Regulatory Capital and Portfolio Investments: Evidence from Life Insurance Companies

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Abstract

I examine how capital requirements affect financial institutions’ portfolio investments by studying life insurers’ portfolio and business decisions. Through a simple model, I show that when regulatory capital becomes cheaper, life insurers may reduce the average investment risk of their portfolios and increase the scale of their insurance business. I test the model using a panel data set of U.S. life insurers and staggered changes in state laws on financial reinsurance that enable the insurers to raise capital more easily. I find that, after these law changes, the insurers significantly reduce their allocation to risky investments and accelerate their annual insurance underwriting growth on average. The effect is more pronounced for insurers that are smaller and less financially competitive.

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Since the Great Recession, regulation of financial institutions’ asset risk has been a major topic in both academic research and political debates. Enhanced standards on regulatory capital, such as Basel III and Solvency II, have been implemented to improve the financial solvency of banks and insurance companies. Financial intermediaries, however, have not favored tighter capital requirements, presumably due to the costliness of raising capital, especially when they experience negative shocks. The understanding of such costs for individual financial firms is limited despite the ample research on capital requirements. In particular, little research has examined, in the cross section, how financial intermediaries manage their investment risk with the costs of raising capital for regulatory compliance being a key decision factor.

In this paper, I examine the relationship between the costs of raising regulatory capital and portfolio investment risk for life insurance companies in the United States. The reason to focus on U.S. life insurers is fourfold. First, life insurers are a major type of investor in financial markets, especially in bond markets. As of year-end 2015, U.S. life insurers’ market share of investment-grade corporate bonds was nearly 25%, and their total cash and invested assets reached $3.71 trillion, higher than the amount of total assets under management by U.S. open-end bond mutual funds, which was $3.15 trillion. Second, life insurers exhibit fundamental similarity to banks in that they both sell standardized products to raise funds, invest these funds in long-duration financial assets, and are subject to risk-based capital regulation. Thus, studying how life insurers’ financial decisions are influenced by regulatory capital should also provide insights into similar issues for banks. Third, the asset risks of life insurers can be dynamically measured since they invest predominantly in publicly traded financial securities. Fourth, while other financial institutions are regulated at the national level, U.S. life insurers are regulated at the state level, which makes possible the use of changes in state laws as quasi-experiments to obtain causal inferences.

I first develop a simple model to illustrate a life insurance company’s fundamental optimization problem as it applies to portfolio decisions. A risk-neutral life insurer starts with an initial capital endowment and an exogenous charter value. The insurer then sells insurance policies, i.e., underwrites insurance, and collects funds from households, from which it makes underwriting profits at an exogenous margin and recognizes the present value of projected future insurance payments as

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1 Charter value refers to the present value of the ability to conduct insurance businesses (e.g., the value of licenses and future services) to an insurance company’s shareholders.
liabilities. The scale of insurance underwriting is subject to a regulatory limit determined by the amount of endowed capital. The funds raised from insurance sales that correspond to outstanding liabilities (labeled “external funds”), together with the sum of initial endowment and underwriting profits (labeled “internal funds”), can be invested in two financial assets, one risk-free with zero net return and the other risky with a binary return distribution. External funds are assumed to bear additional risk — the insurer is subject to a shock to the amount of insurance liabilities, which may result in either a gain or loss. After the liability shock and asset returns are realized, if the insurer’s assets fall short of its liabilities, the insurer will be obliged to raise regulatory capital in order to preserve its charter value. The cost of financing this additional capital is convex in the amount financed.² The insurer maximizes the time-zero expectation of shareholder value by optimally choosing the amount of insurance underwriting and the allocation between the two financial assets.³ In making this decision, the insurer faces a two-fold trade-off: (1) conditional on the scale of external funds, the insurer trades off the risky asset’s return premium with the cost of raising additional capital on the downside; (2) in determining its optimal scale, the insurer trades off the additional profits (from both investments and underwriting) that can be generated by more external funds with the cost of additional downside risk embedded in these funds.

