UNDERSTANDING THE OWNERSHIP STRUCTURE OF CORPORATE BONDS

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<u>ABSTRACT</u>

Insurers are the largest institutional investors of corporate bonds. However, a standard theory of insurance markets, in which insurers maximize firm value subject to regulatory or risk constraints, predicts no allocation to corporate bonds. We resolve this puzzle in an equilibrium asset pricing model with leverage-constrained households and institutional investors. Insurers have relatively cheap access to leverage through their underwriting activity. They hold a leveraged portfolio of low-beta assets in equilibrium, relaxing other investors' leverage constraints. The model explains recent empirical findings on insurers' portfolio choice and its impact on asset prices.

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The corporate bond market plays an essential role in the funding of corporations. Unsurprisingly, fluctuations in corporate bond prices are strongly related to investment (Philippon, 2009) and economic activity more broadly (Gilchrist and Zakrajsek, 2012). Since 1945, US corporate bonds have been held primarily through institutional investors rather than directly by households, and insurers have accounted for the largest share of institutional ownership. In this paper, we study the ownership structure of corporate bonds with a focus on the central role of insurers.

We start by summarizing the ownership structure of corporate bonds and the composition of insurers' bond portfolios. In 2017, insurers owned 38 percent of US corporate bonds, which was the largest share among institutional investors. An important fact is that both life insurers and property and casualty insurers allocate a larger share of their portfolio to corporate bonds than Treasury bonds, and this portfolio tilt has strengthened over time. Within the corporate bond portfolio, insurers tilt toward highly rated bonds relative to the market portfolio and thus have a preference for low-beta assets. The allocation to corporate bonds leads to credit risk mismatch because traditional liabilities are not sensitive to credit risk. Moreover, variable annuities, which are life insurers' largest liability, are exposed to equity risk that is positively correlated with credit risk (Koijen and Yogo, 2022).

The fact that insurers take on credit risk is puzzling from the perspective of a standard theory of insurance markets, in which insurers maximize firm value subject to a risk-based capital or value-at-risk constraint (Gron, 1990; Froot, 2001; Koijen and Yogo, 2015). On the one hand, allocation to riskier assets requires additional capital and tightens the risk-based capital constraint. On the other hand, allocation to riskier assets has no benefit to shareholders if financial markets are efficient, so that risk-adjusted expected returns are equated across assets. Therefore, the theory predicts that insurers hold riskless bonds to minimize the impact on risk-based capital.

The main contribution of this paper is to develop an equilibrium asset pricing model that resolves the puzzle by predicting that insurers hold low-beta assets such as investment-grade corporate bonds. Households buy annuities to insure idiosyncratic longevity risk and save the remaining wealth in a portfolio of risky assets subject to a leverage constraint. Insurers invest the annuity premiums in a portfolio of risky assets and a riskless asset subject to a risk-based capital constraint. Other institutional investors also choose between risky assets and a riskless asset subject to a leverage constraint.

The presence of leverage constraints implies an important deviation from the Capital Asset Pricing Model (CAPM). The CAPM predicts that an asset's expected excess return is equal to the expected excess market return times its beta (i.e., the covariance of an asset's returns with market returns divided by the variance of market returns). The empirical relation between average excess returns and betas is weaker than the theoretical prediction, meaning that the slope is

actually less than the average excess market return. Thus, low-beta assets earn positive alpha (i.e., high risk-adjusted expected returns) and high-beta assets earn negative alpha relative to the CAPM. Leverage constraints are a potential explanation for this "low-beta anomaly" (Black, 1972; Frazzini and Pedersen, 2014).

In this environment, insurers maximize firm value by holding a leveraged portfolio of low-beta assets. Households and institutional investors cannot replicate the insurers' portfolio due to leverage constraints and instead hold the insurers' equity, which is equivalent to a highly leveraged portfolio of low-beta assets. This result holds even when capital regulation is not sensitive to risk. When capital regulation is sensitive to risk, the demand for low-beta assets strengthens. The model provides a unifying explanation of recent empirical findings on insurers' portfolio choice and its impact on asset prices (Ellul et al., 2011; Ge and Weisbach, 2021; Becker et al., 2022). We conclude the paper by discussing potential extensions.

This paper is part of a growing literature on intermediary asset pricing. The theoretical literature studies the impact of institutional investors' agency frictions or leverage constraints on asset prices. The empirical literature focuses on frictions in a particular sector, such as risk factors that arise from broker-dealers' leverage constraints (Adrian et al., 2014; He et al., 2017). We study the important role of insurers among other institutional investors who are subject to leverage constraints. A key implication of the model is that insurers hold low-beta assets in response to the leverage constraints of other institutional investors.

I.   Facts about the Ownership Structure of Corporate Bonds

A.   *Institutional Ownership of Corporate Bonds*

Figure 1 shows the institutional ownership of US corporate bonds from 1945 to 2017. Insurers have always been the largest institutional investors of corporate bonds and thus play a central role in corporate funding and investment. In 2017, insurers owned 38 percent of corporate bonds, which is higher than 16 percent for pension funds, 10 percent for banks, and 30 percent for mutual funds.

B.   *Insurers' Bond Portfolios*

Figure 2 shows the bond holdings of life insurers and property and casualty insurers from 1994 to 2019. We focus on insurers' bond holdings because their equity holdings tend to be small, which can be partly explained by the high capital requirements on equities. We break down the bond holdings into US Treasury bonds, US agency bonds, publicly traded corporate bonds, other US government bonds, local and foreign government bonds, and private corporate bonds. The first three categories represent publicly traded and non-asset-backed securities with coverage in Mergent (2021).

