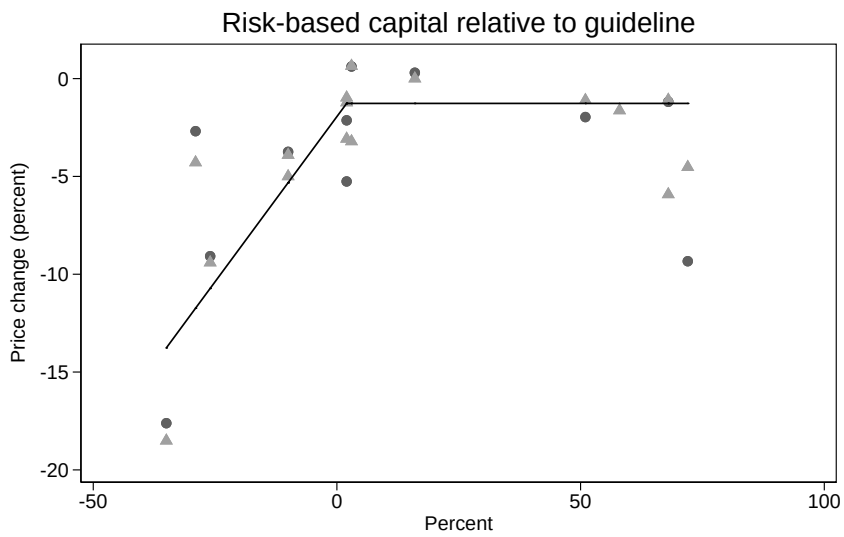


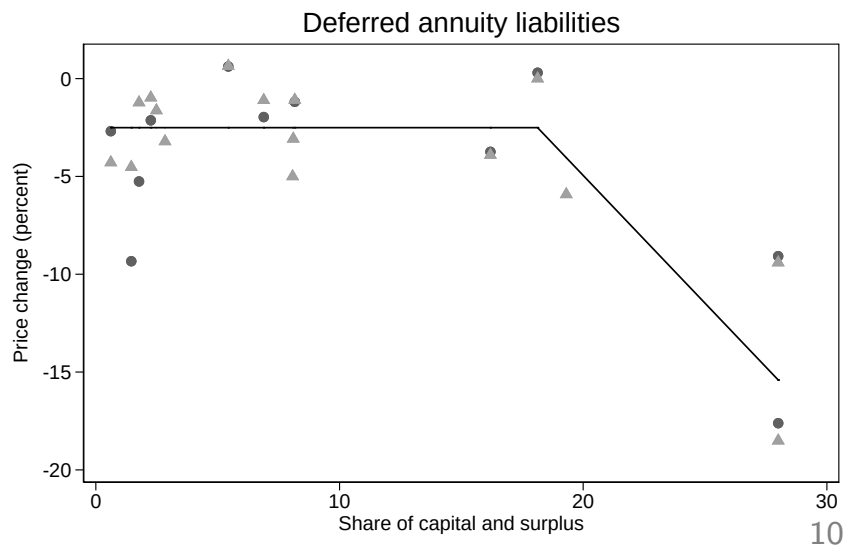


Relation between price changes and balance sheet shocks









Statutory reserve regulation