The model’s equilibrium depends on the relative magnitude of the risky asset’s return premium. If the risky asset’s premium is lower than the risk-adjusted return premium on the insurer’s underwriting, only the first trade-off is meaningful — the insurer will underwrite the maximum amount of insurance allowed by regulation and the weight of risky investments in the portfolio decreases in the cost of raising regulatory capital. Alternatively, if the risky asset’s return premium is so large that it can fully compensate for the shadow cost of external funds’ additional risk, the insurer will treat external funds as internal funds and invest 100% in the risky asset due to risk neutrality, which means only the second trade-off is meaningful. When the risky asset’s return premium falls in between the two thresholds, both trade-offs are meaningful and there is an interplay: in equilibrium, the scale of external funds affects the weight of the risky investments. In particular, the insurer will allocate 100% of internal funds and a constant proportion (less than 100%) of external funds

²The micro-foundations of the model are illustrated in Section I. The key assumption is that the insurer’s charter is so valuable that shareholders always find it optimal to raise regulatory capital in equilibrium.
³In the model, I take as exogenous the insurance market pricing, financial regulation, the insurer’s charter value, and the insurer’s ease of regulatory capital financing.
to the risky asset, the former due to risk-neutrality and the latter due to the embedded insurance risk. As a result, in this equilibrium, if the cost of raising regulatory capital becomes lower (i.e., downside risk is less costly), the insurer will scale up its insurance business given the same amount of initial capital to attain a higher amount of total investable funds, resulting in a higher percentage of these funds bearing insurance risk, which leads to a prudential reduction in the weight of risky investments. Moreover, in this equilibrium, the insurer’s profitability is decreasing in its costs of raising regulatory capital, which is intuitive and consistent with what has been documented for the banking industry (e.g., Kisin and Manela (2016)).

According to the National Association of Insurance Commissioners (NAIC), U.S. life insurers hold a considerable amount of safe assets. In addition, it has been documented that U.S. life insurers tend to stay well above the risk-based capital requirements (Koijen and Yogo (2016)) and the life insurance product market is quite competitive (Krebs, Kuhn, and Wright (2015)). Therefore, the empirically relevant model scenario is indeed the one in which the insurer’s asset allocation and insurance underwriting decisions are both responsive to the cost of raising regulatory capital in equilibrium. I test the corresponding predictions using a sample of U.S. life insurers from 2004 to 2014. First, based on life insurers’ security-level corporate bond and mortgage holdings (data from Thomson EMAXX and SNL Financials) and market prices (data from TRACE), I construct two types of investment risk measures: default risk, which is based on credit ratings, and residual risk, which is based on market-adjusted return volatilities. As U.S. life insurance companies invest predominantly in corporate bonds, mortgages, and safe assets, my measures reasonably reflect their investment risk. I calculate the growth in insurance underwriting as well as the volatility of the insurers’ capital as implied by asset risk measures using balance sheet data (SNL Financials).

To identify how costs of raising capital affect life insurers’ investment decisions, I exploit staggered changes in state laws on financial reinsurance as quasi-experiments. Financial reinsurance vehicles are a common tool for life insurers to finance regulatory capital from reinsurance companies, where information asymmetry exists. Each law change legalizes the establishment of such vehicles

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4 See Figure A1 in Appendix A.
5 Measure construction details are provided in Section III.
6 My sample insurers invest no more than 2% of their assets in common stocks on average. Data limitations and the corresponding robustness tests will be discussed in Sections III and IV.
7 Sections I and III discuss details about financial reinsurance and the state law changes.
8 Although not directly studying life insurers, Garven, Hilliard, and Grace (2014) provide empirical evidence for the impact of information asymmetry on pricing in reinsurance markets.
under the corresponding state regulator’s examination. Since the same regulator assumes the core responsibility of regulating life insurers domiciled in that state, the law change implies a reduction in the costs of raising capital for home-state life insurers due to the alleviation of potential adverse selection problems and reduction in counter-party risk from reinsurance companies’ perspectives.\(^9\)

My empirical findings offer strong support for the model’s predictions. Following state law changes that reduce the costs of raising regulatory capital, the treated life insurers on average reduce their allocation to risky corporate bond and loan investments by 3.28 percentage points (7.14% change), accelerate their annual insurance underwriting growth by 6.18 percentage points (121.89% change), and lower both the default and market risk of their invested assets. The effects are more pronounced for smaller and less financially robust insurers, which is intuitive since they presumably have higher costs of raising regulatory capital for compliance. The reduction in the risky bond and loan investments is not a result of reallocation to other risky asset classes such as private-label mortgage-backed securities and common stocks. Moreover, there is no evidence of increased capital volatility or likelihood of default among treated life insurers.

