Insurance Regulation and Policy Firesales*

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Abstract

During the financial crisis, life insurers sold long-term insurance policies at firesale prices. In January 2009, the average markup, relative to actuarial value, was −25 percent for 30-year term annuities as well as life annuities and −52 percent for universal life insurance. This extraordinary pricing behavior was a consequence of statutory reserve regulation that allowed life insurers to record far less than a dollar of reserves per dollar of future insurance liability. Using exogenous variation in reserve requirements across different types of policies, we identify the shadow cost of financial constraints for life insurers. The shadow cost of raising a dollar of excess reserves was nearly $5 for the average insurance company in January 2009.

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1. Introduction

The traditional view of insurance markets is that insurance companies operate in a perfect capital market that allows them to produce insurance at nearly constant marginal cost. Consequently, the equilibrium price is determined by the demand side of the market, either by life-cycle demand (Yaari, 1965) or informational frictions (Rothschild and Stiglitz, 1976). Contrary to this traditional view, this paper shows that insurance companies are financial institutions whose pricing behavior can be profoundly affected by financial constraints and the regulation of statutory reserves.

Our key finding is that life insurers sold long-term insurance policies at firesale prices during a period of few months around January 2009. The average markup, relative to actuarial value (i.e., the present discounted value of future policy claims), was -25 percent for 30-year term annuities as well as life annuities at age 50. Similarly, the average markup was -52 percent for universal life insurance at age 30. These deep discounts are in sharp contrast to the 6 to 10 percent markup that life insurers earn in ordinary times (Mitchell et al., 1999). In the cross section of insurance policies, the discounts were deeper for those policies with looser statutory reserve requirements. In the cross section of insurance companies, the discounts were deeper for those companies whose balance sheets were most adversely affected prior to January 2009.

This extraordinary pricing behavior was due to a remarkable coincidence of two circumstances. First, the financial crisis had an adverse impact on insurance companies' balance sheets. Insurance companies had to quickly recapitalize in order to control their leverage ratio and to prevent a rating downgrade or regulatory action. Second, the regulation governing statutory reserves in the United States allowed life insurers to record far less than a dollar of reserves per dollar of future insurance liability during a period of few months around January 2009. Therefore, insurance companies were able to reduce their leverage ratio by selling insurance policies at a price far below actuarial value, as long as that price was above the reserve value.

We formalize our hypothesis in a structural model of insurance pricing that is otherwise standard, except for a leverage constraint that is familiar from macroeconomics and finance (e.g., Kiyotaki and Moore, 1997; Brunnermeier and Pedersen, 2009). The insurance company sets prices for various types of policies to maximize profits, subject to a leverage constraint that the ratio of statutory reserves to assets cannot exceed a targeted value. Whenever the leverage constraint binds, the insurance company optimally prices a policy below its actuarial value if the transaction has a negative marginal impact on leverage. The Lagrange multiplier on the leverage constraint has a structural interpretation as the shadow cost of raising a dollar of excess reserves.

To test our hypothesis, we construct a panel dataset of nearly 35,000 observations on insurance prices from January 1989 through July 2011. Our data cover term annuities, life annuities, and universal life insurance for both males and females as well as various age groups. Because statutory reserve regulation implies different reserve requirements for different types of policies, we exploit that exogenous variation to identify the shadow cost of financial constraints, which has remained elusive in the previous literature. We find that the shadow cost of the leverage constraint is essentially zero for most of the sample, except around January 2001 and in January 2009. We find that the shadow cost of raising a dollar of excess reserves was nearly \$5 for the average insurance company in January 2009. This cost varies from \$1 to \$13 per dollar of excess reserves for the cross section of insurance companies in our sample.

From an investor's perspective, January 2009 was an especially attractive opportunity to be in the market for insurance policies. For example, a 30-year term annuity could have been purchased for 25 percent less than a portfolio of Treasury bonds with identical cash flows. While solvency might have been a concern for some insurance companies, insurance policies are ultimately backed by the state guarantee fund (e.g., up to \$250k for annuities and \$300k for life insurance in California). Therefore, the only scenario in which an investor would not be repaid is if all insurance companies associated with the state guarantee fund were to systemically fail.

From an insurance company's perspective, it is less obvious why it was optimal to discount insurance policies in January 2009. A potential explanation is that insurance companies anticipated some chance of default, so that their expected liability was less than the full face value of insurance policies. Unfortunately, this explanation is inconsistent with the evidence during the Great Depression. Warshawsky (1988) finds that annuity prices closely track the actuarial value, based on the 20-year Treasury yield, throughout the Great Depression. In particular, insurance companies did not sell annuities at firesale prices in 1932 when corporate default spreads were much higher than the heights reached during the recent financial crisis. Overall, the evidence is more consistent with our explanation based on financial constraints and statutory reserve regulation.

The remainder of the paper is organized as follows. Section 2 describes our data and documents key facts that motive our study of insurance prices. Section 3 reviews key features of statutory reserve regulation that are relevant for our analysis. In Section 4, we develop a structural model of insurance pricing subject to a leverage constraint, which shows how statutory reserve regulation can affect insurance prices. In Section 5, we use our structural model of insurance pricing to estimate the shadow cost of the leverage constraint. Section 6 concludes.

2. Annuity and Life Insurance Prices

2.1 Data Construction

2.1.1 Annuity Prices

Our annuity prices are from the *Annuity Shopper* (Stern, 2011), which is a semiannual publication (every January and July) of annuity price quotes from the leading life insurers. Following Mitchell et al. (1999), we focus on annuities that are single premium, immediate, and non-qualified. This means that the premium is paid upfront as a single lump sum, that the income payments start immediately after the premium payment, and that only the interest portion of the payments is taxable. Our data consist of three types of policies: term annuities, life annuities, and guaranteed annuities. For term annuities, we have quotes for 5- through 30-year maturities (every 5 years in between). For life and guaranteed annuities, we have quotes for males and females between ages 50 and 90 (every 5 years in between).

A term annuity is a policy with annual income payments for a fixed term of M years. Let $R_t(m)$ be the zero-coupon Treasury yield at maturity m in month t. We define the actuarial value of an M-year term annuity per dollar of income as

$$V_t(M) = \sum_{m=1}^{M} \frac{1}{R_t(m)^m}. \tag{1}$$

A life annuity is a policy with annual income payments until death of the insured. Let p_n be the one-year survival probability at age n, and let N be the maximum attainable age according to the appropriate mortality table. We define the actuarial value of a life annuity at age n per dollar income as

$$V_t(n) = \sum_{m=1}^{N-n} \frac{\prod_{l=0}^{m-1} p_{n+l}}{R_t(m)^m}. \tag{2}$$

A guaranteed annuity is a variant of the life annuity whose income payments are guaranteed to continue for the first M years, even if the insured dies during that period. We define the actuarial value of an M-year guaranteed annuity at age n per dollar of income as

$$V_t(n, M) = \sum_{m=1}^{M} \frac{1}{R_t(m)^m} + \sum_{m=M+1}^{N-n} \frac{\prod_{l=0}^{m-1} p_{n+l}}{R_t(m)^m}. \tag{3}$$

We calculate the actuarial value for each type of policy at each date using the zero-coupon Treasury yield curve (Gürkaynak, Sack, and Wright, 2007) and the appropriate mortality table from the Society of Actuaries. We use the 1983 Annuity Mortality Basic Table prior to

December 2000, and the 2000 Annuity Mortality Basic Table since December 2000. These mortality tables are derived from the actual mortality experience of insured pools, based on data provided by various insurance companies. Therefore, they account for adverse selection in annuity markets, that is, an insured pool of annuitants has higher life expectancy than the overall population. We smooth the transition between the two versions of the mortality tables by geometrically averaging.

2.1.2 Life Insurance Prices

Our life insurance prices are from COMPULIFE Software, which is a computer-based quotation system for insurance brokers. We focus on guaranteed universal life policies, which are quoted for the leading life insurers since January 2005. These policies have constant guaranteed premiums and accumulate no cash value, so they are essentially "permanent" term life policies.[1] We pull quotes for the regular health category at the face amount of $250,000 in the sate of California. COMPULIFE recommended California for our study because it is the most populous state with a wide representation of insurance companies. We focus on males and females between ages 30 and 90 (every 10 years in between).

Universal life insurance is a policy that pays out a death benefit upon death of the insured. The policy is in effect as long as the policyholder makes an annual premium payment while the insured is alive. We define the actuarial value of universal life insurance at age n per dollar of death benefit as

$$V_t(n) = \left(1 + \sum_{m=1}^{N-n-1} \frac{\prod_{l=0}^{m-1} p_{n+l}}{R_t(m)^m}\right)^{-1} \left(\sum_{m=1}^{N-n} \frac{\prod_{l=0}^{m-2} p_{n+l}(1 - p_{n+m-1})}{R_t(m)^m}\right). \tag{4}$$

Note that this formula does not take into account the potential lapsation of policies, that is, the policyholder may drop coverage prior to the death of the insured. There is currently no

[1] While COMPULIFE has quotes for various types of policies from annual renewable to 30-year term life policies, they are not useful for our purposes. This is because a term life policy typically has a renewal option at the end of the guaranteed term. Because the premiums under the renewal option vary significantly across insurance companies, cross-sectional price comparisons are difficult and imprecise.

agreed upon standard for lapsation pricing, partly because lapsations are difficult to model and predict. While some insurance companies price in low levels of lapsation, others take the conservative approach of assuming no lapsation in life insurance valuation.