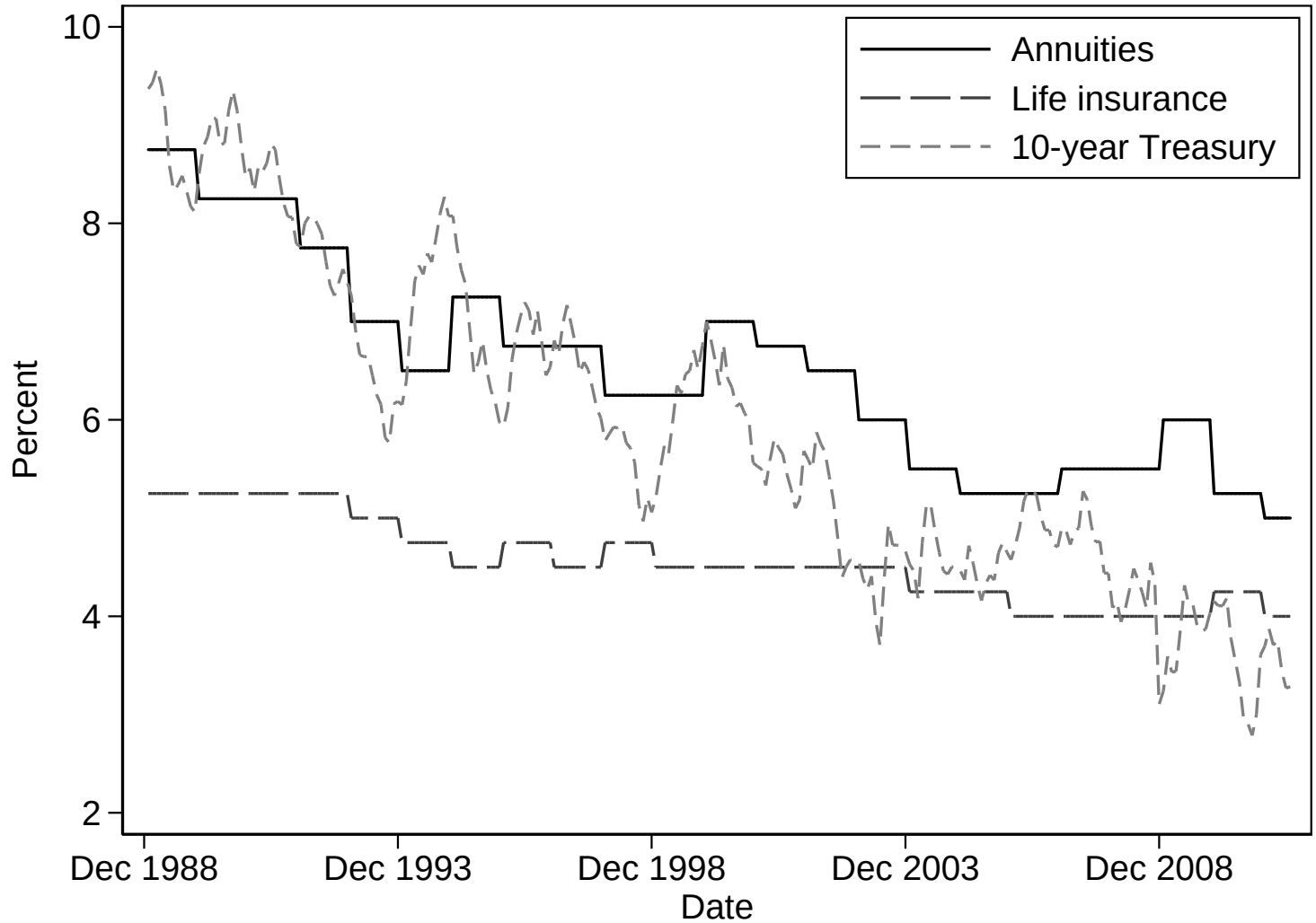
- Standard Valuation Law: "Present value" formula for calculating statutory reserves for each type of policy.
- Discount rate for annuities:

$$0.03 + 0.8(y_t - 0.03)$$

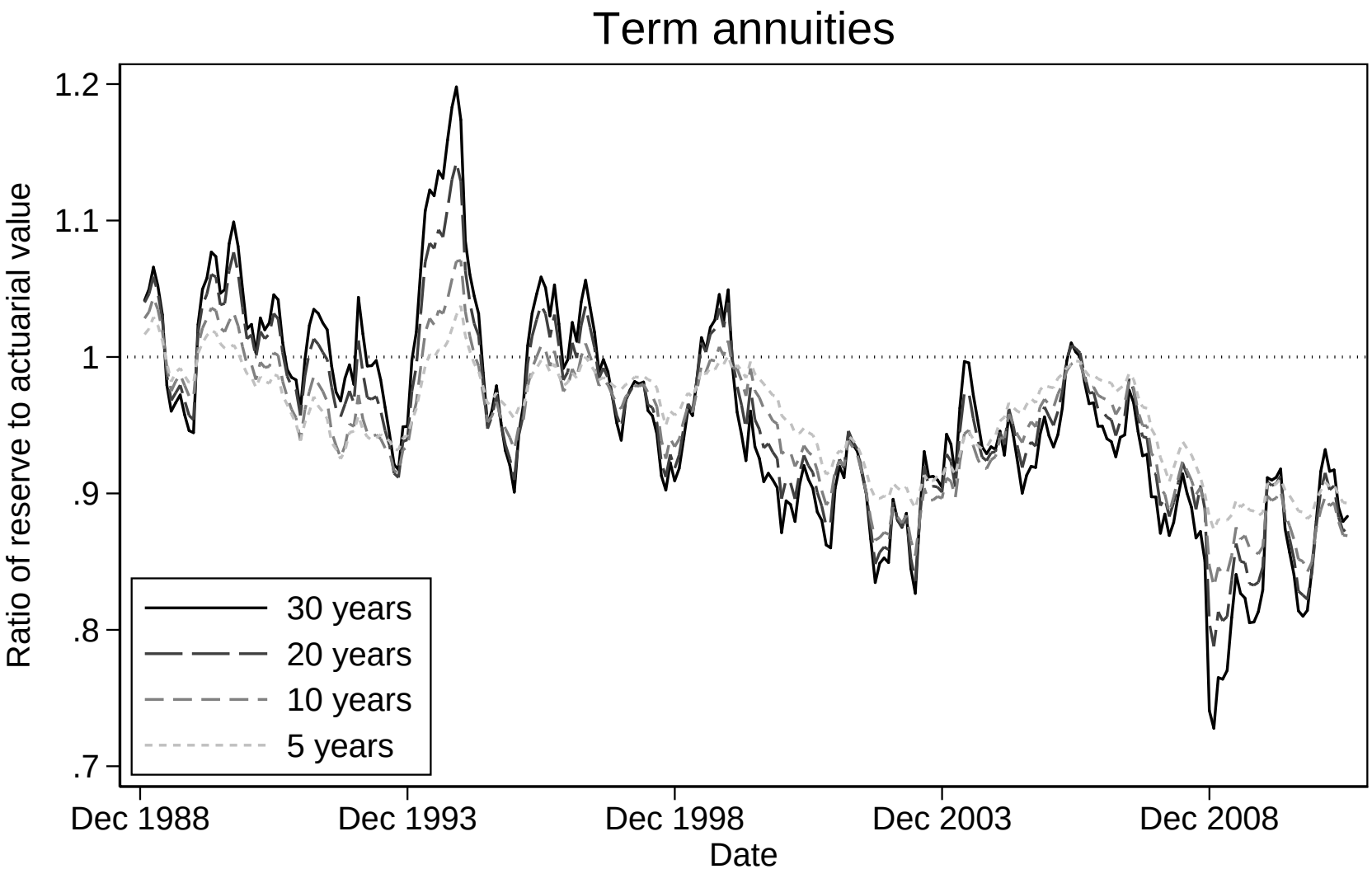
  where y_t is a moving average of the Moody's composite bond yield.
- Discount rate for life insurance:

$$0.03 + 0.35(\min\{y_t, 0.09\} - 0.03) + 0.175(\max\{y_t, 0.09\} - 0.09)$$

Discount rates for annuities and life insurance



Reserve to actuarial value for term annuities



Risk-based capital regulation

- Insurance regulators use the risk-based capital ratio:

$$\text{RBC} = \frac{\text{Assets} - \text{Reserves}}{\text{Required capital}}$$

- Low RBC leads in regulatory action.
- Required capital determined by a complicated formula, but a simple way to think about it is

$$\text{Required capital} = \phi \text{Reserves}$$

- Riskier liabilities have higher ϕ.
- A.M. Best bases ratings on a version of RBC called Best's Capital Adequacy Ratio.

Optimal pricing model

- Insurance company sells $i = 1, \ldots, I$ different types of policies:
  - $P_{i,t}$: Price.
  - $V_{i,t}$: Actuarial (market) value.
  - $\widehat{V}_{i,t}$: Reserve (accounting) value.
  - $Q_{i,t}(P)$: Downward-sloping demand.
- Profit:

$$Y_t = \sum_{i=1}^{I} (P_{i,t} - V_{i,t}) Q_{i,t}$$

- Firm value:

$$J_t = Y_t + \mathbb{E}_t[M_{t+1} J_{t+1}]$$

Balance sheet dynamics

- Assets:

$$A_t = R_{A,t} A_{t-1} + \sum_{i=1}^{I} P_{i,t} Q_{i,t}$$

- Statutory reserves:

$$L_t = R_{L,t} L_{t-1} + \sum_{i=1}^{I} \widehat{V}_{i,t} Q_{i,t}$$

- Risk-based capital constraint:

$$\frac{A_t - L_t}{\phi L_t} \geq 1 \Leftrightarrow \frac{L_t}{A_t} \leq \frac{1}{1+\phi}$$

or

$$K_t = A_t - (1+\phi) L_t \geq 0$$

Optimal pricing equation

- Choose $P_{i,t}$ to maximize

$$L_t = J_t + \lambda_t K_t = Y_t + \mathbb{E}_t \left[M_{t+1} J_{t+1} \right] + \lambda_t K_t.$$