The findings in this paper shed new light on effects of financial regulation. First, they serve as direct evidence that life insurance companies prudentially manage their asset and liability risks and that costs at which regulatory capital can be acquired play an economically meaningful role in this process. In fact, the implication on investment risk might appear counter-intuitive at first glance since one may find a reduction in regulatory costs for financial institutions naturally associated with increased risk taking incentives. This rationale, however, implicitly holds the liability side of the balance sheet constant. Indeed, in my model, the weight of risky investments would have been decreasing in the cost of raising regulatory capital if the scale of insurance underwriting were fixed.\(^10\) Yet once the amount of insurance underwriting is endogenized, my model and the empirical results show that the opposite is true in equilibrium. Such business scale consideration is particularly relevant here as my empirical findings are stronger for smaller insurers. Second, my results indicate that regulatory capital becoming cheaper does not necessarily lead to higher risk of insolvency. A plausible explanation, which is also embedded in my model, is that shareholders

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\(^9\)If home-state financial reinsurance vehicles are not allowed, a life insurer may establish such vehicles under other jurisdictions with a reinsurance company, like a foreign jurisdiction, but the reinsurance company would be disadvantaged in obtaining information from and monitoring its counter-party due to lesser regulatory oversight.

\(^10\)Section II illustrates this in detail.
of a regulated financial institution prudentially manage their capital level and strive to preserve their institution’s charter value in stress scenarios. Thus, my findings imply potential negative externalities of financial regulation, especially for smaller, less financially competitive institutions. This implication is conceptually consistent with the results obtained by Karolyi and Taboada (2015), who document a benign form of regulatory arbitrage in cross-border bank acquisitions.

This paper also contributes to the small but growing literature in finance that assess insurance companies’ liability risks and financial frictions (Koijen and Yogo (2015, 2016, 2018), Irresberger and Peng (2017), Ge (2017)). In particular, the “shadow insurance” as first discussed by Koijen and Yogo (2016) is the subset of financial reinsurance vehicles that are both unauthorized by state regulators and unrated by rating agencies. An important distinction of my paper is that the tests focus on the cross section, which means findings that cheaper regulatory capital leads to lower investment risk taken by treated insurers are not necessarily in conflict with the potential increase in the long-run aggregate risk of the life insurance industry as a result of shadow insurance usage, as estimated by Koijen and Yogo (2016).

Finally, this paper contributes to the growing literature on bond-market investor behaviors, which has been largely treating life insurance companies, and insurers in general, as a source of \textit{ex post} selling pressure in bond markets when defaults or downgrades arise (e.g., Ellul, Jotikasthira, and Lundblad (2011), Ellul, Jotikasthira, Lundblad, and Wang (2015), Nanda, Wu, and Zhou (2017)), since insurers are subject to risk-based capital requirements. A notable exception is Becker and Ivashina (2015), who document the reaching-for-yield incentives of insurance companies in the aggregate. My paper adds to this literature by examining the \textit{ex ante} asset-liability risk management of life insurers and establishing its link to financial regulation.

The rest of the paper is organized as follows. Section I describes institutional details of the life insurance industry. Section II presents a simple model that yields testable predictions. Section III explains the empirical design. Section IV discusses the empirical results and robustness tests. Section V concludes.
I. Life Insurance Industry Background

This section briefly lays out the background and characteristics of the life insurance industry in the United States, including ownership structure, key financial items and risk factors, financial regulation, and financial reinsurance.

A. Ownership Structure

U.S. life insurers are primarily organized as either mutual companies or stock companies (public or private). A mutual insurance company is owned by its policyholders, who share the company’s income typically in the form of dividends, while a stock insurance company is owned by its shareholders, where policyholders do not have voting rights. A mutual insurance company may change its ownership structure and become a stock company, a process called “demutualization”. According to the NAIC, more than 200 life insurance companies have demutualized since 1930. Among them are several large ones that demutualized in the late 1990s and early 2000s, including MetLife and Prudential Life, which demutualized in 2000 and 2001, respectively. As of year-end 2013, total assets of all mutual life insurers in the U.S. are around $0.6 trillion, while those of all stock life insurers are $3 trillion.\footnote{Source: https://www.naic.org/capital_markets_archive/150428.htm} I only consider stock life insurers in this paper since their firm-level decision-making processes resemble those of typical commercial banks and non-financial corporations, and they constitute the majority of the industry in terms of total assets.