We calculate the actuarial value for each type of policy at each date using the zero-coupon Treasury yield curve and the appropriate mortality table from the Society of Actuaries. We use the 2001 Valuation Basic Table prior to December 2008, and the 2008 Valuation Basic Table since December 2008. These mortality tables are derived from the actual mortality experience of insured pools, based on data provided by various insurance companies. Therefore, they account for adverse selection in life insurance markets. We smooth the transition between the two versions of the mortality tables by geometrically averaging.

2.1.3 Insurance Companies' Balance Sheets

We obtain balance sheet data and A.M. Best ratings for insurance companies through the *Best's Insurance Reports* CD-ROM for fiscal years 1992 through 2010. We merge annuity and life insurance prices to the A.M. Best data through company name. The insurance price observed in January and July of each calender year is matched to the balance sheet data for the previous fiscal year (i.e., as of December of the previous calendar year).

2.2 Summary Statistics

We start with a broad overview of the industry that we study. Figure 1 reports the annual premiums paid for individual annuities and life insurance, summed across all insurance companies in the United States with an A.M. Best rating. In the early 1990's, insurance companies collected nearly \$100 billion in annual premiums for individual life insurance and about \$50 billion for individual annuities. More recently, the annuity market expanded to \$383 billion in 2008. The financial crisis had an adverse effect on annuity demand in 2009, which subsequently bounced back in 2010.

Table 1 summarizes our data on annuity and life insurance prices. We have 988 observations on 10-year term annuities across 98 insurance companies, covering January 1989 through July 2011. The average markup, defined as the percentage deviation of the quoted price from actuarial value, is 6.9 percent. Given that term annuities provide a fixed income stream that an investor can also achieve with Treasury bonds, it is curious why the average markup is so high. There is considerable cross-sectional variation in pricing across insurance companies, as indicated by a standard deviation of 5.9 percent (Mitchell et al., 1999).

We have 11,879 observations on life annuities across 106 insurance companies, covering January 1989 through July 2011. The average markup is 9.8 percent with a standard deviation of 8.2 percent. Our data on guaranteed annuities start in July 1989. For 10-year guaranteed annuities, the average markup is 5.5 percent with a standard deviation of 6.1 percent. For 20-year guaranteed annuities, the average markup is 4.2 percent with a standard deviation of 4.8 percent.

We have 3,989 observations on universal life insurance across 52 companies, covering January 2005 through July 2011. The average markup is -4.2 percent with a standard deviation of 17.9 percent. The negative average markup does not mean that insurance companies systematically lose money on these policies. With a constant premium and a rising mortality rate, policyholders are essentially prepaying for coverage later in life. Whenever a universal life policy is lapsed, the insurance company earns a windfall profit because the present value of remaining premium payments is typically less than the present value of the future death benefit. Since there is currently no agreed upon standard for lapsation pricing, our calculation of actuarial value does not take lapsation into account. We are not especially concerned that the average markup might be slightly mismeasured because our focus is mostly on the variation in markups over time and across different types of polices.

2.3 Firesales of Insurance Policies

Figure 2 reports the time series of average markup on term annuities at various maturities, averaged across insurance companies and reported with a 95 percent confidence interval.

The average markup varies between 0 and 10 percent, with the exception of a period of few months around January 2009. If insurance companies were to change prices on term annuities to perfectly offset interest rate movements, then the markup would be constant over time. Hence, variation in the average markup imply that insurance companies do not necessarily change prices to offset interest rate movements (Charupat, Kamstra, and Milevsky, 2012).

For 30-year term annuities, the average markup fell to an extraordinary −25 percent in January 2009. This large negative markup was due to insurance companies actively cutting prices when the historically low Treasury yields implied high actuarial value for these policies. In January 2009, there is a monotonic relation between the maturity of the policy and the magnitude of the average markup. Average markup was −16 percent for 20-year, −8 percent for 10-year, and −3 percent for 5-year term annuities. Excluding the extraordinary period around January 2009, average markup was negative for 20- and 30-year term annuities only twice before in our sample, in January 2001 and July 2002.

Figure 3 reports the time series of average markup on life annuities at different ages. We find a similar phenomenon to that for term annuities. For life annuities at age 50, the average markup fell to an extraordinary −25 percent in January 2009. There is a monotonic relation between age, which is negatively related to the effective maturity of the policy, and the magnitude of the average markup. Average markup was −19 percent at age 60, −11 percent at age 70, and −3 percent at age 80.

Figure 4 reports the time series of average markup on universal life insurance at different ages. We again find a similar phenomenon to that for term and life annuities. For universal life insurance at age 30, the average markup fell to an extraordinary −52 in January 2009. There is a monotonic relation between age and the magnitude of the average markup. Average markup was −47 percent at age 40, −42 percent at age 50, and −29 percent at age 60.

A potential explanation for the negative markup in January 2009 is that insurance companies anticipated some chance of default, so that their expected liability was less than the full face value of insurance policies. Therefore, their cost of capital was the Baa corporate bond yield, for example, instead of the Treasury yield. Unfortunately, this explanation does not work for three reasons. First, if the Baa corporate bond yield were used to calculate the actuarial value, it would imply that insurance companies earn incredibly high markups in ordinary times (Mitchell et al., 1999). Second, the firesale of insurance policies was very short-lived around January 2009, while the corporate default spread remained elevated for much longer. Third, and perhaps most convincingly, this explanation is inconsistent with the evidence during the Great Depression as we discussed in the introduction. We now turn to an alternative explanation based on financial constraints and statutory reserve regulation, which is more consistent with the evidence.

3. Statutory Reserve Regulation for Life Insurers

When an insurance company sells an annuity or life insurance policy, its assets increase by the purchase price of the policy. At the same time, the insurance company must record reserves on the liability side of its balance sheet to cover future policy claims. In the United States, the amount of statutory reserves that are required for each type of policy is governed by state law, but all states essentially follow recommended guidelines known as Standard Valuation Law (National Association of Insurance Commissioners, 2011, Appendix A-820). Standard Valuation Law establishes discount rates and mortality tables that are to be used for reserve valuation.

In this section, we review the reserve valuation rules for annuities and life insurance. Because these policies essentially have zero market beta, finance theory implies that the economic value of these policies is determined by the term structure of riskless interest rates. However, Standard Valuation Law requires that the reserve value of these policies be calculated using a mechanical discount rate that is proportional to the Moody's composite yield on seasoned corporate bonds. Insurance companies care about the reserve value of policies insofar as it is used by regulators and rating agencies to determine the adequacy of statutory reserves. For example, a state regulator may force liquidation of an insurance company whose assets are insufficient relative to its statutory reserves. Or a rating agency may downgrade an insurance company whose asset value has fallen relative to its statutory reserves (A.M. Best Company, Inc., 2011, p. 31).

3.1 Term Annuities

Let y_t be the 12-month moving average of the Moody's composite yield on seasoned corporate bonds, over the period ending on June 30 of the issuance year of the policy. Standard Valuation Law specifies the following discount rate for reserve valuation of annuities:

$$\widehat{R}_t - 1 = 0.03 + 0.8(y_t - 0.03), \tag{5}$$

which is rounded to the nearest 25 basis point. This a constant discount rate that is to be applied to all expected future cash flows, regardless of maturity. The exogenous variation in statutory reserve requirements that this mechanical rule generates, both over time and across different types of policies, allows us to identify the shadow cost of financial constraints for life insurers.

Figure 5 reports the time series of the discount rate for annuities, together with the 10-year zero-coupon Treasury yield. The discount rate for annuities has generally declined over the last 20 years as nominal interest rates have fallen. However, the discount rate for annuities has declined more slowly than the 10-year Treasury yield. This means that statutory reserve requirements for annuities have become looser over time because a high discount rate implies low reserve valuation.

The reserve value of an M-year term annuity per dollar of income is

$$\widehat{V}_t(M) = \sum_{m=1}^{M} \frac{1}{\widehat{R}_t^m}. \tag{6}$$

Figure 6 reports the ratio of reserve to actuarial value for term annuities (i.e., $\widehat{V}_t(M)/V_t(M)$) at maturities of 5 to 30 years. Whenever this ratio is equal to one, the insurance company records a dollar of reserves per dollar of future policy claims in present value. Whenever this ratio is greater than one, the reserve valuation is conservative in the sense that the insurance company records reserves that are greater than the present value of future policy claims. Conversely, whenever this ratio is less than one, the reserve valuation is aggressive in the sense that the insurance company records reserves that are less than the present value of future policy claims.

For the 30-year term annuity, the ratio reaches a peak of 1.20 in November 1994 and a trough of 0.73 in January 2009. If the insurance company were to sell a 30-year term annuity at actuarial value in November 1994, its reserves would increase by $1.20 per dollar of policies sold. This implies a loss of $0.20 in capital surplus funds (i.e., total admitted assets minus total liabilities) per dollar of policies sold. In contrast, if the insurance company were to sell a 30-year term annuity at actuarial value in January 2009, its reserves would only increase by $0.73 per dollar of policies sold. This implies a gain of $0.27 in capital surplus funds per dollar of policies sold.