Life insurers hold most of their portfolio in publicly traded and private corporate bonds instead of Treasury bonds. In the 1990s, property and casualty insurers
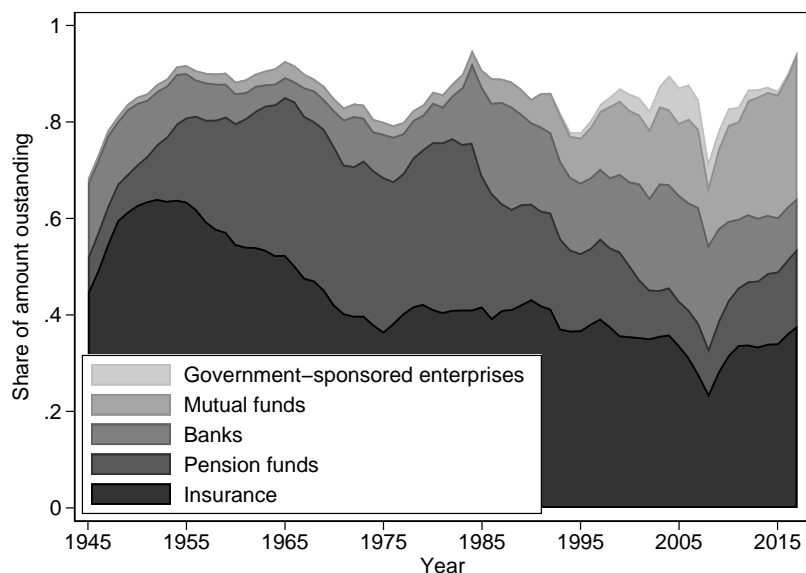
held a larger share of their portfolio in Treasury bonds than publicly traded corporate bonds, but this relation has reversed in recent years. In 2019, property and casualty insurers held 9 percent of their portfolio in Treasury bonds and 31 percent in publicly traded corporate bonds. Because insurers' liabilities are not directly exposed to credit risk, corporate bond holdings introduce credit risk mismatch.

Figure 3 shows the corporate bond portfolios of life insurers and property and casualty insurers by National Association of Insurance Commissioners (NAIC) designation from 1994 to 2019. The NAIC designates assets into six categories based on credit ratings, where NAIC 1 corresponds to the lowest risk and NAIC 6 corresponds to the highest risk. For perspective, the figure also shows the market portfolio weights for the universe of corporate bonds that are held by the insurance sector. Life insurers hold NAIC 1 bonds close to market weights but overweight NAIC 2 bonds. Property and casualty insurers overweight NAIC 1 bonds but hold NAIC 2 bonds close to market weights. Both life insurers and property and casualty insurers underweight corporate bonds that are NAIC 3 and below. Insurers tilt toward highly rated corporate bonds relative to the market portfolio and thus have a preference for low-beta assets.

Figure 3 shows that the distribution of corporate bonds has shifted from NAIC 1 to NAIC 2 as credit risk has increased after the global financial crisis. From
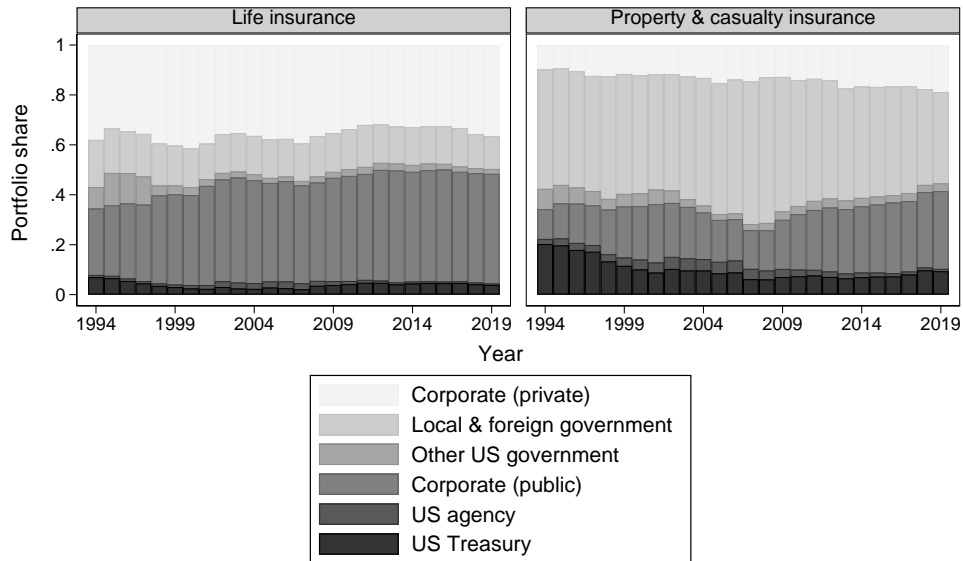
FIGURE 2. PORTFOLIO COMPOSITION

Note: The long-term bond holdings are from the National Association of Insurance Commissioners (1994–2019, Schedule D Part 1). The bottom three categories (US Treasury, US agency, and publicly traded corporate bonds) represent publicly traded and non-asset-backed securities with coverage in Mergent (2021). The top three categories include asset-backed securities, mortgage-backed securities, and private placement bonds.

2007 to 2019, the market portfolio weight has decreased by 8 percentage points in NAIC 1, has increased by 13 percentage points in NAIC 2, and has decreased by 5 percentage points in NAIC 3 and below. During the same period, life insurers have decreased their allocation to NAIC 1 by 4 percentage points, have increased their allocation to NAIC 2 by 7 percentage points, and have decreased their allocation to NAIC 3 and below by 3 percentage points. Property and casualty insurers have decreased their allocation to NAIC 1 by 10 percentage points, have increased their allocation to NAIC 2 by 12 percentage points, and have decreased their allocation to NAIC 3 and below by 2 percentage points. The growth of the NAIC 2 share (particularly the BBB-rated bonds) exposes insurers to the risk of a large-scale credit migration, in which these bonds are downgraded from investment to speculative grade.