B. Key Financial Items and Risk Factors

I illustrate the key financial items and risk factors on a life insurance company’s balance sheet by describing its fundamental business procedures. Suppose a newly incorporated life insurer starts with only equity capital and then underwrites a portfolio of life insurance policies. It would collect cash proceeds from households, termed “insurance premiums”, and recognize liabilities, termed “policy reserves”, whose calculation follows a pre-specified mortality table (annual probabilities). The insurer example in Appendix A shows the balance sheet outcome of this process.

Next, the insurer invests its assets in financial securities to generate investment income, an important source of revenue.\footnote{According to Nissim (2010), investment income on average accounts for 35% of U.S. life insurers’ total revenue} Because its liability is not short-term, the life insurer is subject to
interest rate risk. As a result, the life insurer would typically invest in bonds to match the duration of its assets and liabilities. According to the NAIC, bonds account for around 80% of life insurers’ investment portfolio in the aggregate.\textsuperscript{13} Thus, the nature of the insurer’s asset risk is largely similar to that of commercial banks, yet life insurers would be able to adjust their asset risks more actively since most of the invested assets are publicly traded.

It should be noted that the liability side of the life insurer is not risk-free, though a life insurer sells a portfolio of insurance policies to diversify away idiosyncratic mortality risk. Unlike property and casualty insurance companies that are frequently prone to material, negative cash flow shocks brought by natural disasters, life insurers tend to be much less concerned about liquidity constraints on a normal basis because it is highly unlikely that there would exist recurring events in which a significant portion of life insurance policy holders decease simultaneously.\textsuperscript{14} Instead, there is a recurring, dynamically managed source of liability risk for life insurers stemming from the calculation of reserves (liabilities). The reason is that a tiny unexpected change in projected mortality rates can result in material reduction in regulatory capital. The insurer example in Appendix A demonstrates this effect.

Due to the importance of the life insurance industry for social welfare, financial regulation is in place as a guidance for life insurers’ risk management and to protect insurance policy holders, which I discuss next.

\textbf{C. Financial Regulation and Financial Reinsurance}

In the United States, insurers are regulated at the state level, for which the NAIC provides general guidelines. The main components of financial regulation currently in the United States for life insurers are statutory reserve requirements (see the American Academy of Actuaries (AAA)) and the risk-based capital requirements (RBC) (see NAIC). Specifically, the AAA provides statutory reserve calculation formulas for insurance products sold;\textsuperscript{15} the NAIC defines a minimum amount of

\textsuperscript{13}Source: https://www.naic.org/capital_markets_archive/110819.htm

\textsuperscript{14}For annuity products, however, early termination (surrender) is a type of cash flow risk. Yet the liquidity constraint is still small since the surrendering amount would be less than the account holder’s carrying value on the insurer’s balance sheet due to surrendering fee charges.

\textsuperscript{15}Historically, statutory reserves are typically higher than the corresponding actuarial value predominantly due to the formula-based nature, where insurer-specific characteristics are neglected. For instance, the statutory formula does not account for insurer-specific diversification benefit of policy portfolio and local economic conditions. In recent years, life insurance reserve regulation has moved toward principle-based reserving (PBR, effective January 1, 2017),

\textsuperscript{7}
regulatory capital based on an aggregation of individual capital requirements for six risk components: risk from affiliates, investment risk, insurance risk, interest rate risk, and general business risk.\textsuperscript{16} In other words, both regulatory requirements imply a definition of solvency as having a sufficient amount of assets given risk exposures.

Figure 1 shows the RBC requirements for life insurers’ investments as of 2016.\textsuperscript{17} The insurer example in Appendix A illustrates the RBC calculation in detail. It is important to note that the RBC requirement provides a cushion for risk in addition to what is captured by the statutory reserve calculation. In other words, the two types of regulation are complimentary to each other.\textsuperscript{18}

Asset and liability risk exposures, along with regulatory requirements in place, can lead a life insurer to the necessity of financing regulatory capital. As a result, the cost of raising capital for compliance plays an important role in a life insurer’s risk management decisions.

Besides standard debt and equity, life insurance companies have access to a third, unique form of regulatory capital financing termed “financial reinsurance” or “capital-oriented reinsurance”, where a reinsurance company provides capital to the insurer upfront, expecting to be reimbursed by the insurer with its future cash flows and sharing some risk embedded in the ceded insurance policies. In general, such risk sharing qualifies as risk transfer on a statutory basis by construction, so the amount of capital requirement for insurance risk is lowered. Financial reinsurance thus improves the ceding insurer’s regulatory capital adequacy by the sum of the reduction in capital requirement and the amount of asset injection by the reinsurer.\textsuperscript{19} The insurer example in Appendix A explains financial reinsurance in more detail.