3.2 Life Annuities

The reserve valuation of life annuities requires mortality tables. The Society of Actuaries produces two versions of mortality tables, which are called basic and loaded. The loaded tables, which are used for reserve valuation, are conservative versions of the basic tables that underestimate the mortality rates. The loaded tables ensure that insurance companies have adequate reserves, even if actual mortality rates turn out to be lower than those projected by the basic tables. For calculating the reserve value, we use the 1983 Annuity Mortality Table prior to December 2000, and the 2000 Annuity Mortality Table since December 2000.

Let $\widehat{p}_n$ be the one-year survival probability at age n, and let N be the maximum attainable age according to the appropriate loaded mortality table. The reserve value of a life annuity at age n per dollar of income is

$$\widehat{V}_t(n) = \sum_{m=1}^{N-n} \frac{\prod_{l=0}^{m-1} \widehat{p}_{n+l}}{\widehat{R}_t^m}, \tag{7}$$

where the discount rate is given by equation (5). Similarly, the reserve value of an M-year guaranteed annuity at age n per dollar of income is

$$\widehat{V}_t(n, M) = \sum_{m=1}^{M} \frac{1}{\widehat{R}_t^m} + \sum_{m=M+1}^{N-n} \frac{\prod_{l=0}^{m-1} \widehat{p}_{n+l}}{\widehat{R}_t^m}. \tag{8}$$

Figure 6 reports the ratio of reserve to actuarial value for life annuities, 10-year guaranteed annuities, and 20-year guaranteed annuities for males aged 50 to 80 (every 10 years in between). For these life annuities, the time-series variation in the ratio of reserve to actuarial value is quite similar to that for term annuities. In particular, the ratio reaches a peak in November 1994 and a trough in January 2009. Since the reserve valuation of term annuities depends only on the discount rates, the similarity with term annuities implies that discount rates, rather than mortality tables, have a predominant effect on the reserve valuation of life annuities.

3.3 Life Insurance

Let y_t be the minimum of the 12-month and the 36-month moving average of the Moody's composite yield on seasoned corporate bonds, over the period ending on June 30 of the year prior to issuance of the policy. Standard Valuation Law specifies the following discount rate for reserve valuation of life insurance:

$$\widehat{R}_t(M) - 1 = 0.03 + w(M)(\min\{y_t, 0.09\} - 0.03) + 0.5w(M)(\max\{y_t, 0.09\} - 0.09), \tag{9}$$

which is rounded to the nearest 25 basis point. The weighting function for a policy with a term of M years is

$$w(M) = \begin{cases} 0.50 & \text{if } M \leq 10 \\ 0.45 & \text{if } 10 < M \leq 20 \\ 0.35 & \text{if } M > 20 \end{cases} . \tag{10}$$

As with life annuities, the American Society of Actuaries produces basic and loaded mortality tables for life insurance. The loaded tables, which are used for reserve valuation, are conservative versions of the basic tables that overestimate the mortality rates. The loaded tables ensure that insurance companies have adequate reserves, even if actual mortality rates turn out to be higher than those projected by the basic tables. For calculating the reserve value, we use the 2001 Commissioners Standard Ordinary Mortality Table. The reserve value of life insurance at age n per dollar of death benefit is

$$\widehat{V}_t(n) = \left(1 + \sum_{m=1}^{N-n-1} \frac{\prod_{l=0}^{m-1} \widehat{p}_{n+l}}{\widehat{R}_t(N-n)^m}\right)^{-1} \left(\sum_{m=1}^{N-n} \frac{\prod_{l=0}^{m-2} \widehat{p}_{n+l}(1-\widehat{p}_{n+m-1})}{\widehat{R}_t(N-n)^m}\right). \tag{11}$$

Figure 7 reports the ratio of reserve to actuarial value for universal life insurance for males aged 30 to 60 (every 10 years in between). In a period of few months around January 2009, the reserve value falls significantly relative to actuarial value. As shown in Figure 5, this is caused by the fact that the discount rate for life insurance stays constant during this period, while the 10-year Treasury yield falls significantly. If an insurance company were to sell universal life insurance to a 30-year old male in January 2009, its reserves would only increase by \$0.87 per dollar of policies sold. This implies a gain of \$0.13 in capital surplus funds per dollar of policies sold.

4. Insurance Pricing under Statutory Reserve Regulation

We now develop a simple model to show how financial constraints and statutory reserve regulation can affect insurance prices.

4.1 An Insurance Company's Profit Maximization Problem

An insurance company sells I different types of annuity and life insurance policies, which we index as $i = 1, \ldots, I$. These policies are differentiated not only by term, but also by sex and age of the insured. The insurance company faces a downward-sloping demand curve $Q_i(P)$ for each policy i, where $Q_i'(P) < 0$. There are various micro-foundations that give rise to such a demand curve. For example, such a demand curve can be motivated as an industry equilibrium subject to search frictions (Hortaçsu and Syverson, 2004). We will simply take the demand curve as exogenously given because the precise micro-foundations are not essential for our purposes.

Let V_i be the actuarial value of policy i. The insurance company chooses the price P_i for each type of policy to maximize profits:

$$\Pi = \sum_{i=1}^{I} (P_i - V_i) Q_i(P_i). \tag{12}$$

A simple way to interpret this profit function is that for each type of policy that the insurance company sells for P_i, it can pay V_i to buy a portfolio of zero-coupon Treasury bonds that replicate the expected future policy claims. For term annuities, this interpretation is exact in the sense that there is no uncertainty regarding future policy claims. For life annuities and life insurance, we assume that the insured pools are sufficiently large for the law of large numbers to apply.

We now describe how the sale of new policies affects the insurance company's balance sheet. Let A_- be its assets prior to the sale of new policies (but after external sources of financing such as capital injection from the holding company). Its assets after the sale of new policies is

$$A = A_- + \sum_{i=1}^{I} P_i Q_i(P_i). \tag{13}$$

As explained in Section 3, the insurance company must also record reserves on the liability side of its balance sheet. Let $\widehat{V}_i$ be the reserve value of policy i. Let $\widehat{L}_-$ be its statutory reserves prior to the sale of new policies. Its statutory reserves after the sale of new policies is

$$\widehat{L} = \widehat{L}_- + \sum_{i=1}^{I} \widehat{V}_i Q_i(P_i). \tag{14}$$

The insurance company faces a leverage constraint on the value of its statutory reserves relative to its assets. Consequently, the insurance company maximizes its profits subject to the constraint that

$$\frac{\widehat{L}}{A} \leq \phi, \tag{15}$$

where $\phi \leq 1$ is the maximum leverage ratio. The underlying assumption is that exceeding the maximum leverage ratio leads to bad consequences, such as forced liquidation by state regulators or a rating downgrade.

4.2 Optimal Insurance Pricing

Let $\lambda \geq 0$ be the Lagrange multiplier on the leverage constraint (15). The Lagrangian for the insurance company's maximization problem is

$$\begin{aligned}\mathcal{L} =& \Pi + \lambda \left(\phi A - \widehat{L}\right) \\ =& \sum_{i=1}^{I} (P_i - V_i) Q_i(P_i) + \lambda \left[\phi \left(A_- + \sum_{i=1}^{I} P_i Q_i(P_i)\right) - \left(\widehat{L}_- + \sum_{i=1}^{I} \widehat{V}_i Q_i(P_i)\right)\right]. \end{aligned} \tag{16}$$

The first-order condition for each policy i is

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial P_i} =& \frac{\partial \Pi}{\partial P_i} + \lambda \frac{\partial \left(\phi A - \widehat{L}\right)}{\partial P_i} \\ =& Q_i(P_i) + (P_i - V_i) Q_i'(P_i) + \lambda \left[\phi Q_i(P_i) + \left(\phi P_i - \widehat{V}_i\right) Q_i'(P_i)\right] \\ =& 0. \end{aligned} \tag{17}$$

Rearranging equation (17), the price of policy i is

$$P_i = V_i \left(1 - \frac{1}{\epsilon_i}\right)^{-1} \left(\frac{1 + \lambda \widehat{V}_i / V_i}{1 + \lambda \phi}\right), \tag{18}$$

where

$$\epsilon_i = -\frac{P_i Q_i'(P_i)}{Q_i(P_i)} > 1 \tag{19}$$

is the elasticity of demand. Moreover, the Lagrange multiplier is

$$\lambda = -\frac{\partial \Pi}{\partial \left(\phi A - \widehat{L}\right)}. \tag{20}$$

Note that $\phi A - \widehat{L}$ can be interpreted as the excess reserves of the insurance company. Hence, the Lagrange multiplier measures the dollar losses that the insurance company is willing to take in order to increase its excess reserves by a dollar.

Suppose the leverage constraint does not bind (i.e., $\lambda = 0$). Then the price of policy i is

$$P_i = V_i \left(1 - \frac{1}{\epsilon_i}\right)^{-1}. \tag{21}$$

This is the standard Bertrand price of the policy, which is equal to marginal cost plus a markup that arises from imperfect competition. Now suppose that the leverage constraint binds (i.e., $\lambda > 0$). Then the price of policy i is

$$P_i \gtrless V_i \left(1 - \frac{1}{\epsilon_i}\right)^{-1} \text{ if } \frac{\widehat{V}_i}{V_i} \gtrless \phi. \tag{22}$$

When the leverage constraint binds, the price of the policy is higher than the Bertrand price if issuing the policy tightens the leverage constraint on the margin. Conversely, the price of the policy is lower than the Bertrand price if issuing the policy relaxes the leverage constraint.