Figure 4 shows the credit risk of bond portfolios for life insurers and property and casualty insurers from 1994 to 2019. We quantify credit risk by mapping credit ratings to ten-year cumulative default rates and computing the weighted average for the overall portfolio. This calculation is based on a sample of US Treasury, US agency, and corporate bonds that are publicly traded and not asset-backed. We assume that Treasury and agency bonds have no default risk for
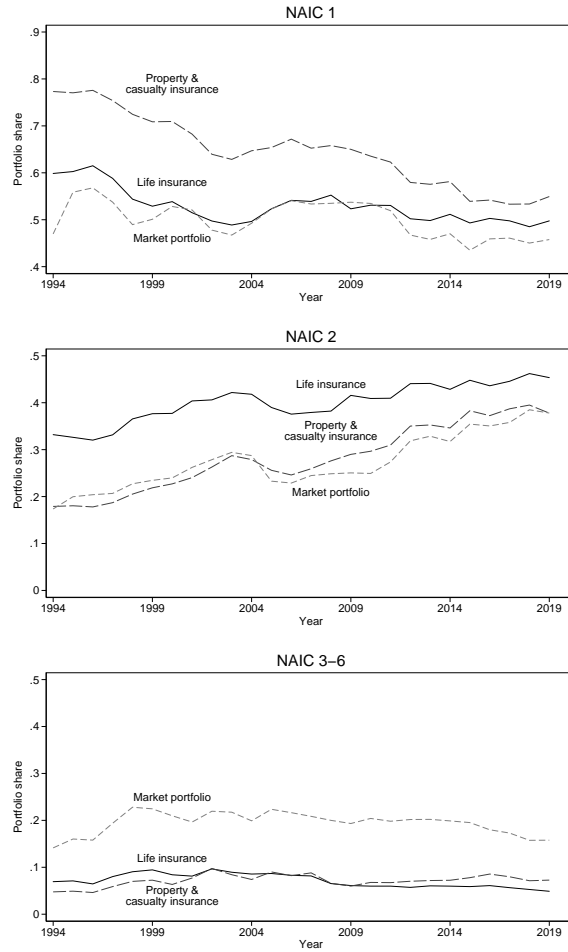
FIGURE 3. CORPORATE BOND PORTFOLIO COMPOSITION

Note: This figure shows the corporate bond portfolio share by NAIC designation for life insurers and property and casualty insurers. It also shows the market portfolio weights for the universe of corporate bonds that are held by the insurance sector. The long-term bond holdings are from the National Association of Insurance Commissioners (1994–2019, Schedule D Part 1). The sample consists of corporate bonds in Mergent (2021) that are publicly traded and not asset-backed.

the purposes of this calculation. Thus, the overall credit risk depends on the allocation to corporate bonds and the portfolio choice across rating categories within corporate bonds.

For life insurers, the weighted average ten-year cumulative default rate is stable at 2 to 4 percent, which reflects the stable allocation to corporate bonds in Figure 2. Figure 3 shows that the portfolio share increased for NAIC 2 and decreased for NAIC 3 and below from 2007 to 2019. The combination of these off-

FIGURE 4. CREDIT RISK OF BOND PORTFOLIOS

Note: This figure shows the weighted average ten-year cumulative default rate of bond portfolios for life insurers and property and casualty insurers. The long-term bond holdings are from the National Association of Insurance Commissioners (1994–2019, Schedule D Part 1). The sample consists of US Treasury, US agency, and corporate bonds in Mergent (2021) that are publicly traded and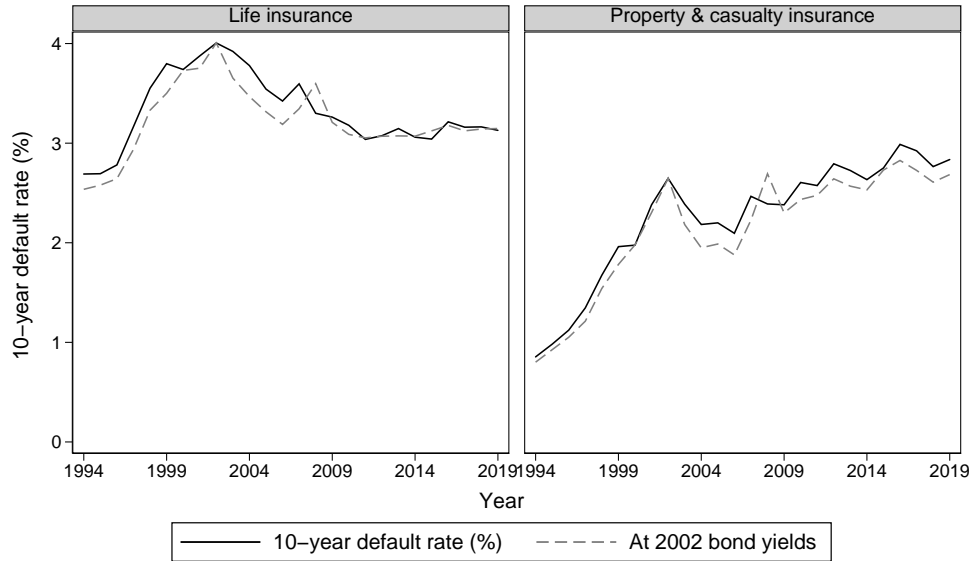 not asset-backed. The ten-year cumulative default rate is assigned to each bond based on the median of its S&P, Moody's, and Fitch rating. An alternative calculation of the weighted average ten-year cumulative default rate fixes bond yields by maturity and credit rating to their values in 2002.

setting trends implies that the weighted average default rate has remained nearly constant after the global financial crisis.

For property and casualty insurers, the weighted average ten-year cumulative default rate increased from 0.9 percent in 1994 to 2.8 percent in 2019. This increase in credit risk is due to the shift from Treasury bonds to corporate bonds in Figure 2 and the shift from NAIC 1 to NAIC 2 in Figure 3. Property and casualty insurers have always taken less credit risk than life insurers, presumably because of the less predictable nature of their liabilities with tail risk. However, the difference in the level of credit risk between life insurers and property and casualty insurers is not a focus of this paper.

In summary, there are two important facts about insurers' bond portfolios that the model in Section III explains. First and most importantly, both life insurers and property and casualty insurers allocate a large share of their portfolio to corporate bonds with credit risk. This fact is puzzling from the perspective of a standard theory of insurance markets as we explain in Section II. Second, the credit risk of life insurers' bond portfolios has decreased relative to that of

property and casualty insurers after the global financial crisis. In Section IV, we discuss a potential connection between this trend in relative credit risk, the low interest rate environment, and financial frictions in the life insurance sector.

II. A Portfolio Puzzle for Insurers

In a standard theory of insurance markets, insurers maximize firm value subject to a risk-based capital or value-at-risk constraint (Gron, 1990; Froot, 2001; Koijen and Yogo, 2015). Let us introduce portfolio choice under the null hypothesis that financial markets are efficient and that insurers have no special ability to earn alpha. Then the insurer cannot affect firm value through portfolio choice because all portfolios have the same risk-adjusted expected value. In the absence of risk-based capital regulation, the optimal portfolio is indeterminate. In the presence of risk-based capital regulation, the optimal portfolio consists of only riskless bonds.