In the United States, state laws on life insurers’ financial reinsurance are typically nested in which allows insurers to determine the amount of reserves (liabilities) according to their own experience with dynamic adjustments.

\textsuperscript{16}The calculation involves both market inputs and modeling assumptions, such as credit ratings of financial securities and the simulated loss distribution of outstanding insurance claims. For further details, refer to www.naic.org.

\textsuperscript{17}An exception is private-label mortgage-backed securities, whose capital requirements have been specified using model estimations since 2010. Becker and Opp (2013) provide a detailed discussion on this.

\textsuperscript{18}For example, the insurance risk considered by the RBC represents possibilities of more severe losses than those embedded in the statutory reserve calculation. Additionally, the NAIC does not define RBC requirements at the insurance group level; life insurers’ financial reporting to the NAIC is at the legal-entity level. As a result, firms are not aggregated to the insurance group level in the empirical analysis of this paper.

\textsuperscript{19}The reduction in capital requirement is isomorphic to a reduction in statutory reserve recognition, called “reserve credit” that can be taken by the ceding insurer. For simplicity, I consider the situation where the amount of statutory reserve is unchanged. This corresponds to the case of “mirror reserving” and reinsurance letters of credit as admitted assets mentioned by Koijen and Yogo (2016) in their online appendix.
the laws for captive insurance, as the special purpose financial vehicles (SPFVs) under financial reinsurance are one type of captive insurance. Although they include SPFVs, captive insurance entities are predominantly self-insurance mechanisms for non-financial firms to manage such risks as property loss and reputation, for which readily available insurance products are either nonexistent or too expensive. Historically, captive insurance businesses are likely under foreign jurisdictions such as Bermuda and Cayman Islands due to lesser regulation in those areas. In the past two decades, however, there has been a clear trend among domestic states to attract captive insurance businesses through new legislation due to the additional source of revenue for the government and increased employment opportunities for state residents. Appendix B lists all states that legalized in-state SPFVs from 2004 to 2014; Figure 2 shows the states that are used as quasi-experiments graphically.

II. Model

I develop a simple model to illustrate the role of regulatory capital financing cost in a life insurer’s asset and liability risk management. Specifically, the model takes the insurance market and financial regulation as exogenous and examines a life insurer’s joint decisions on insurance underwriting and asset risk taking.

A. Setup

I assume the life insurer is risk neutral. Time is discrete at 0, 1, 2, and 3. At $t = 0$, the insurer is licensed and endowed with equity capital $W_0$. The shareholder value right after endowment is $V + W_0$, where $V$ represents the present value to shareholders of the insurer’s future ability to sell insurance products (i.e., charter value) and is exogenously specified. Then the insurer sells insurance claims, whose actuarial value equals $D_0$, and collects premium payments of $(1 + m)D_0$. The total amount of investable assets right after the insurance sales is thus $W_0 + (1 + m)D_0$. At $t = 1$, the insurer allocates investable funds between a risk-free asset, whose gross return is constant and normalized to 1, and a risky asset whose gross return $\hat{R}$ to be realized at $t = 3$ is $R > 1$ with probability $p$, and 0 with probability $1 - p$. Denote the total amount of risky asset as $I_1$ and the
weight of the risky asset at $t = 1$ as $x$. Then, by definition,

$$x = \frac{I_1}{W_0 + (1 + m)D_0}.$$  

Empirically, the two-security setup can be interpreted as two portfolios, one containing safer assets (government bonds, municipal bonds, agency-backed MBS, zero-loss private-label MBS, etc.), and the other riskier assets (corporate bonds, mortgage loans, common stock, etc.).

To capture the liability risk on the life insurer’s balance sheet, I impose a random shock to the total amount of liability at $t = 2$, in which the magnitude is proportional to outstanding insurance claims and denoted as $\bar{\rho} \cdot D_0$. $\bar{\rho}$ equals either $\rho$ or $-\rho$, resulting in total liability of $(1 + \rho)D_0$ or $(1 - \rho)D_0$, with equal probabilities. It is assumed that $m < \rho < 1$. This random shock is best interpreted as an *ex post* unexpected change in projected mortality rates for a portfolio of life insurance policies, where the insurer correctly recognizes the liability amount on average *ex ante*.\textsuperscript{20}

Since the profits from insurance sales are defined as the difference between premiums collected and liabilities recognized, this liability shock has a direct, material impact on profits. As illustrated by the example in Figure A2, a tiny change in projected mortality rates can significantly reduce the amount of regulatory capital. At $t = 3$, investment returns are realized.