When the leverage constraint binds, equation (18) and the leverage constraint (i.e., $\phi A = \widehat{L}$) forms a system of $I + 1$ equations in $I + 1$ unknowns (i.e., P_i for each policy $i = 1, \ldots, I$ and λ). Solving this system of equations for the Lagrange multiplier,

$$\lambda = \frac{1}{\phi} \left(\frac{\sum_i \left(\phi V_i (1 - 1/\epsilon_i)^{-1} - \widehat{V}_i\right) Q_i - \widehat{L}_- + \phi A_-}{\widehat{L}_- - \phi A_- - \sum_i \widehat{V}_i (\epsilon_i - 1)^{-1} Q_i} \right). \tag{23}$$

To understand the intuition for this expression, consider the limiting case of perfectly elastic demand. The limit as $\epsilon_i \to \infty$ for all policies is

$$\lambda \to \frac{1}{\phi} \left(\frac{\sum_i \left(\phi V_i - \widehat{V}_i\right) Q_i}{\widehat{L}_- - \phi A_-} - 1 \right). \tag{24}$$

This expression shows that the Lagrange multiplier depends on the product of two terms. The first term says that the Lagrange multiplier is inversely related to the targeted leverage ratio. The second term says that the Lagrange multiplier is proportional to the marginal increase in excess reserves from selling new policies as a percentage of the initial shortfall in excess reserves.

5. Estimating the Shadow Cost of Financial Constraints

In this section, we use our structural model of insurance pricing to estimate the shadow cost of the leverage constraint. Before doing so, we first present reduced-form evidence that is consistent with a key prediction of the model. Namely, the price cuts were deeper for those insurance companies that experienced more adverse balance sheet shocks just prior to January 2009, which are presumably the companies for which the leverage constraint was more binding.

5.1 Price Changes versus Balance Sheet Shocks

Figure 8 gives an overview of how the balance sheet has evolved over time for the cross section of insurance companies in our data. From 1989 through 2010, assets grew by 3 to 14 percent per year for the median insurance company. The only exception to this growth is 2008 when assets shrank by 3 percent for the median insurance company. The leverage ratio stays remarkably constant between 0.91 and 0.95 throughout this period, including 2008 when the leverage ratio was 0.93 for the median insurance company (Berry-Stölzle, Nini, and Wende, 2011).

Figure 9 is a scatter plot of the percentage change in annuity prices between January 2008 and 2009 versus asset growth from end of fiscal year 2007 to 2008. The four panels represent term annuities, life annuities, and 10- and 20-year guaranteed annuities. In each panel, the 13 dots represent the insurance companies in our sample in January 2009. The linear regression line shows that there is a strong positive relation between annuity price changes and asset growth. That is, the price cuts were deeper for those insurance companies that experienced more adverse balance sheet shocks just prior to January 2009.

Our joint interpretation of Figures 8 and 9 is that insurance companies were able to maintain a low leverage ratio in 2008 and 2009 by taking advantage of statutory reserve regulation that allowed them to record far less than a dollar of reserves per dollar of future insurance liability. The incentive to discount prices was stronger for those insurance companies that experienced more adverse balance sheet shocks and, therefore, had a higher need to recapitalize.

5.2 Empirical Specification

Let i index the type of policy, j index the insurance company, and t index time. Based on equation (18), we model the markup as a nonlinear regression model:

$$\log\left(\frac{P_{i,j,t}}{V_{i,j,t}}\right) = -\log\left(1 - \frac{1}{\epsilon_{i,j,t}}\right) + \log\left(\frac{1 + \lambda_{j,t}\widehat{V}_{i,t}/V_{i,t}}{1 + \lambda_{j,t}\widehat{L}_{j,t}/A_{j,t}}\right) + e_{i,j,t}, \tag{25}$$

where $e_{i,j,t}$ is an error term with conditional mean zero. This empirical specification makes it clear that the Lagrange multiplier is primarily identified by cross-sectional variation in the ratio of reserve to actuarial value across different types of policies. As reported in Table 1, the data for most types of annuities are not available prior to July 1998. We therefore estimate our pricing model on the sample from July 1998 through July 2011.

We model the elasticity of demand as

$$\epsilon_{i,j,t} = 1 + \exp\{-\beta' X_{i,j,t}\}, \tag{26}$$

where $X_{i,j,t}$ is a vector of policy and insurance company characteristics. In our baseline specification, the policy characteristics are sex and age. The insurance company characteristics are the A.M. Best rating, the leverage ratio, asset growth, and log assets. We also include a full set of time dummies to control for any variation in the elasticity of demand over the business cycle. We interact each of these variables, including the time dummies, with dummy variables that allow their impact on the elasticity of demand to differ across term annuities, life annuities, and life insurance.

In theory, the Lagrange multiplier depends only on insurance company characteristics that appear in equation (23). However, most of these characteristics do not have obvious counterparts in the data except for ϕ, which is equal to the leverage ratio when the constraint binds (i.e., $\phi = \widehat{L}/A$). Therefore, we model the Lagrange multiplier as

$$\lambda_{j,t} = \exp\{-\gamma' Z_{j,t}\}, \tag{27}$$

where $Z_{j,t}$ is a vector of insurance company characteristics. In our baseline specification, the insurance company characteristics are the leverage ratio and asset growth. Our use of asset growth is motivated by the reduced-form evidence in Figure 8. We also include a full set of time dummies and their interaction with insurance company characteristics to allow for the fact that the leverage constraint may only bind at certain times.

5.3 Empirical Findings

Table 2 reports our estimates for the elasticity of demand in the nonlinear regression model (25). Instead of reporting the raw coefficients (i.e., β), we report the average marginal effect of the explanatory variables on the markup. The average markup on policies sold by A or A− rated insurance companies is 3.13 percentage points higher than that for policies sold by A++ or A+ rated companies. The leverage ratio and asset growth have a relatively small economic impact on the markup through the elasticity of demand. Every one percentage point increase in the leverage ratio is associated with a 6 basis point increase in the markup. Every one percentage point increase in asset growth is associated with a 4 basis point increase in the markup.

Figure 10 reports the time series for the shadow cost of the leverage constraint for the average insurance company in our data. The leverage constraint does not bind for most of the sample period. There is evidence that the leverage constraint was binding around January 2001 with a point estimate of $0.79 per dollar of excess reserves. The leverage constraint was clearly binding in January 2009 with a point estimate of $4.58 per dollar of excess reserves. The 95 percent confidence interval ranges from $2.78 to $6.39 per dollar of excess reserves.

In Table 3, we report the shadow cost of the leverage constraint for the cross section of insurance companies in our data that sold annuities in January 2009. The table shows that there is considerable heterogeneity in the shadow cost of the leverage constraint. The shadow cost is positively related to the leverage ratio and negatively related to asset growth. In January 2009, MetLife was the most constrained insurance company with a shadow cost of $13.38 per dollar of excess reserves. Metlife had a relatively high leverage ratio of 0.97 at the end of 2008 and suffered a balance sheet loss of 10 percent from the end of 2007 to 2008. American General Life Insurance Company was the least constrained insurance company with a shadow cost of $1.41 per dollar of excess reserves.

6. Conclusion

This paper shows that financial constraints and the regulation of statutory reserves have a large and measurable impact on insurance prices. More broadly, this paper provides micro evidence for a class of macro models based on financial frictions, which is a leading explanation for the Great Recession (see Gertler and Kiyotaki, 2010; Brunnermeier, Eisenbach, and Sannikov, 2012, for recent reviews of the literature). We feel that this literature would benefit from further empirical investigation on the cost of these frictions (i.e., structural estimates of the Lagrange multiplier) in other parts of the financial sector, such as banking and health insurance.

We also feel that further work is necessary on the optimal regulation of statutory reserves. The current regulation causes the statutory reserve requirement to vary arbitrarily, both over time and across different types of policies. While this exogenous variation is useful for identifying the shadow cost of the leverage constraint, it does not seem optimal from the perspective of insurance regulation. In the context of our model (18), a simple reserve rule that achieves price stability is to set the reserve value equal to the targeted leverage ratio times the actuarial value (i.e., $\widehat{V}_i = \phi V_i$). Under this reserve rule, the insurance price would always be the Bertrand price (21), even when the leverage constraint binds. Although this simple rule may not be the socially optimal policy in a fully specified model, it seems like a good starting point for thinking about optimal regulation.

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Table 1: Summary Statistics for Annuity and Life Insurance Prices

Markup is defined as the logarithmic percentage deviation of the quoted price from the actuarial value. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. The sample is semiannual from January 1989 through July 2011.

		Number of		Markup		
Policy	Sample starts in	Observations	Insurance companies	Mean	Median	Standard deviation
Term annuities:						
5-year	January 1993	732	83	6.7	6.5	8.4
10-year	January 1989	988	98	6.9	7.0	5.9
15-year	July 1998	418	62	4.3	4.8	5.6
20-year	July 1998	414	62	3.8	4.4	6.6
25-year	July 1998	339	53	3.4	3.7	7.5
30-year	July 1998	325	50	2.9	2.8	8.8
Life annuities:						
Life only	January 1989	11,879	106	9.8	9.8	8.2
10-year guaranteed	July 1998	7,885	66	5.5	6.1	7.0
20-year guaranteed	July 1998	7,518	66	4.2	4.8	7.5
Universal life insurance	January 2005	3,989	52	-4.2	-5.5	17.9

Table 2: Structural Model of Insurance Pricing

This table reports the average marginal effect of the explanatory variables on the markup through the elasticity of demand in percentage points. The model for the elasticity of demand also includes time dummies and its interaction effects for life annuities and life insurance, which are omitted in this table for brevity. The omitted categories for the dummy variables are term annuities, A++ or A+ rated, male, and age 50. The t-statistics, reported in parentheses, are based on robust standard errors clustered by insurance company, type of policy, sex, and age. The sample is semiannual from July 1998 through July 2011.