Optimal pricing equation

- Choose $P_{i,t}$ to maximize

$$L_t = J_t + \lambda_t K_t = Y_t + \mathbb{E}_t \left[M_{t+1} J_{t+1} \right] + \lambda_t K_t.$$

- The first-order condition for the price of policy i in period t is

$$\begin{aligned}
\frac{\partial L_t}{\partial P_{i,t}} =& \frac{\partial J_t}{\partial P_{i,t}} + \lambda_t \frac{\partial K_t}{\partial P_{i,t}} = \frac{\partial Y_t}{\partial P_{i,t}} + \overline{\lambda}_t \frac{\partial K_t}{\partial P_{i,t}} \\
=& Q_{i,t} + (P_{i,t} - V_{i,t}) \frac{\partial Q_{i,t}}{\partial P_{i,t}} \\
& + \overline{\lambda}_t \left[Q_{i,t} + \left(P_{i,t} - (1+\phi) \widehat{V}_{i,t} \right) \frac{\partial Q_{i,t}}{\partial P_{i,t}} \right] = 0,
\end{aligned}$$

where we refer to

$$\overline{\lambda}_t = \lambda_t + \mathbb{E}_t \left[M_{t+1} \frac{\partial J_{t+1}}{\partial K_t} \right] = - \frac{\partial Y_t}{\partial P_{i,t}} \left(\frac{\partial K_t}{\partial P_{i,t}} \right)^{-1}$$

as the shadow cost of capital.

Optimal pricing equation

- Price of policy i:

$$P_{i,t} = \underbrace{V_{i,t}\left(1 - \frac{1}{\epsilon_{i,t}}\right)^{-1}}_{\text{Bertrand price}} \underbrace{\left(\frac{1 + \overline{\lambda}_t(1+\phi)\widehat{V}_{i,t}/V_{i,t}}{1+\overline{\lambda}_t}\right)}_{\text{financial frictions}}$$

where

$$\epsilon_{i,t} = -\frac{\partial \log Q_{i,t}}{\partial \log P_{i,t}} > 1,$$

is the elasticity of demand.

- Without constraints, $\overline{\lambda}_t = 0$, we obtain the Bertrand price

$$P_{i,t} = V_{i,t}\left(1 - \frac{1}{\epsilon_{i,t}}\right)^{-1}.$$

Predictions

1. Price depends on statutory reserve requirements:

$$\frac{\widehat{V}_{i,t}}{V_{i,t}} \lessgtr \frac{1}{1+\phi} \Leftrightarrow P_{i,t} \lessgtr \text{Bertrand price}$$

   - Intuition: Insurance company eager to sell policies with low statutory reserve requirements that loosen the constraint.
   - Literature on banking (Peek and Rosengren 2000) and P-C insurance (Froot and O'Connell 1999) suggest that supply shifts in, but that's because $\widehat{V}_{i,t}/V_{i,t} \geq 1$ in these contexts.

2. Price reductions are larger for more constrained companies (i.e., higher $\overline{\lambda}_t$).

Empirical specification

- Policy i, company j, and time t:

$$\log\left(\frac{P_{i,j,t}}{V_{i,t}}\right) = -\log\left(1-\frac{1}{\epsilon_{i,j,t}}\right) + \log\left(\frac{1+\overline{\lambda}_{j,t}(L_{j,t}/A_{j,t})^{-1}\widehat{V}_{i,t}/V_{i,t}}{1+\overline{\lambda}_{j,t}}\right) + e_{i,j,t}$$

- Elasticity of demand:

$$\epsilon_{i,j,t} = 1 + \exp\{-\beta'\mathbf{y}_{i,j,t}\}$$

- Shadow cost:

$$\overline{\lambda}_{j,t} = \exp\{\gamma'\mathbf{z}_{j,t}\}$$

- Explanatory variables:
  - A.M. Best rating, log assets, asset growth, leverage ratio, RBC, current liquidity, and ROE.
  - Dummies for time and domiciliary state.