This prediction is inconsistent with the fact that insurers take credit risk and incur risk charges by allocating a larger share of their portfolio to corporate bonds than Treasury bonds. The literature proposes several resolutions to this puzzle. Chodorow-Reich et al. (2021) propose that the same asset has a higher value when held by insurers, which is an arbitrage opportunity from the insurers' perspective. Knox and Sørensen (2020) propose that insurers have a comparative advantage in earning a liquidity premium on corporate bonds and mortgage-backed securities (MBSs) because of their long-term liability structure. In general, insurers may have market power or may be able to take advantage of mispricing in some markets because of their long-term liability structure. An interesting empirical question is whether insurers have a special ability to earn alpha beyond the standard anomalies such as the low-beta anomaly.

Another potential resolution is to modify the insurer's objective function, following the literature on intermediary asset pricing with value-at-risk constraints (Adrian and Shin, 2014; Coimbra and Rey, 2017). For example, Ellul et al. (2018) assume that insurers maximize expected value instead of risk-adjusted expected value. Although this model may explain portfolio choice, other decisions such as product pricing and capital structure may be more puzzling when insurers maximize expected value.

We propose a different resolution that does not rely on special ability or a different objective function. We introduce insurers to a standard asset pricing model with leverage constraints. An important insight is that insurers are highly leveraged institutions that have relatively cheap access to leverage through their underwriting activity. Therefore, insurers have a comparative advantage in holding a leveraged portfolio of low-beta assets and earn a positive alpha in equilibrium. Thus, insurers play an important role in financial markets by relaxing the leverage constraints of households and other institutional investors.

III. Asset Pricing with an Insurance Sector

We develop an asset pricing model with three types of investors: households, insurers, and other institutional investors (e.g., mutual funds, hedge funds, and pension funds). Households and institutional investors are subject to leverage constraints. Each investor chooses a portfolio of risky assets and a riskless asset in period 0, and the assets pay terminal dividends in period 1. We assume that each investor type is composed of a continuum of atomistic investors, so that investors do not account for price impact in choosing their portfolio.

Insurers have market power and earn profits by selling annuities to households at a markup. They also choose a portfolio of risky assets and a riskless asset subject to a risk-based capital constraint. In equilibrium, insurers derive their value from three sources. The first source is high expected returns on low-beta assets because households and institutional investors are leverage constrained. The second source is the cost of regulatory frictions due to the risk-based capital constraint. The third source is the underwriting profits that arise from market power.

In the notation that follows, bold letters denote vectors and matrices. Let $\mathbf{0}$ be a vector of zeros, and $\mathbf{1}$ be a vector of ones. Let $\mathbf{1}_n$ be a vector whose nth element is one and the other elements are zeros. Let $\mathrm{diag}(\cdot)$ be a diagonal matrix (e.g., $\mathrm{diag}(\mathbf{1})$ is the identity matrix).

A. Financial Assets

Riskless Asset

All investors can hold a riskless asset with gross interest R_f from period 0 to 1.

Annuities

Households do not have a bequest motive and survive in period 1 with probability π. Households can buy annuities from insurers in period 0 to insure longevity risk.[1] Annuities have a gross return of zero conditional on death and

$$(1) \qquad R_L = \frac{1}{P_L} = \left(1 - \frac{1}{\epsilon}\right)\frac{R_f}{\pi}$$

conditional on survival. P_L is the annuity price in period 0 per unit of death benefit. Insurers have market power and price annuities accounting for the demand elasticity $\epsilon > 1$. We assume that the demand elasticity is sufficiently high so that $R_L > R_f$. That is, annuities strictly dominate the riskless asset for households without bequest motives.

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[1] We could modify the model so that some households have a bequest motive, which generates a demand for life insurance. Similarly, a tax advantage could generate additional demand for annuities.

Insurers potentially face two sources of risk. The first source is idiosyncratic longevity risk from annuities. We assume that the insured pool is sufficiently large for the law of large numbers to apply. Alternatively, insurers can perfectly diversify longevity risk through a state guaranty association. The second source is systematic risk from portfolio choice. We assume that the insurers' dividends can be negative to ensure full payment of annuity claims. Thus, annuities are riskless from the households' perspective.

Risky Assets

Insurers pay out dividends d_I in period 1, which is endogenously determined by their optimal portfolio choice in period 0. Other firms pay exogenous dividends $\mathbf{d}$ in period 1, where each element of the N-dimensional vector corresponds to a firm's dividend. The dividends have a factor structure:

$$(2) \qquad \mathbf{d} = \mathbb{E}[\mathbf{d}] + \boldsymbol{\beta} F + \boldsymbol{\nu},$$

where $\boldsymbol{\beta} > \mathbf{0}$ is a vector of factor loadings. The common factor F has the moments $\mathbb{E}[F] = 0$ and $\mathrm{Var}(F) = \sigma_F^2$. The vector of idiosyncratic shocks has the moments $\mathbb{E}[\boldsymbol{\nu}] = \mathbf{0}$ and $\mathrm{Var}(\boldsymbol{\nu}) = \mathrm{diag}(\boldsymbol{\sigma}_\nu^2)$, where $\boldsymbol{\sigma}_\nu^2$ is a vector of idiosyncratic variance. Thus, the covariance matrix of dividends is

$$(3) \qquad \mathrm{Var}(\mathbf{d}) = \sigma_F^2 \boldsymbol{\beta}\boldsymbol{\beta}' + \mathrm{diag}(\boldsymbol{\sigma}_\nu^2).$$

We stack the dividends of insurers and other firms in a vector as $\mathbf{D} = (\mathbf{d}', d_I)'$. We denote the moments of dividends as $\boldsymbol{\mu} = \mathbb{E}[\mathbf{D}]$ and $\boldsymbol{\Sigma} = \mathrm{Var}(\mathbf{D})$. We denote the price of risky assets in period 0 as p_I for insurers, $\mathbf{p}$ for other firms, and $\mathbf{P} = (\mathbf{p}', p_I)'$. We normalize the supply of all risky assets to one unit.

B.   Insurers

Insurers allocate their assets to $\mathbf{X}_I = (\mathbf{x}_I', 0)'$ units of risky assets, where the last element is zero under the assumption that insurers cannot invest in other insurers. Insurers are subject to risk-based capital regulation that limits risk-shifting motives that could arise from limited liability and the presence of state guaranty associations.[2] We assume that the NAIC designation (i.e., 1 through 6) increases in beta, so that riskier assets require more capital.[3] Let $\exp(\phi\boldsymbol{\beta})$ be a diagonal matrix of risk weights with nth diagonal element $\exp(\phi\beta(n))$. We define

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[2] As we discuss in Koijen and Yogo (2022), we could equivalently formulate the model with an economic risk constraint, such as a value-at-risk constraint.