Explanatory variable	Average marginal effect	
Rating: A to A−	3.13	(17.69)
Rating: B++ to B−	9.16	(13.28)
Leverage ratio	6.13	(23.55)
Asset growth	3.91	(15.08)
Log assets	2.31	(40.53)
Interaction effects for life annuities:		
Rating: A to A−	-2.26	(-17.94)
Rating: B++ to B−	-8.77	(-11.02)
Leverage ratio	16.88	(26.27)
Asset growth	-5.58	(-19.58)
Log assets	-1.89	(-44.69)
Female	0.27	(10.18)
Age 55	0.25	(1.74)
Age 60	0.60	(3.90)
Age 65	0.83	(11.94)
Age 70	1.14	(10.25)
Age 75	1.45	(2.99)
Age 80	1.80	(10.60)
Age 85	2.36	(10.41)
Age 90	3.28	(6.58)
Interaction effects for life insurance:		
Rating: A to A−	-23.21	(-5.12)
Leverage ratio	21.78	(3.02)
Asset growth	-30.05	(-5.27)
Log assets	-13.21	(-7.36)
Female	0.18	(1.03)
Age 30	2.38	(0.21)
Age 40	0.62	(0.03)
Age 60	0.18	(0.00)
Age 70	0.64	(0.31)
Age 80	0.65	(0.27)
Age 90	24.12	(4.74)
R^2 (percent)	48.51	
Observations	29,570	

Table 3: Shadow Cost of the Leverage Constraint in January 2009

This table reports the shadow cost of the leverage constraint for the cross section of insurance companies in our data that sold annuities in January 2009, implied by our estimated strutural model of insurance pricing.

Insurance company	A.M. Best rating	Leverage ratio	Asset growth	Shadow cost of excess reserves
MetLife Investors USA Insurance Company	A+	0.97	-0.10	13.38
Allianz Life Insurance Company of North America	A	0.97	-0.03	10.47
Lincoln Benefit Life Company	A+	0.87	-0.45	8.76
OM Financial Life Insurance Company	A-	0.95	-0.04	8.31
Aviva Life and Annuity Company	A	0.95	0.12	4.44
Presidential Life Insurance Company	B+	0.91	-0.06	4.33
EquiTrust Life Insurance Company	B+	0.95	0.13	4.12
Integrity Life Insurance Company	A+	0.92	0.03	3.85
United of Omaha Life Insurance Company	A+	0.91	-0.03	3.65
Genworth Life Insurance Company	A	0.90	0.00	3.13
North American Company for Life and Health Insurance	A+	0.94	0.24	2.44
American National Insurance Company	A	0.87	-0.02	1.84
American General Life Insurance Company	A	0.87	0.05	1.41

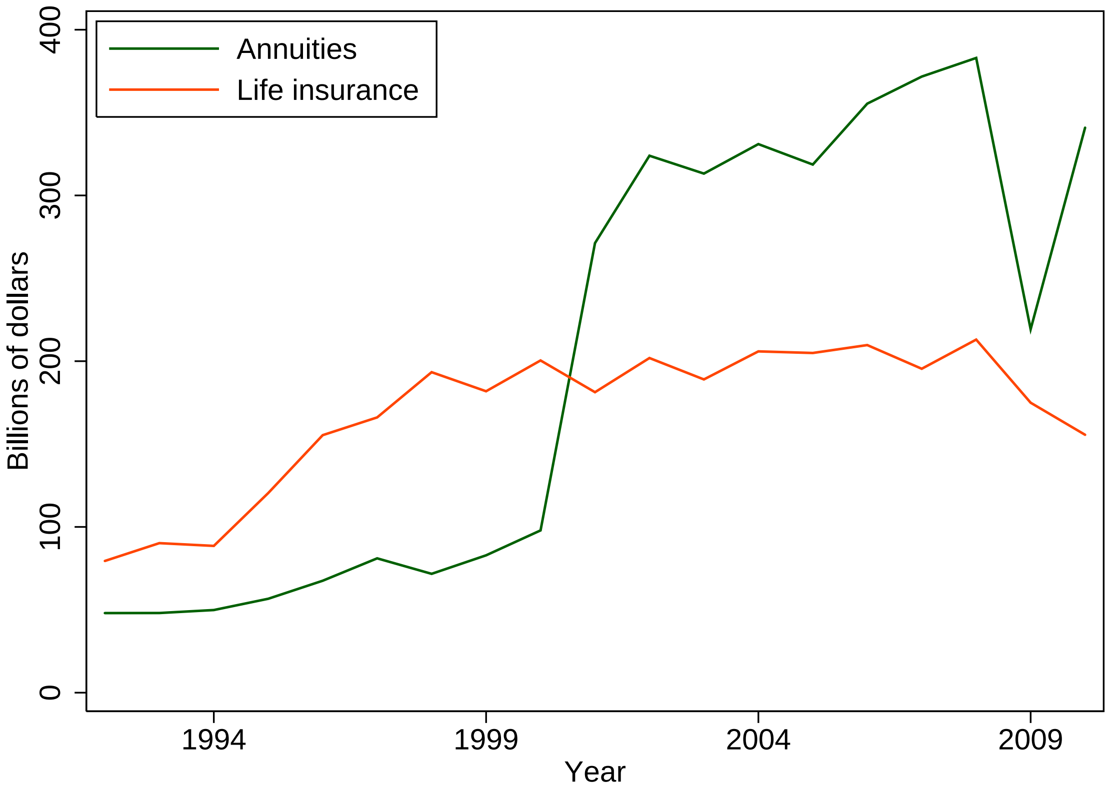

Figure 1: Annual Premiums for Individual Annuities and Life Insurance
This figure reports the total annual premiums paid for individual annuities and life insurance, summed across all insurance companies in the *Best's Insurance Reports*. The sample is from fiscal year 1992 through 2010.

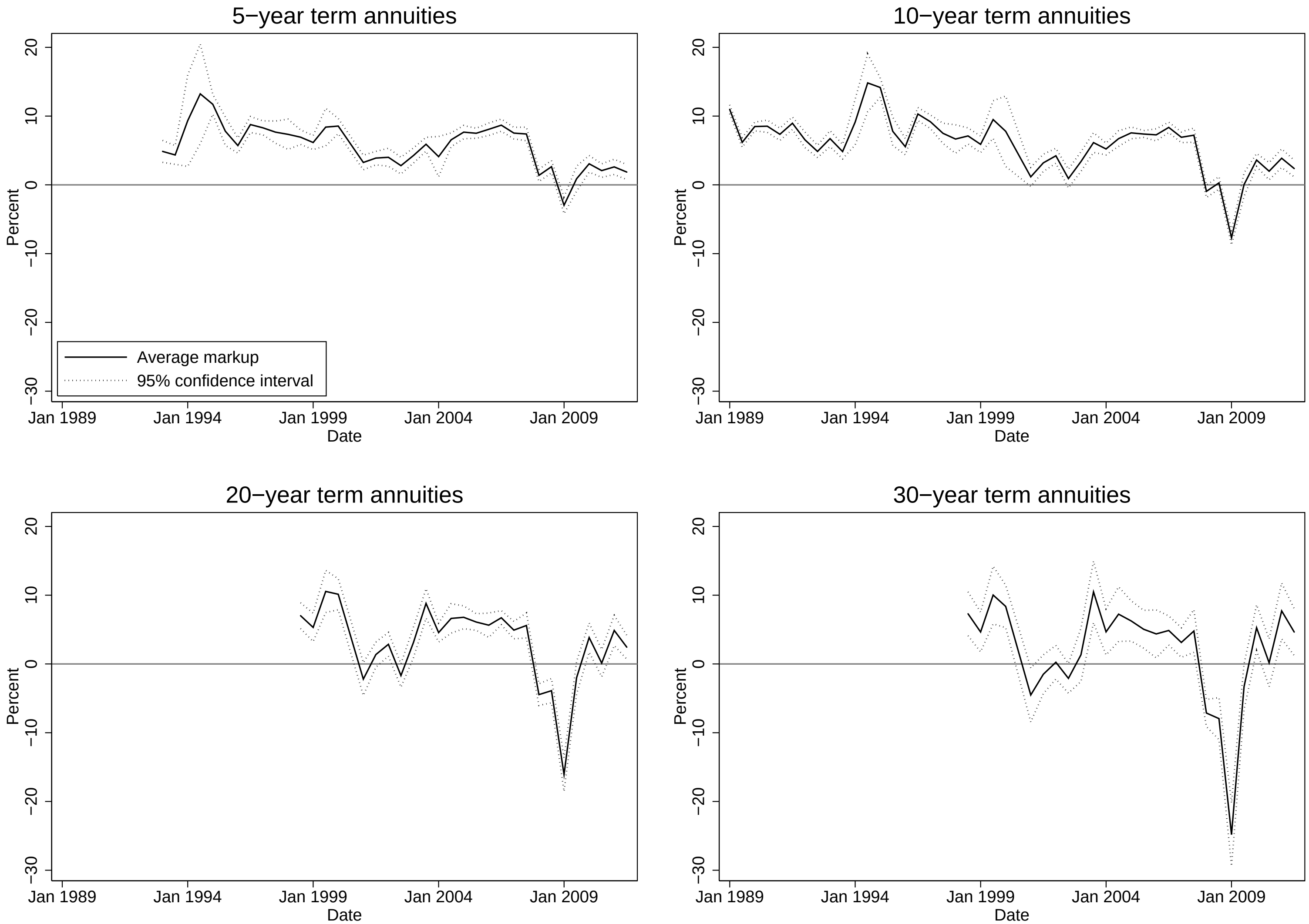

Figure 2: Average Markup of Term Annuities

Markup is defined as the logarithmic percentage deviation of the quoted price from the actuarial value. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. Average markup is estimated from a regression of markups onto dummy variables for A.M. Best rating and time. The figure reports the conditional mean for policies sold by A++ and A+ rated companies. The confidence interval is based on robust standard errors clustered by insurance company. The sample is semiannual from January 1989 through July 2011.