Identifying assumptions

1. Identification if demand is correctly specified.
   - Average markup must be nonnegative in the absence of financial frictions.
2. Identification even if demand is potentially misspecified.
   - Linear approximation to the pricing model:

$$\log\left(\frac{P_i}{V_i}\right) \approx \alpha + \frac{\overline{\lambda}}{1+\overline{\lambda}}\left(\frac{L}{A}\right)^{-1}\frac{\widehat{V}_i}{V_i} + u_i,$$

   - Standard Valuation Law generates relative shifts in supply that are orthogonal to demand:

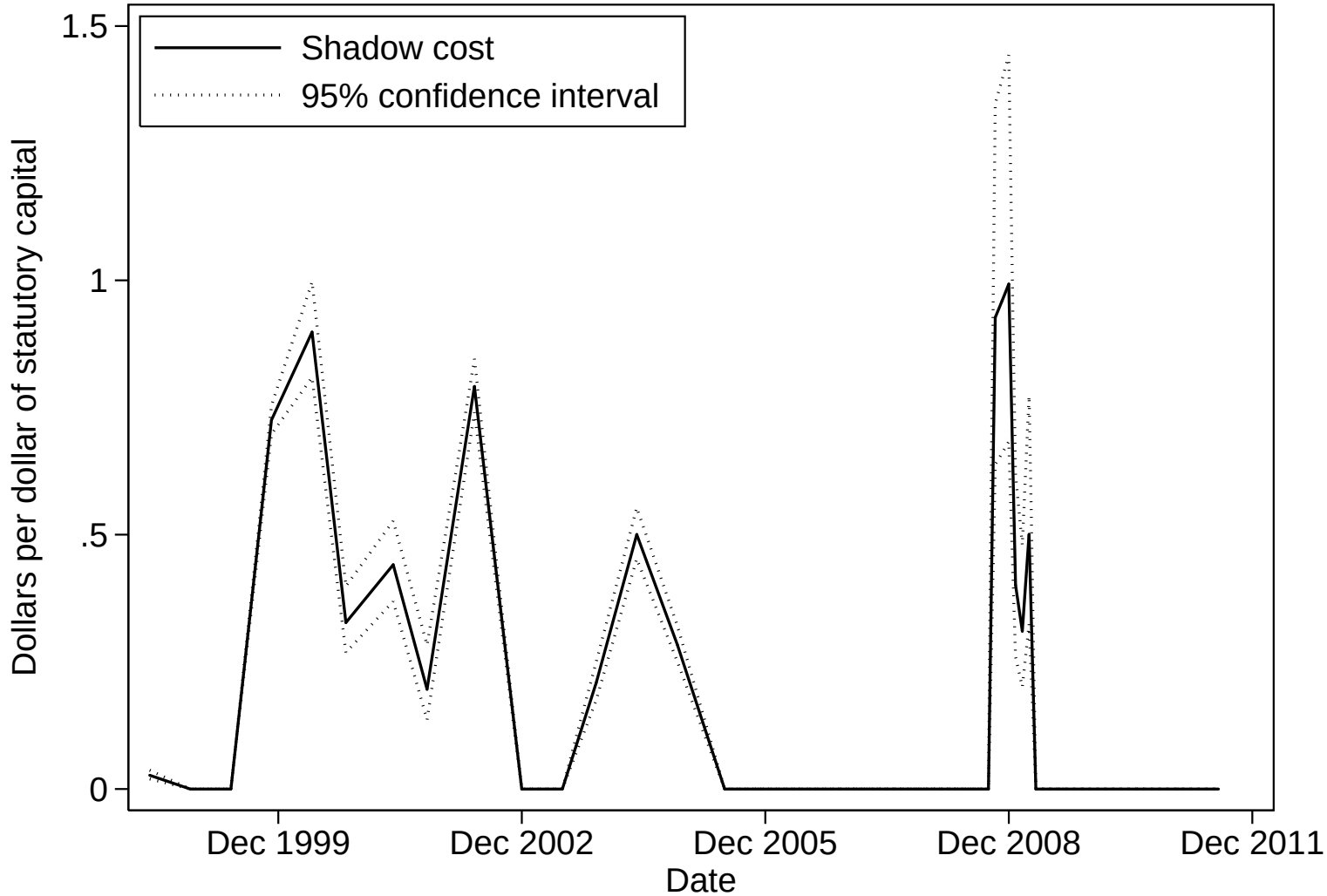
$$\mathrm{Cov}\left(\frac{\widehat{V}_i}{V_i}, u_i\right) = 0$$

   - Exploits exogenous variation in capital requirements across policies.