[3] We abstract from the fact that the NAIC designation does not perfectly correspond to credit risk for corporate bonds (Becker and Ivashina, 2015) or MBSs (Becker et al., 2022).

required capital as

$$(4) \qquad \sqrt{\mathbf{x}_I' \exp(\phi\boldsymbol{\beta})\mathbf{x}_I} = \sqrt{\sum_{n=1}^{N} \exp(\phi\beta(n))x_I(n)^2}.$$

We assume that the cost of regulatory frictions is a quadratic function of required capital:

$$(5) \qquad C(\mathbf{x}_I) = \frac{\mathbf{x}_I' \exp(\phi\boldsymbol{\beta})\mathbf{x}_I}{2}.$$

The assumption that the matrix of risk weights is diagonal ignores the impact of correlation between assets on required capital. The parameter $\phi \geq 0$ captures the interaction between the riskiness of assets and liabilities. Insurers with riskier liabilities (e.g., variable annuities) have higher values of ϕ. Thus, the marginal impact of holding riskier assets is greater for insurers with riskier liabilities.

Insurers have initial equity E and sell Q units of annuities to households at the price P_L. The insurers' assets in period 0 are

$$(6) \qquad A_{I,0} = E - C(\mathbf{x}_I) + P_L Q.$$

Insurers pay out their equity in period 1 as dividends. The dividends are equal to the gross return on their assets minus the annuity claims:

$$(7) \qquad \begin{aligned} d_I &= \mathbf{d}'\mathbf{x}_I + R_f(A_{I,0} - \mathbf{p}'\mathbf{x}_I) - \pi Q \\ &= \mathbf{d}'\mathbf{x}_I + R_f(E - C(\mathbf{x}_I) - \mathbf{p}'\mathbf{x}_I) + (R_f P_L - \pi)Q, \end{aligned}$$

where the second equality follows from substituting equation (6).

The last term of equation (7) represents the underwriting profits, which insurers maximize by choosing the annuity price P_L. The price and the quantity of annuities enter equation (7) only through the underwriting profits, which are known in period 0. We differentiate the underwriting profits with respect to P_L to derive the optimal annuity price. Equation (1) is the resulting expression for the optimal annuity price with $\epsilon = -\partial \log(Q)/\partial \log(P_L)$.

Substituting equation (1) in equation (7), the dividends are

$$(8) \qquad d_I = \mathbf{d}'\mathbf{x}_I + R_f(E - C(\mathbf{x}_I) - \mathbf{p}'\mathbf{x}_I) + \frac{\pi Q}{\epsilon - 1}.$$

If insurers were to hold only the riskless asset, their dividends would be the riskless return on their initial equity plus the underwriting profits (i.e., $d_I = R_f E + \pi Q/(\epsilon - 1)$).

C. Portfolio-Choice Problem

Households

Households allocate initial wealth $A_{H,0}$ to $\mathbf{X}_H$ units of risky assets and Q units of annuities subject to the budget constraint:

$$(9) \qquad\qquad A_{H,0} = \mathbf{P}'\mathbf{X}_H + P_L Q.$$

Conditional on survival, their wealth in period 1 is

$$(10) \qquad\qquad
\begin{aligned}
A_{H,1} =& \mathbf{D}'\mathbf{X}_H + Q \\
=& \mathbf{D}'\mathbf{X}_H + R_L(A_{H,0} - \mathbf{P}'\mathbf{X}_H),
\end{aligned}$$

where the second equality follows from equation (9) and $P_L = 1/R_L$.

In the absence of bequest motives, households have mean-variance preferences over wealth conditional on survival:

$$(11) \qquad\qquad \mathbb{E}[A_{H,1}] - \frac{\gamma_H}{2}\mathrm{Var}(A_{H,1}),$$

where $\gamma_H > 0$ is risk aversion. Households choose $\mathbf{X}_H$ to maximize this objective function subject to the intertemporal budget constraint (10) and a leverage constraint:

$$(12) \qquad\qquad \mathbf{P}'\mathbf{X}_H \leq A_{H,0}.$$

This leverage constraint implies that households cannot short annuities.

Institutional Investors

There are J types of institutional investors, indexed as $j = 1, \ldots, J$. For example, there are mutual funds, hedge funds, pension funds, and so on. Institutional investors allocate their initial wealth $A_{j,0}$ to $\mathbf{X}_j$ units of risky assets and the remainder in the riskless asset. Their wealth in period 1 is

$$(13) \qquad\qquad A_{j,1} = \mathbf{D}'\mathbf{X}_j + R_f(A_{j,0} - \mathbf{P}'\mathbf{X}_j).$$

Institutional investors have mean-variance preferences over wealth:

$$(14) \qquad\qquad \mathbb{E}[A_{j,1}] - \frac{\gamma_j}{2}\mathrm{Var}(A_{j,1}),$$

where $\gamma_j > 0$ is risk aversion. Institutional investors choose $\mathbf{X}_j$ to maximize this objective function subject to the intertemporal budget constraint (13) and a

leverage constraint:

$$(15) \qquad \mathbf{P}'\mathbf{X}_j \leq \frac{A_{j,0}}{\omega_j}.$$

The leverage constraint limits risk-shifting motives that could arise from limited liability and moral hazard. In practice, margin requirements operate as a leverage constraint. The parameter $\omega_j > 0$ captures the tightness of the leverage constraint, which could be heterogeneous across investors.

D. Optimal Portfolio Choice

We solve the model in three steps. First, we solve the portfolio-choice problem for households and institutional investors. Second, we impose market clearing to solve for asset prices conditional on the insurers' portfolio. Finally, we solve the insurers' portfolio-choice problem that maximizes firm value.