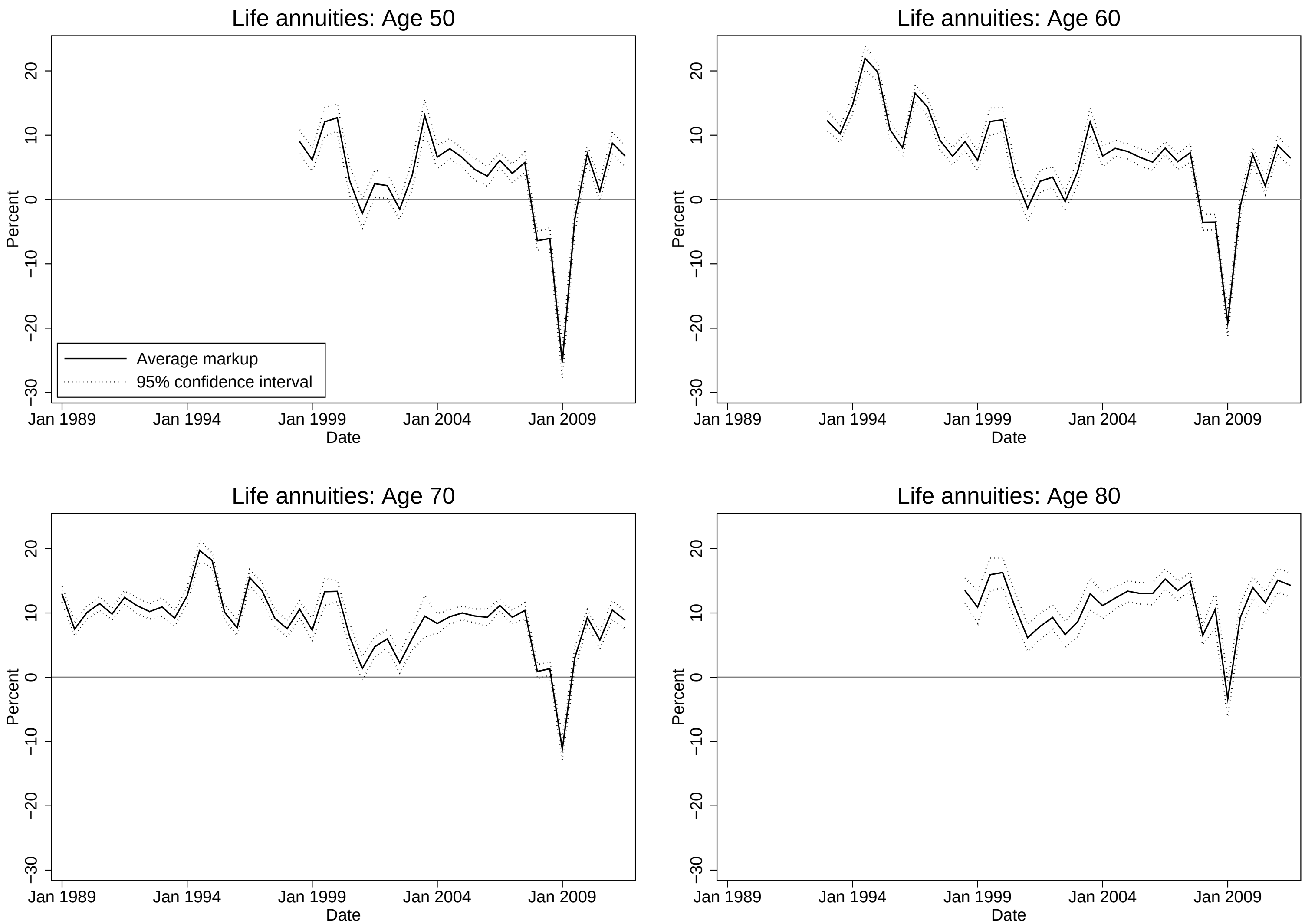

Figure 3: Average Markup of Life Annuities

Markup is defined as the logarithmic percentage deviation of the quoted price from the actuarial value. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. Average markup is estimated from a regression of markups onto dummy variables for A.M. Best rating, sex, and time. The figure reports the conditional mean for male policies sold by A++ and A+ rated companies. The confidence interval is based on robust standard errors clustered by insurance company, sex, and age. The sample is semiannual from January 1989 through July 2011.

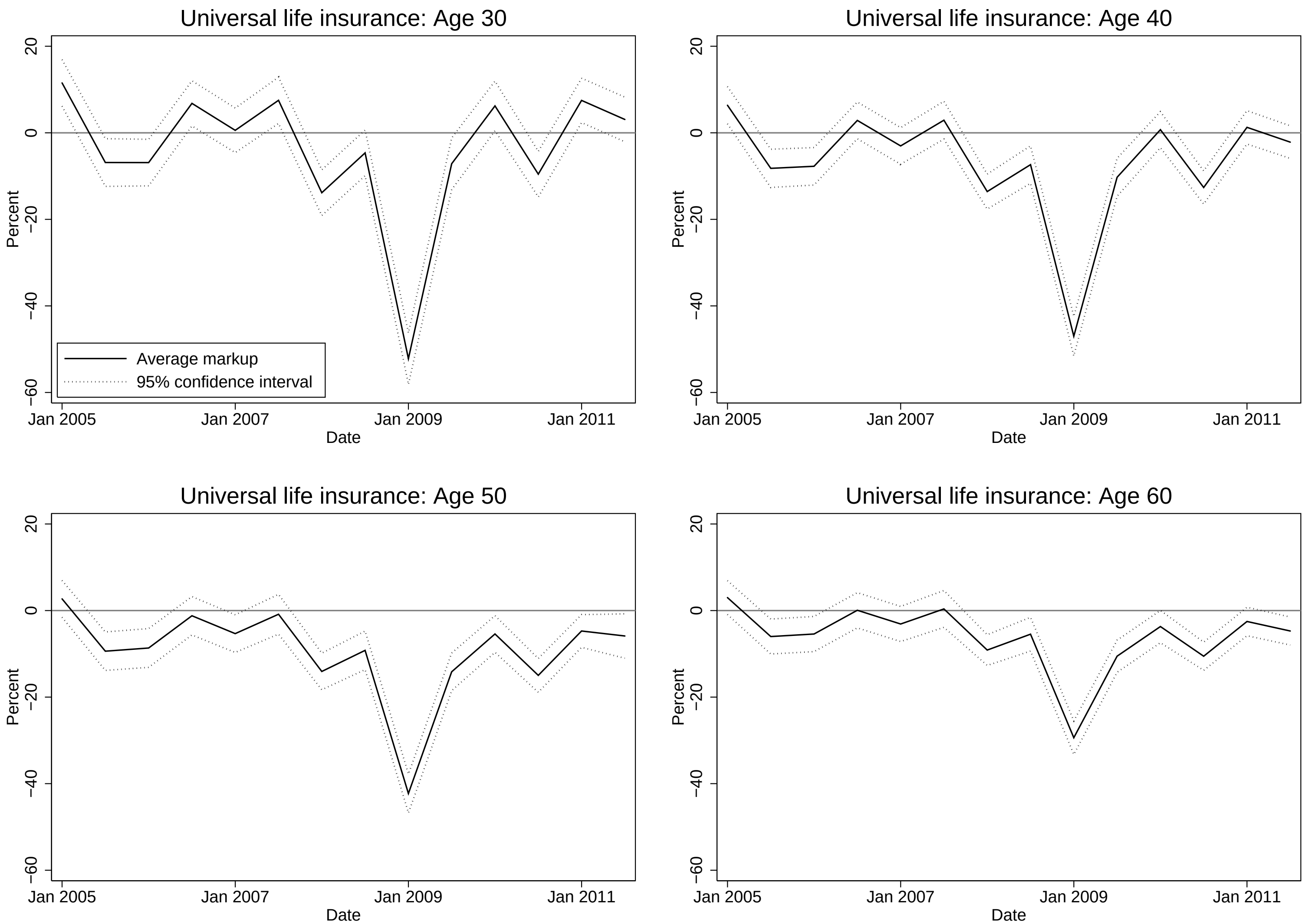

Figure 4: Average Markup of Universal Life Insurance

Markup is defined as the logarithmic percentage deviation of the quoted price from the actuarial value. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. Average markup is estimated from a regression of markups onto dummy variables for A.M. Best rating, sex, and time. The figure reports the conditional mean for male policies sold by A++ and A+ rated companies. The confidence interval is based on robust standard errors clustered by insurance company, sex, and age. The sample is semiannual from January 2004 through July 2011.