Estimated model of insurance pricing

Explanatory variable	Coefficient	
Panel B. Shadow cost of capital		
Corporate yield spread	0.660	(0.052)
Log assets	-0.240	(0.034)
Asset growth	-0.255	(0.030)
Leverage ratio	1.545	(0.130)
Risk-based capital relative to guideline	0.393	(0.047)
Net equity inflow	0.085	(0.024)
R^2	0.232	
Observations	45,430	

Shadow cost of capital



Shadow cost of capital in November 2008

Insurance company	Shadow cost (dollars)		Asset growth (percent)	Leverage ratio (percent)	Net equity inflow (percent)
MetLife Investors USA Insurance	5.53	(1.52)	-9	97	163
Pruco Life Insurance	5.38	(1.39)	-19	97	43
National Integrity Life Insurance	5.37	(1.20)	10	95	59
John Hancock Life Insurance of New York	5.02	(1.39)	-15	96	134
Pruco Life Insurance of New Jersey	4.97	(1.26)	-13	97	0
AXA Equitable Life Insurance	4.52	(1.12)	-22	97	0
John Hancock Life Insurance (USA)	3.87	(1.09)	-18	98	25
Lincoln National Life Insurance	3.50	(0.82)	-17	96	-7
Sun Life Assurance of Canada (US)	3.31	(0.88)	-11	97	95
Phoenix Life Insurance	3.06	(0.64)	-8	94	-7
OM Financial Life Insurance	2.88	(0.66)	-4	95	44
Aviva Life and Annuity of New York	2.75	(0.61)	4	94	25
Allianz Life Insurance of North America	2.75	(0.70)	-3	97	22
Texas Life Insurance	2.44	(0.51)	5	93	0
United States Life Insurance in City of New York	2.19	(0.51)	0	94	90
EquiTrust Life Insurance	2.18	(0.47)	14	95	20
Integrity Life Insurance	2.07	(0.40)	3	92	25
OM Financial Life Insurance of New York	1.96	(0.42)	-2	93	0
Companion Life Insurance	1.92	(0.39)	4	91	0
Sun Life Insurance and Annuity of New York	1.85	(0.37)	-2	92	69

Additional evidence on financial frictions

- In order for the subsidiary to be constrained, you need frictions in either
  - External capital markets: Holding company doesn't have capital to inject into the subsidiary.
  - Internal capital markets: Holding company doesn't have proper incentives to inject capital into the subsidiary.
- Evidence that external capital was costly during the financial crisis.
- Insurance Holding Company System Regulatory Act may have led to frictions in internal capital markets.

Cost of external equity issuance: MetLife

- October 7, 2008: Announced issuance of 86.25 million shares.
- October 8: Abnormal return of -24%.
  - Its market cap was \$26.170 billion.
  - Announcement effect: $0.24 \times \$26.170 = \$6.370$ billion
- Raised \$2.329 billion in new equity.
- Average cost of

$$\frac{\$6.370}{\$2.286} = \$2.79 \text{ per dollar of capital}$$

- Marginal cost (i.e., shadow cost of capital) is
  - \$0.96 for the average company.
  - \$5.53 for MetLife.