HOUSEHOLDS

The Lagrangian for the households' portfolio-choice problem is

$$(16) \qquad \begin{aligned} \mathcal{L}_H &= \mathbb{E}[A_{H,1}] - \frac{\gamma_H}{2}\mathrm{Var}(A_{H,1}) + \lambda_H(A_{H,0} - \mathbf{P}'\mathbf{X}_H) \\ &= \boldsymbol{\mu}'\mathbf{X}_H + (R_L + \lambda_H)(A_{H,0} - \mathbf{P}'\mathbf{X}_H) - \frac{\gamma_H}{2}\mathbf{X}_H'\boldsymbol{\Sigma}\mathbf{X}_H, \end{aligned}$$

where $\lambda_H \geq 0$ is the Lagrange multiplier on the leverage constraint. The first-order condition implies optimal portfolio choice:

$$(17) \qquad \mathbf{X}_H = \frac{1}{\gamma_H}\boldsymbol{\Sigma}^{-1}(\boldsymbol{\mu} - (R_L + \lambda_H)\mathbf{P}).$$

A binding leverage constraint $\lambda_H > 0$ is equivalent to a higher annuity return, which reduces the allocation to risky assets.

INSTITUTIONAL INVESTORS

The Lagrangian for institution j's portfolio-choice problem is

$$(18) \qquad \begin{aligned} \mathcal{L}_j &= \mathbb{E}[A_{j,1}] - \frac{\gamma_j}{2}\mathrm{Var}(A_{j,1}) + \lambda_j(A_{j,0} - \mathbf{P}'\mathbf{X}_j) \\ &= \boldsymbol{\mu}'\mathbf{X}_j + (R_f + \lambda_j)\left(\frac{A_{j,0}}{\omega_j} - \mathbf{P}'\mathbf{X}_j\right) - \frac{\gamma_j}{2}\mathbf{X}_j'\boldsymbol{\Sigma}\mathbf{X}_j, \end{aligned}$$

where $\lambda_j \geq 0$ is the Lagrange multiplier on the leverage constraint. The first-order condition implies optimal portfolio choice:

$$(19) \qquad \mathbf{X}_j = \frac{1}{\gamma_j}\boldsymbol{\Sigma}^{-1}(\boldsymbol{\mu} - (R_f + \lambda_j)\mathbf{P}).$$

A binding leverage constraint $\lambda_j > 0$ is equivalent to a higher riskless rate, which reduces the allocation to risky assets.

E.   Asset Prices

By market clearing, the sum of the demand across all investors equals supply:

$$(20) \qquad \mathbf{X}_I + \mathbf{X}_H + \sum_{j=1}^{J}\mathbf{X}_j = \mathbf{1}.$$

Substituting the optimal demand of households (17) and institutional investors (19), we have

$$(21) \qquad \mathbf{X}_I + \frac{1}{\gamma}\boldsymbol{\Sigma}^{-1}(\boldsymbol{\mu} - (R + \lambda)\mathbf{P}) = \mathbf{1},$$

where

$$(22) \qquad \frac{1}{\gamma} = \frac{1}{\gamma_H} + \sum_{j=1}^{J}\frac{1}{\gamma_j},$$

$$(23) \qquad R = \frac{\gamma}{\gamma_H}R_L + \sum_{j=1}^{J}\frac{\gamma}{\gamma_j}R_f,$$

$$(24) \qquad \lambda = \frac{\gamma}{\gamma_H}\lambda_H + \sum_{j=1}^{J}\frac{\gamma}{\gamma_j}\lambda_j.$$

Thus, asset prices conditional on the insurers' portfolio are

$$(25) \qquad \mathbf{P} = \frac{1}{R + \lambda}(\boldsymbol{\mu} - \gamma\boldsymbol{\Sigma}(\mathbf{1} - \mathbf{X}_I)).$$

OTHER FIRMS

We break up equation (25) into two blocks, representing the asset prices of other firms and insurers separately. The asset prices of other firms are

$$(26) \qquad \begin{aligned} \mathbf{p} &= \frac{1}{R+\lambda}(\mathbb{E}[\mathbf{d}] - \gamma(\mathrm{Var}(\mathbf{d})(\mathbf{1} - \mathbf{x}_I) + \mathrm{Cov}(\mathbf{d}, d_I))) \\ &= \frac{1}{R+\lambda}(\mathbb{E}[\mathbf{d}] - \gamma\mathrm{Var}(\mathbf{d})\mathbf{1}), \end{aligned}$$

where the second equality uses the definition of the insurers' dividends (8). The insurers' portfolio choice affects the asset prices of other firms only through the aggregate Lagrange multiplier λ. That is, insurers can affect asset prices by relaxing other investors' leverage constraints.

INSURERS

The insurers' equity price is

$$(27) \qquad \begin{aligned} p_I &= \frac{1}{R+\lambda}(\mathbb{E}[d_I] - \gamma(\mathrm{Cov}(\mathbf{d}, d_I)'(\mathbf{1} - \mathbf{x}_I) + \mathrm{Var}(d_I))) \\ &= \frac{1}{R+\lambda}(\mathbb{E}[d_I] - \gamma\mathbf{1}'\mathrm{Var}(\mathbf{d})\mathbf{x}_I). \end{aligned}$$

Substituting the insurers' dividends (8) in this equation, we have

$$(28) \quad p_I = \frac{1}{R+\lambda}\left((\mathbb{E}[\mathbf{d}] - \gamma\mathrm{Var}(\mathbf{d})\mathbf{1} - R_f\mathbf{p})'\mathbf{x}_I + R_f(E - C(\mathbf{x}_I)) + \frac{\pi Q}{\epsilon - 1}\right).$$

Substituting the asset prices of other firms (26) in this equation, we have

$$(29) \qquad p_I = \frac{1}{R+\lambda}\left(\underbrace{\frac{R - R_f + \lambda}{R+\lambda}(\mathbb{E}[\mathbf{d}] - \gamma\mathrm{Var}(\mathbf{d})\mathbf{1})'\mathbf{x}_I}_{\text{portfolio choice}} + \underbrace{R_f(E - C(\mathbf{x}_I))}_{\text{regulatory frictions}} \right.$$

$$\left. + \underbrace{\frac{\pi Q}{\epsilon - 1}}_{\text{underwriting profits}} \right).$$

Equation (29) shows that insurers derive their value from three sources. The first source is the portfolio choice $\mathbf{x}_I$. Suppose that insurance markets are competitive (i.e., $\epsilon \to \infty$) and that there is no longevity risk (i.e., $\pi = 1$). Then the

first term in parentheses simplifies to

$$(30) \qquad \frac{\lambda}{R_f + \lambda}(\mathbb{E}[\mathbf{d}] - \gamma \mathrm{Var}(\mathbf{d})\mathbf{1})' \mathbf{x}_I,$$

which increases in the tightness of the leverage constraints as captured by λ. Holding the insurers' equity is equivalent to holding a highly leveraged portfolio of the assets that insurers hold. Insurers maximize firm value by holding low-beta assets, which relaxes other investors' leverage constraints.