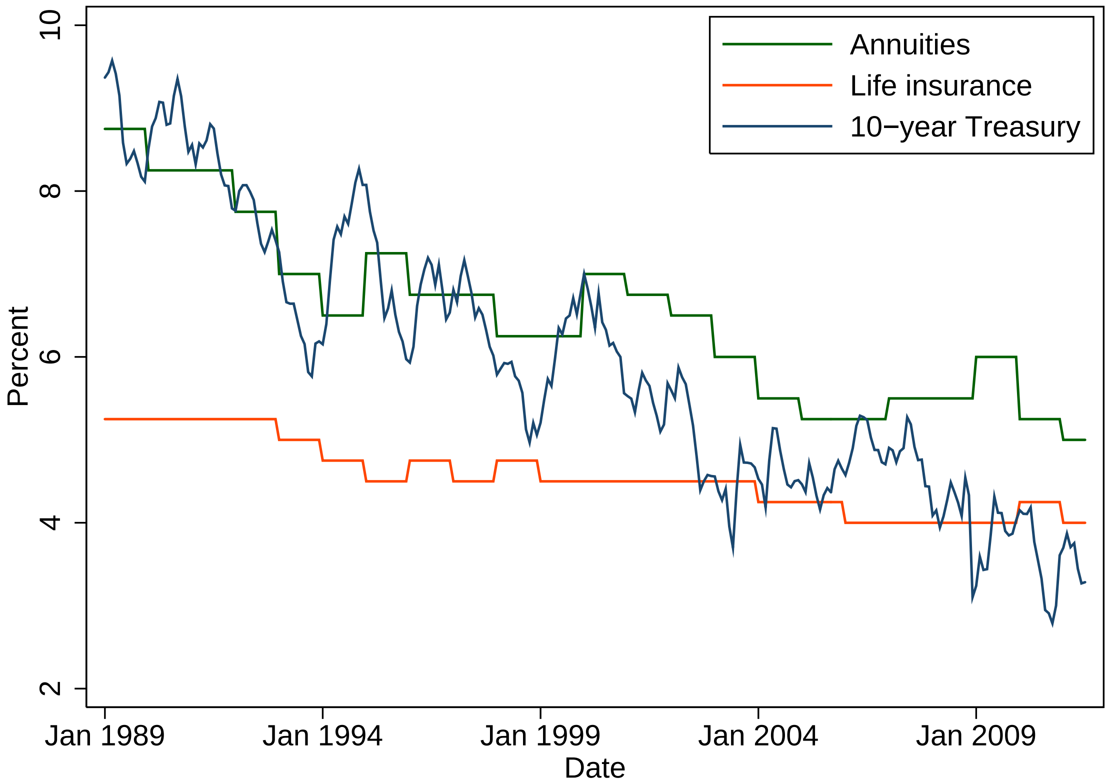

Figure 5: Discount Rates for Annuities and Life Insurance
This figure reports the discount rates used for statutory reserve valuation of annuities and life insurance (with term greater than 20 years), together with the 10-year zero-coupon Treasury yield. The sample is monthly from January 1989 through July 2011.

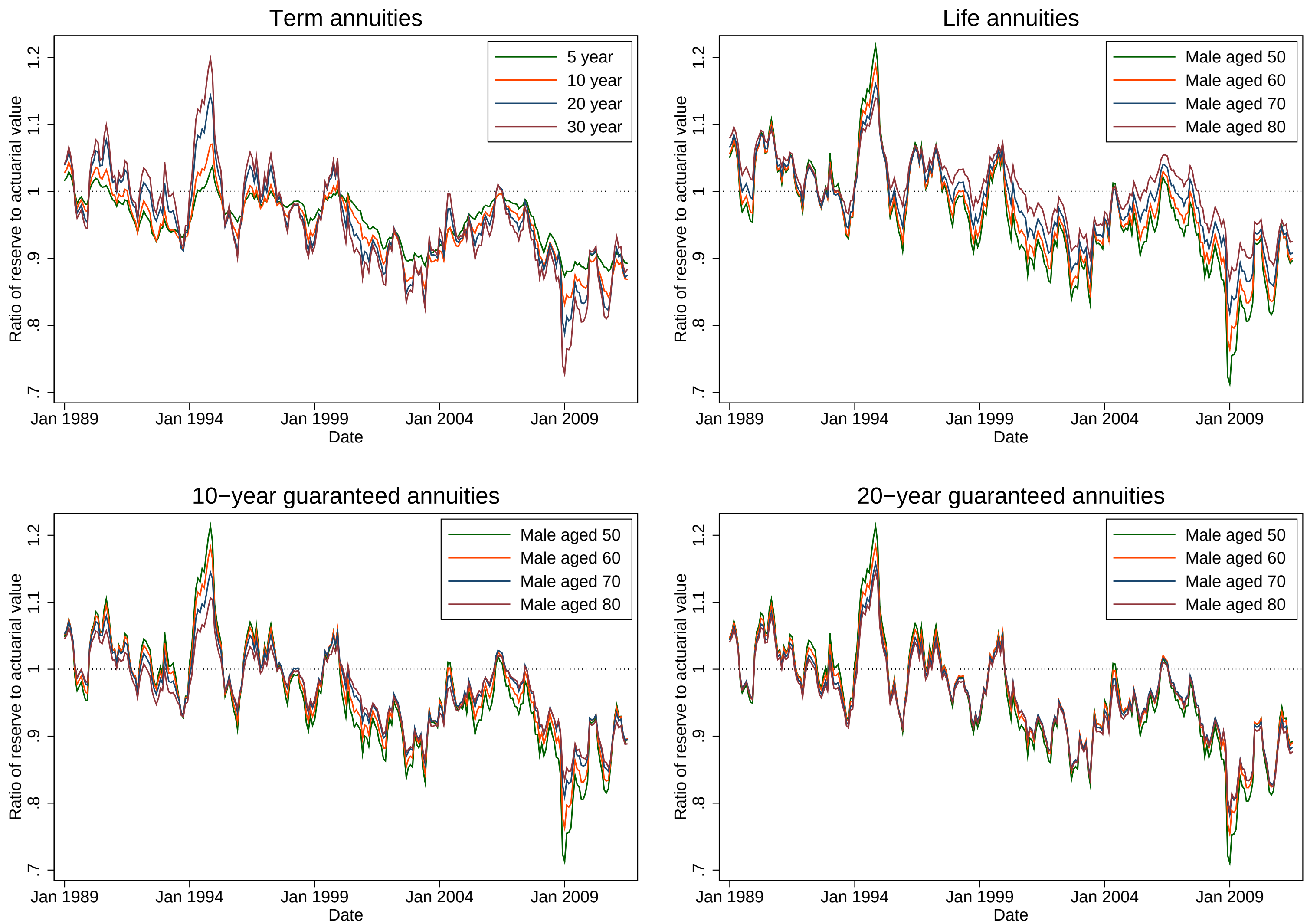

Figure 6: Reserve to Actuarial Value for Annuities

This figure reports the ratio of reserve value to actuarial value for various types of annuities. The reserve value is calculated using the appropriate loaded life table from the American Society of Actuaries and the discount rate specified by Standard Valuation Law. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. The sample is monthly from January 1989 through July 2011.