Significant activity to recapitalize by the holding companies

Holding company	Date	Significant activity	Announcement effect (dollars)
Panel A. Applied for government assistance			
Allstate	11/14/2008	Applies for TARP.	
	2/25/2009	Reduces quarterly dividend from $0.41 to $0.20 per share.	
	5/15/2009	Receives approval for TARP.	
	5/19/2009	Withdraws application for TARP.	
American International Group	9/22/2008	Suspends dividends under an $85 billion credit agreement with the New York Fed.	
	11/25/2008	Issues $40 billion of preferred equity to the US Treasury under TARP.	
Genworth Financial	11/1/2008	Suspends dividends.	
	11/16/2008	Applies for TARP with plans to acquire InterBank, FSB.	
	4/9/2009	Is rejected for TARP and cancels the acquisition of InterBank, FSB.	
ING Group	10/19/2008	Issues 10 billion euros of preferred equity to the Dutch government.	
	10/19/2008	Suspends dividends.	
Lincoln National	10/10/2008	Reduces quarterly dividend from $0.415 to $0.21 per share.	
	11/13/2008	Applies for TARP with plans to acquire Newton County Loan and Savings, FSB.	
	2/24/2009	Reduces quarterly dividend from $0.21 to $0.01 per share.	
	6/22/2009	Issues $690 million of common equity.	
	7/10/2009	Issues $950 million of preferred equity to the US Treasury under TARP.	
Phoenix Companies	1/15/2009	Applies for TARP with plans to acquire American Sterling Bank.	
	2/7/2009	Suspends dividends.	
	4/20/2009	Withdraws application for TARP after failing to acquire American Sterling Bank.	
Protective Life	11/3/2008	Reduces quarterly dividend from $0.235 to $0.12 per share.	
	1/15/2009	Applies for TARP with plans to acquire Bonifay Holding Company.	
	4/1/2009	Withdraws application for TARP after failing to acquire Bonifay Holding Company.	
	5/20/2009	Issues $133 million of common equity.	0.76
Prudential Financial	10/1/2008	Applies for TARP.	
	11/11/2008	Reduces annual dividend from $1.15 to $0.58 per share.	
	5/14/2009	Receives approval for TARP.	
	6/1/2009	Withdraws application for TARP.	
	6/9/2009	Issues $1,438 million of common equity.	1.18
Panel B. Issued public equity			
Manulife Financial	12/11/2008	Issues $2,275 million of common equity.	0.72
	3/4/2009	Issues $450 million of preferred equity.	
	6/3/2009	Issues $350 million of preferred equity.	
	8/6/2009	Reduces quarterly dividend from $0.26 to $0.13 per share.	
MetLife	10/15/2008	Issues $2,286 million of common equity.	2.79
Panel C. Reduced or suspended dividends			
Allianz Group	2/26/2009	Reduces annual dividend from 5.50 to 3.50 euros per share.	
AXA	4/30/2009	Reduces annual dividend from 1.20 to 0.40 euros per share.	
FBL Financial Group	5/21/2009	Reduces quarterly dividend from $0.125 to $0.0625 per share.	
Legal and General Group	3/25/2009	Reduces final dividend from 4.10 to 2.05 pence per share.	
Old Mutual	3/4/2009	Suspends dividends.	

Frictions in internal capital markets

- Policyholders are senior to creditors of the holding company.
- State regulators severely restrict capital flow from the subsidiary to the holding company.
  - For example, dividends authorized under the Insurance Holding Company System Regulatory Act.
- Leads to "regulatory overhang".
  - Regulatory uncertainty over the ability to move capital out reduces ex-ante incentives to inject capital.

Default risk

1. Policies backed by the state guaranty fund. What if it fails?
   - Lower bound on the recovery rate: 84%.
     - Capital regulation: Only 16% of assets are risky.
     - Asset deficit of 5–10% in past cases of insolvency.
   - Risk-neutral default probabilities implied by term annuities in November 2008:
     - 100% for maturity greater than 15 years.
     - Higher than default probabilities implied by CDS.
     - Upward sloping term structure inconsistent with CDS.
2. No discounts on life annuities during the Great Depression.
   - Inconsistent with default story.
   - Consistent with the explanation based on statutory reserve regulation.

Related evidence (Ge 2017)

- After a weather shock, P-C subsidiary loses capital.
- Holding company reallocates capital from the life subsidiary to the P-C subsidiary.
- Life subsidiary becomes constrained, and price changes consistent with optimal pricing equation.
  - Prices for universal life insurance go down because $\widehat{V}/V < (1+\phi)^{-1}$.
  - Prices for term life insurance go up because $\widehat{V}/V > (1+\phi)^{-1}$.

Next steps

- Clean evidence that financial frictions affect insurance prices.
- Is this isolated to the financial crisis? Or do supply-side frictions matter at lower frequencies?
- Questions to be addressed next:
  1. Why did insurers get constrained in the first place? For a traditional insurer, liability matching implies that overall balance sheet should be insensitive to market risk.
  2. Pricing is only one dimension of insurance policies. How do we extend the theory to other contract characteristics?
  3. Lack of detailed data on quantities prevents demand estimation.