The insurer is subject to regulatory constraints at both $t = 0$ and $t = 3$.\textsuperscript{21} At $t = 0$, financial regulation imposes an upper limit of insurance sales, defined as:

$$\rho D_0 \leq W_0 + mD_0 , \quad (1)$$

which means the insurer is not allowed to sell more insurance than what its initial capital can support in a potential future stress scenario.\textsuperscript{22} At $t = 3$, after investment returns and the liability shock are both realized, the insurer’s balance sheet needs to satisfy the following constraint:

$$A_3 \geq D_3 , \quad (2)$$

which simply means the insurer needs to have enough assets to back up liabilities. To comply with

\textsuperscript{20}The model specification is also consistent with a shock in long-term interest rates or unexpected contribution / surrender associated with a portfolio of annuity policies.

\textsuperscript{21}Implicitly, financial regulation exists to guarantee the willingness of households in insurance purchase and support the assumption that the insurance profit margin, $m$, is exogenous.

\textsuperscript{22}This specification is consistent with both the risk-based capital requirement and statutory reserve calculation, which typically results in an amount above the corresponding actuarial value.
this regulatory requirement, the insurer would have to raise regulatory capital at \( t = 3 \) if necessary and incur financing costs that are represented as \( \frac{1}{2} \cdot c \cdot K^2 \), where \( K \) is the amount of capital to be financed and \( c \) captures the insurer’s private cost of raising capital. If the regulatory requirement is violated at either \( t = 0 \) or \( t = 3 \), regulators would step in to gain control, which makes shareholders of the insurer lose its charter value \( V \).\(^{23}\) I assume that \( V \) is large enough — shareholders of the insurer are always willing to incur capital financing costs to avoid being deprived of the charter value.\(^{24}\) It is straightforward to see that with a fixed charter value \( V \), the insurer would raise an amount of additional capital just enough for compliance. The sequence of events is summarized as follows:

\[
\begin{array}{|c|c|c|c|}
\hline
&t = 0&t = 1&t = 2&t = 3 \\
\hline
\text{Endowed Capital} & \text{Insurer Allocates} & \text{Shock to Projected} & \text{Asset Returns} \\
\text{\( W_0 \); Insurance} & \text{Portfolio between} & \text{Mortality Rates} & \text{Realized; Capital} \\
\text{Sales of Actuarial} & \text{a Risky Asset} & \text{Observed; Liabilities} & \text{Financing to} \\
\text{Value \( D_0 \) at Initial} & (\text{weight } x) \text{ and} & \text{Change by } \tilde{\rho} \cdot D_0 & \text{Comply with} \\
\text{Profit Margin } m, \text{ a Risk-free Asset} & & \text{Regulation} & \\
\text{Subject to} & & & \\
\text{Regulatory Limit} & & & \\
\end{array}
\]

The insurer maximizes time-zero expectation of the shareholder value at \( t = 3 \):

\[
E[V_3] = V + W_0 + (pR - 1)I_1 + mD_0 - \frac{1}{2}(1 - p) \cdot \frac{1}{2}c(I_1 - W_0 - \rho D_0 - mD_0)^2 \cdot 1_{(I_1 \geq W_0 + mD_0 + \rho D_0)} \\
- \frac{1}{2}(1 - p) \cdot \frac{1}{2}c(\rho D_0 + I_1 - W_0 - mD_0)^2 \cdot 1_{(\rho D_0 + I_1 \geq W_0 + mD_0)} ,
\]

(3)

where the quadratic terms represent financing costs that the insurer potentially incurs to comply with regulation when the risky asset’s gross return turns out to be zero (no financing is needed when the risky asset return is positive given the regulatory limit on insurance sales).

I solve the model in two steps. First, I derive the optimal asset allocation at \( t = 1 \), taking the amount of insurance sales, \( D_0 \), as given. The insurer’s trade-off is between the risky asset’s return...

\(^{23}\) In reality, if an insurer falls short of capital per regulatory requirements, state regulators may suspend the insurer’s license or even liquidate the firm.