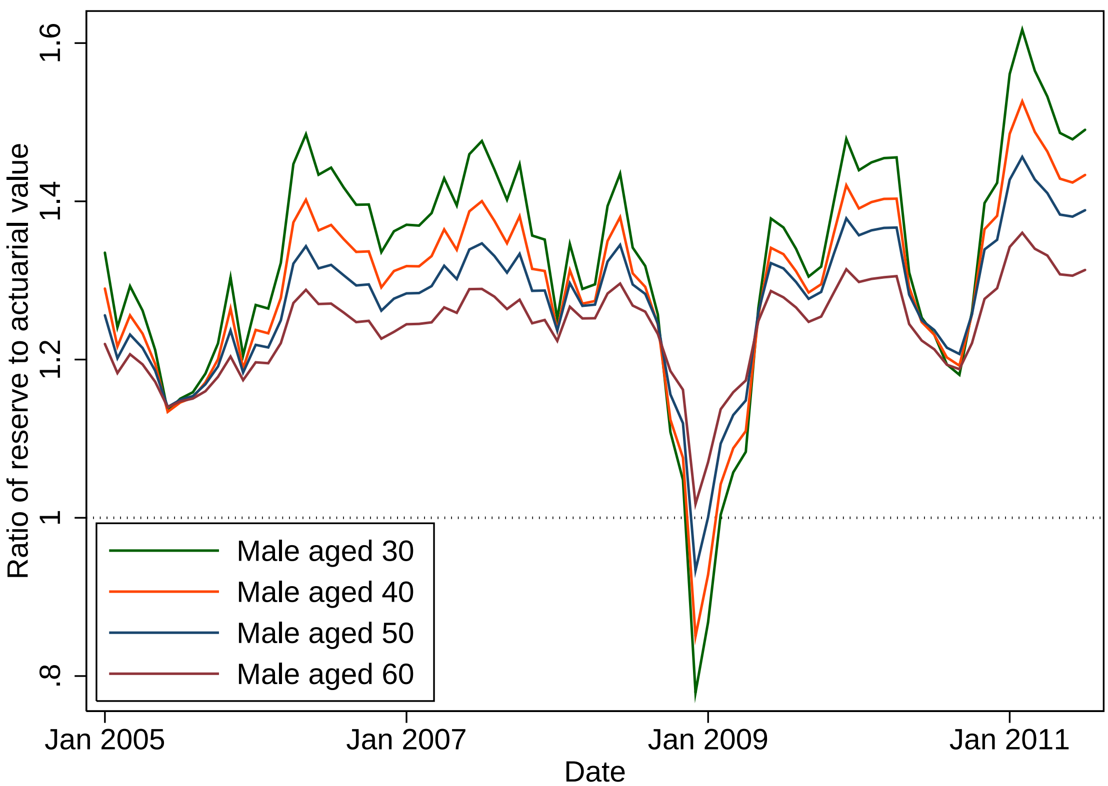

Figure 7: Reserve to Actuarial Value for Universal Life Insurance
This figure reports the ratio of reserve value to actuarial value for universal life insurance. The reserve value is calculated using the appropriate loaded life table from the American Society of Actuaries and the discount rate specified by Standard Valuation Law. The actuarial value is calculated using the appropriate basic life table from the American Society of Actuaries and the zero-coupon Treasury yield curve. The sample is monthly from January 2005 through July 2011.

Figure 8: Asset Growth and the Leverage Ratio for Life Insurers
This figure reports the median of the growth rate of total admitted assets and the leverage ratio for the cross section of insurance companies in our data. The leverage ratio is the ratio of total liabilities to total admitted assets. The sample is from fiscal year 1989 through 2010.

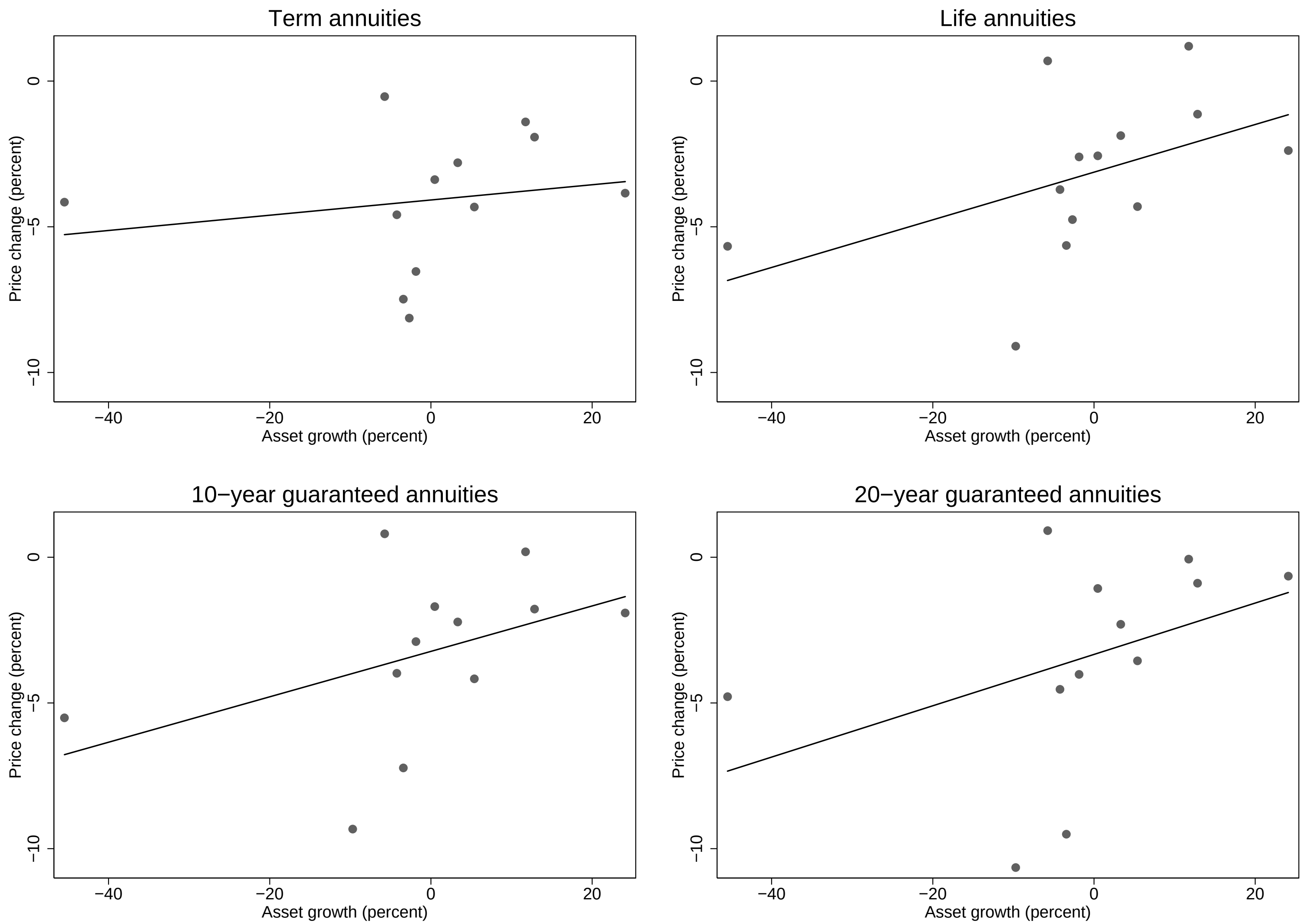

Figure 9: Price Change versus Asset Growth in January 2009

Price change is the logarithmic percentage change from January 2008 to January 2009. Asset growth is the logarithmic percentage change from fiscal year 2008 to 2009. For term annuities, the average price change is estimated from a regression of the price change onto dummy variables for maturity and insurance company. The figure reports the conditional mean for 30-year term policies. For life annuities, the average price change is estimated from a regression of the price change onto dummy variables for sex, age, and insurance company. The figure reports the conditional mean for male policies at age 50.

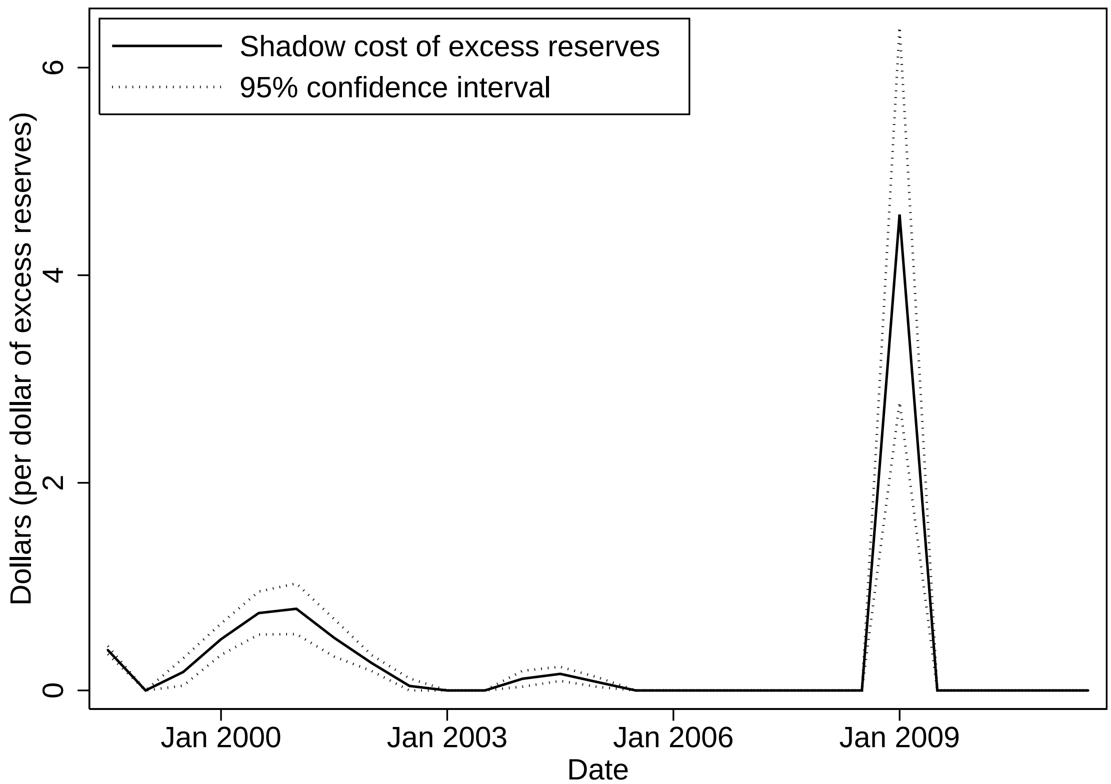

Figure 10: Shadow Cost of the Leverage Constraint
This figure reports the shadow cost of the leverage constraint for the average insurance company, implied by our estimated strutural model of insurance pricing. The confidence interval is based on robust standard errors clustered by insurance company, type of policy, sex, and age. The sample is semiannual from July 1998 through July 2011.