In the presence of longevity risk (i.e., $\pi < 1$), portfolio choice matters for the insurers' equity price, even if the leverage constraints do not bind (i.e., $\lambda = 0$). In this case, firm value increases in the spread $R - R_f$. The reason is that R is the effective riskless rate used for firm valuation according to equation (26), while R_f is the insurers' borrowing rate. Insurers earn a spread that reflects the "convenience yield" that households are willing to pay to insure idiosyncratic longevity risk. This spread is analogous to the liquidity premium that depositors are willing to pay in banking models.

The second source is the cost of regulatory frictions due to the risk-based capital constraint. By choosing a safer portfolio, insurers could reduce the cost of regulatory frictions. The third source is the underwriting profits that arise from market power, which are decreasing in the demand elasticity.

F. Insurers' Optimal Portfolio

Insurers choose a portfolio of risky assets to maximize their value (29). We assume that there is a continuum of atomistic insurers that do not account for price impact in choosing their portfolio. In particular, they take the other investors' portfolio choice as fixed and do not internalize the impact of their choice on the aggregate Lagrange multiplier λ. Because the insurance sector is concentrated in reality, the extension to strategic investors with price impact is a relevant direction for future research.

Substituting the cost of regulatory frictions (5) in equation (29), the first-order condition implies that

$$(31) \qquad \begin{aligned} \mathbf{x}_I &= \frac{\lambda + R - R_f}{R_f(R + \lambda)} \exp(-\phi\boldsymbol{\beta})(\mathbb{E}[\mathbf{d}] - \gamma \mathrm{Var}(\mathbf{d})\mathbf{1}) \\ &= \frac{\lambda + R - R_f}{R_f(R + \lambda)} \exp(-\phi\boldsymbol{\beta})(\mathbb{E}[\mathbf{d}] - \gamma\sigma_F^2\boldsymbol{\beta}\boldsymbol{\beta}'\mathbf{1} - \gamma\boldsymbol{\sigma}_\nu^2), \end{aligned}$$

where the second equality follows from equation (3). The optimal portfolio trades off the gains from relaxing the leverage constraints of households and institutional investors through λ, the gains from providing longevity insurance to households through $R - R_f$, and the cost of regulatory frictions through $\exp(-\phi\boldsymbol{\beta})$.

For intuition, consider the special case when leverage constraints are not binding

(i.e., $\lambda = 0$) and the markup exactly offsets the mortality credit on annuities (i.e., $R = R_L = R_f$). Then the optimal portfolio is $\mathbf{x}_I = \mathbf{0}$, which means that insurers hold only the riskless asset. Because risk-based capital regulation penalizes risky asset holdings, insurers choose the riskless asset to minimize the cost of regulatory frictions.

IV. Empirical Implications

We now explain how equation (31) is consistent with the two motivating facts in Section I. First, insurers allocate a large share of their portfolio to corporate bonds with credit risk. Second, the credit risk of life insurers' bond portfolios has decreased relative to that of property and casualty insurers after the global financial crisis.

A. Demand for Low-Beta Assets

When $\lambda > 0$, insurers hold risky assets but tilt their portfolio toward low-beta assets. Differentiating the allocation to asset n with respect to its beta, we have

$$(32) \qquad \frac{\partial x_I(n)}{\partial \beta(n)} = - \frac{R - R_f + \lambda}{R_f(R + \lambda)} \exp(-\phi\beta(n))$$
$$\times \, (\phi\mathbf{1}'_n(\mathbb{E}[\mathbf{d}] - \gamma\mathrm{Var}(\mathbf{d})\mathbf{1}) + \gamma\sigma_F^2(\beta(n) + \boldsymbol{\beta}'\mathbf{1})) < 0.$$

Thus, the optimal allocation to a risky asset decreases in its beta. This result holds even when capital regulation is not sensitive to risk (i.e., $\phi = 0$). When capital regulation is sensitive to risk, the demand for low-beta assets strengthens.

Insurers have significant leverage because of their liability structure, which they use to earn leveraged returns on low-beta assets. Leverage-constrained investors have high demand for the insurers' equity because holding low-beta assets indirectly through the insurance sector relaxes their leverage constraints. In equilibrium, insurers earn high expected returns on low-beta assets, reflecting their value in relaxing the leverage constraints of households and institutional investors. This central mechanism that depends on the insurers' access to cheap leverage could remain important because of demographic trends. The demand for annuities that provide longevity insurance and minimum return guarantees could continue to grow because of an aging population and the secular decline of pension plans.

B. Sensitivity to Risk-Based Capital

Ellul et al. (2011) find that insurers sell downgraded corporate bonds. This finding is consistent with equation (32) if we interpret a bond downgrade as an increase in its beta. Moreover, insurers with lower risk-based capital are more likely to sell downgraded corporate bonds. This finding corresponds to the second

partial derivative:

$$(33) \quad \frac{\partial^2 x_I(n)}{\partial \beta(n) \partial \phi} = -\frac{R - R_f + \lambda}{R_f(R + \lambda)} \exp(-\phi \beta(n))$$
$$\times [(1 - \phi \beta(n)) \mathbf{1}'_n (\mathbb{E}[\mathbf{d}] - \gamma \text{Var}(\mathbf{d}) \mathbf{1}) - \gamma \sigma_F^2 \beta(n)(\beta(n) + \boldsymbol{\beta}' \mathbf{1})].$$

This expression is negative for $\beta(n) = 0$. More generally, it is negative for a low-beta asset because the quadratic equation inside the square brackets is positive for $\beta(n)$ sufficiently low. Thus, insurers with higher ϕ have lower risk-based capital, and they are more likely to sell downgraded corporate bonds. Ellul et al. (2011) find that when the insurance sector as a whole is relatively constrained, the selling pressure leads to an asset fire sale.[4]

Becker et al. (2022) find that life insurers held on to downgraded nonagency MBSs after the global financial crisis, even though they sold downgraded bonds in the rest of their portfolio to reduce required capital. The reason is that state regulators eliminated risk-based capital regulation for nonagency MBSs by making required capital a function of expected loss instead of ratings. In the context of equation (33), life insurers effectively have a lower value of ϕ for nonagency MBSs than for the rest of their portfolio. When risk-based capital regulation is not sensitive to risk, insurers do not have an incentive to sell downgraded bonds.