\(^{24}\) The majority of life insurance firms in the U.S. are private, and it is plausible to impose this assumption for internal equity. Additionally, as the empirical section later discusses, the number of receivership cases is very low for U.S. life insurers.
premium and the cost of raising additional capital on the downside. Then, with the optimal asset allocation policy, I solve for the optimal level of insurance sales at $t = 0$. Here, the insurer trades off the additional profits (from both investments and underwriting) that can be generated by more external funds with the cost of additional downside risk embedded in these funds.

I restrict my attention to parameter values that satisfy the following assumption:

$$\frac{m}{\rho} < 1 - \frac{1}{\rho R} < \frac{m}{\rho^2}.$$  \hfill (4)

The interpretation of this assumption is that the expected return premium of the risk asset is higher than the risk-adjusted expected return premium of insurance underwriting, but not high enough to fully compensate the downside risk of insurance liabilities given the convex cost of raising additional capital.\footnote{It is embedded in this assumption that the risky asset’s expected net return is positive, which means the insurer can expect to earn a risk premium on risky investments despite being risk-neutral. The main justification for this assumption is that life insurers are unique among investors as liquidity providers since their liabilities’ long duration enables them to commit to illiquid investments with low costs and thus earn a risk premium. Private placement corporate bonds and mortgage loans are two examples of such investments.} Appendix C shows that this assumption is necessary for making meaningful the asset-liability management in equilibrium and discusses solutions under an extended parameter space. It will also be shown later in this section that the parameter space specified by condition (4) is numerically relevant. In addition, I assume that $W_0$ is large enough to simplify the analysis. In other words, the initial capital amount does not restrict insurance underwriting unless the regulatory constraint at $t = 0$ is binding in equilibrium regardless of the value of $W_0$. Formally, the maximization problem at $t = 1$ is as follows:

$$\max_{I_1} E[V_3 | D_0]$$

$s.t. \quad 0 \leq I_1 \leq W_0 + (1 + m)D_0$ \hfill (5)

And the maximization problem at $t = 0$ is as follows:

$$\max_{D_0} E[V_3]$$

$s.t. \quad 0 \leq D_0 \leq \frac{W_0}{\rho - m}$ \hfill (6)

$$I_1 = \arg\max \quad E[V_3 | D_0]$$
B. Equilibrium Asset Allocation Rule

The asset allocation rule in equilibrium is summarized by the following two lemmas.

**LEMMA 1:** Conditional on an amount of insurance underwriting $D_0$, the optimal dollar amount of risky investments is:

$$I^*_1|_{D_0} = \frac{pR - 1}{(1-p)c} + W_0 + mD_0 .$$

Proof: See Appendix C.

**LEMMA 2:** Unconditionally, the equilibrium dollar amount of risky investments equals the initial endowment plus a proportion of the equilibrium amount of insurance underwriting:

$$I^*_1 = \left[\frac{(pR-1)p^2}{pR \cdot m} + m\right] D^*_0 + W_0 .$$

Proof: See Appendix C.

Lemma 1 states that if the insurer’s scale is fixed (the amount of insurance sales is given), the dollar amount allocated to the risky investment is decreasing in the cost of raising additional regulatory capital and so is the weight. This fits in the standard intuition that lower costs of regulation are associated with higher incentives to take risk. What Lemma 2 indicates, however, is that the relationship between the amount of risky investments and the cost of raising capital is solely determined by the equilibrium insurance underwriting ($D^*_0$) if scale is endogenous. This leads to the testable predictions below.

C. Testable Predictions

I summarize the testable predictions regarding the effect of regulatory capital financing cost on investment risk, insurance underwriting, and firm profitability in the following two propositions.

**PROPOSITION 1:** In equilibrium, the amount of risky investments as a percentage of total invested assets is increasing in the cost of raising regulatory capital, and the amount of insurance underwriting is decreasing in the cost of raising regulatory capital:

$$\frac{\partial x^*}{\partial c} \geq 0 , \quad \frac{\partial D^*_0}{\partial c} \leq 0 .$$
Proof: See Appendix C.