Ge and Weisbach (2021) find that property and casualty insurers shift their portfolio toward safer corporate bonds after a severe weather event that causes operating losses. Operating losses could tighten a risk-based capital or value-at-risk constraint, which would be equivalent to an increase in ϕ. Thus, equation (33) could explain why insurers shift their portfolio toward safer assets in response to operating losses.

C. Trend in Relative Credit Risk

As a consequence of the secular decline in interest rates, a growing literature discusses the incentives of institutional investors such as mutual funds, pension funds, and endowment funds as well as households to reach for yield (Choi and Kronlund, 2018; Lian et al., 2019; Campbell and Sigalov, 2022). As other investors become more leverage constrained in a low interest rate environment, the model predicts that insurers increase their allocation to risky assets. According to equation (31), the insurers' allocation to risky assets increases in λ, which represents the tightness of other investors' leverage constraints. This force could partly explain why property and casualty insurers have increased credit risk.

For life insurers, there is an offsetting force that they were financially constrained during the global financial crisis and the subsequent low interest rate environment (Koijen and Yogo, 2015). Life insurers have had equity and interest

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[4]Ellul et al. (2011) and Becker and Ivashina (2015) emphasize discrete differences in selling pressure by NAIC designation, which we could model by making the risk weights an increasing step function of beta.

risk mismatch as variable annuities have become their primary liability. As we discuss in Koijen and Yogo (2022), life insurers' stock returns are negatively exposed to long-term bond returns in the low interest rate environment. Moreover, variable annuity insurers that had low stock returns during the global financial crisis had low stock returns during the COVID-19 crisis, highlighting the persistent fragility of the life insurance sector. According to equation (31), the insurers' allocation to risky assets decreases in ϕ, which represents the tightness of the risk-based capital constraint.

As pension funds and sovereign wealth funds reach for yield in the low interest rate environment, property and casualty insurers have gained access to more debt financing through catastrophe bonds and insurance-linked securities. Hedge funds have invested in property and casualty insurers to access cheap leverage, as emphasized by our model. Similarly, private equity firms have invested in life insurers to increase leverage and to reduce tax liabilities (Kirti and Sarin, 2020). This capital inflow into the insurance sector suggests that ϕ has decreased, especially for property and casualty insurers.

In summary, life insurers have become more financially constrained relative to property and casualty insurers after the global financial crisis. At the same time, other investors have become more leverage constrained in the low interest rate environment. The combination of these forces could explain why the credit risk of bond portfolios for life insurers has decreased relative to that for property and casualty insurers after the global financial crisis.

V.   Potential Extensions

We have made simplifying assumptions to focus on why insurers are the largest institutional investors of corporate bonds. We consider this question to be important because corporate bonds play an essential role in corporate funding and investment. Moreover, a standard theory of insurance markets predicts that insurers hold riskless bonds instead of corporate bonds. We conclude by discussing potential extensions of the model for future research.

A.   *Interest Risk Mismatch*

In our two-period model, assets differ by beta but not by maturity. Thus, insurers choose credit risk but not interest rate risk. In reality, insurers affect not only credit risk but also interest rate risk by shifting their portfolio from Treasury to corporate bonds. Because Treasury bonds have a longer maturity distribution than corporate bonds, insurers may decrease the duration of their portfolio by shifting from Treasury to corporate bonds.

Insurers have a negative duration gap between their assets and their liabilities with minimum return guarantees (Koijen and Yogo, 2022). Insurers would increase the duration gap by shifting from Treasury bonds with longer maturities to corporate bonds with shorter maturities. Thus, insurers face a tradeoff between

earning a credit risk premium and reducing the duration gap. Although insurers could hedge interest rate risk through derivatives, the size of the hedging demand would be large relative to the size of the derivatives market. Consequently, insurers may have to accept interest risk mismatch to earn a credit risk premium on low-beta assets, which is the central force in our model.

Several papers show that interest rate risk is an important consideration in portfolio choice, especially when interest rates are low. In the low interest rate environment after the global financial crisis, US life insurers have increased the duration but not the credit risk of their portfolios (Ozdagli and Wang, 2019). Similarly, euro-area insurers have increased the duration but not the credit risk of their portfolios during the quantitative easing program that started in March 2015 (Koijen et al., 2021). Greenwood and Vissing-Jørgensen (2018) hypothesize that the liability hedging demand by insurers and pension funds could depress long-term government bond yields. Consistent with this hypothesis, they find a negative correlation between the slope of the government yield curve and the size of the insurance and private pension sectors across countries.

B.   Capital Structure

In an economy with a low-beta anomaly, firms with low-beta assets have an incentive to increase leverage to take advantage of the anomaly (Baker and Wurgler, 2015; Baker et al., 2020). In our model, insurers hold low-beta assets and have significant leverage because of their liability structure. However, leverage is entirely determined by the demand for annuities because insurers cannot issue public debt or pay out dividends.

Depending on the strength of the low-beta anomaly, insurers may have an incentive to increase leverage by selling more policies, issuing public debt, or paying out dividends. Thus, capital structure choice is an interesting extension that could potentially explain the high level of leverage in the insurance sector.

C.   Insurance Pricing

We have assumed that annuities are not subject to risk-based capital regulation, which implies that the pricing of annuities in equation (1) does not depend on the cost of regulatory frictions. In reality, risk-based capital depends not only on portfolio choice, but it also interacts with insurance pricing and capital structure choice. Depending on the strength of the low-beta anomaly, insurers may have an incentive to increase leverage by selling more policies at lower prices.

We have assumed that annuities are riskless because the insurers' dividends can be negative to ensure full payment of annuity claims. If we were to assume nonnegativity of dividends through limited liability, annuities would be defaultable. In that case, portfolio choice could interact with insurance pricing because demand could depend on the default probability.

D. *Agency Problems*

We have abstracted from agency problems that could affect portfolio choice and capital structure choice. For example, risk-shifting motives could arise from limited liability and the presence of state guaranty associations (Lee et al., 1997). The asset pricing literature has studied the impact of agency problems on other types of institutional investors such as mutual funds, hedge funds, and pension funds (Basak et al., 2007; Huang et al., 2011). The insights from this literature may be useful for studying insurers as well.

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