Proposition 1 predicts that when life insurers must comply with capital requirements to retain their charter value, cheaper (more expensive) regulatory capital results in their underwriting more (less) insurance contracts per unit of initial capital, and their prudentially reducing (increasing) the risk taken per unit of investment. Note that, as shown in Appendix C, the conditions as in (4) are necessary and sufficient to make meaningful both of the insurer’s two trade-offs discussed previously. Hence, the intuition of Proposition 1 lies in the interplay of the insurer’s two decisions: in equilibrium, the scale of insurance underwriting affects the weight of risky investments. Specifically, suppose the insurer increases its scale marginally by selling one additional unit of insurance. Then even if this additional funding is all invested in the risky asset, the increase in expected return premium will not fully compensate for the increase in the cost of the downside risk associated with the liabilities, following conditions as in (4). As a result, the additional funding will not be fully invested in the risky asset in equilibrium, which implies that if the cost of raising regulatory capital becomes lower, the marginal effect on scale will exceed that on the dollar amount of risky investments, and hence the weight of risky investments decreases. Empirically, Proposition 1 is testable using the insurers’ asset holdings and proxies for costs of raising regulatory capital.

PROPOSITION 2: In equilibrium, the life insurer’s expected return on initial capital is decreasing in its cost of raising regulatory capital:

$$\frac{\partial E[V_A] - V}{W_0} \leq 0.$$ 

Proof: See Appendix C.

The intuition of Proposition 2 is straightforward given Proposition 1: for life insurers, with a fixed amount of initial capital, the cost of raising regulatory capital for compliance is negatively associated with the amount of insurance underwriting and positively associated with the costliness of stress scenarios, and thus, a reduction in capital financing costs improves a life insurer’s profitability. Alternatively, Proposition 2 implies that if a life insurer targets an expected firm-level profit margin, the lower its cost of raising capital, the less initial capital the insurer will need to pledge. Proposition 2 is also testable though it is of the difficulty in estimating the insurers’ internal rates of return.
and the number of publicly traded life insurance companies is small. An indirect test, however, is plausible using book values of assets and liabilities and an implied capital volatility measure. That is, controlling for the size and book leverage of a life insurance company, its implied capital volatility should be negatively associated with its market value.

With reasonable parameterization of the model as shown in Appendix D, the testable predictions discussed above are visualized in Figure 3, where the x-axis is the cost coefficient $c$ (private cost of regulation) and the y-axis the equilibrium outcome variables: risky investment percentage, insurance liabilities as a percentage of total assets, and expected return on initial capital.

[Insert Figure 3 Here]

The equilibrium allocation to risky investments is between 30% and 40% and the initial insurance liabilities as a percentage of total assets between 85% and 98%, both of which are reasonable as shown later in the empirical section. There is no clear empirical reference for the expected excess return on initial capital, but a magnitude between 2% and 6% is arguably sensible if interpreted as a life insurer’s internal rate of return in excess of the risk-free rate. Hence, though not a calibration exercise, this numerical example provides evidence that the model is quantitatively viable.

D. Generalizability

I now discuss the model’s generalizability, in particular its relevance for the commercial banking industry. First, life insurers and commercial banks have fundamentally similar business characteristics in that they both sell products to households to raise funds, which become liabilities on their balance sheets, and then lend out these funds through capital-market investments and private loans. Both life insurers and commercial banks tend to hold long-duration fixed-income assets, have high leverage, and are subject to risk-based capital requirements, where regulatory capital tends to be costly. As a result, the model’s sequence of events and implied interaction between asset risk and liability risk are suitable for commercial banks.

There is one key difference between commercial banks and life insurers: there is significant maturity mismatch between banks’ assets and liabilities by construction, whereas life insurers generally do not face this issue, being better able to match the duration of their assets and liabilities. Con-
sequently, a large strand of the banking literature focuses on bank runs (e.g., Diamond and Dybvig (1983)). I argue that the stress scenario captured by my model, where a loss due to liability shock coinciding with default of the risky asset results in a shortfall of regulatory capital, is analogous to the situation where banks’ long-term assets are liquidated prematurely with a loss to fulfill a liquidity demand from depositors, resulting in a reduction in regulatory capital (in the spirit of Diamond and Dybvig (1983)). In that sense, the model is not only illustrative of life insurers, but also informative about the interaction between banks’ loan risk and liability risk. In particular, the intuition of both propositions is transferable to commercial banks: when regulatory capital becomes cheaper to acquire or the price of deposit insurance lower, banks would scale up by taking more deposits or issuing bank bonds, prudentially reduce lending risk per dollar of loans, and become more profitable, conditional on the assumption that commercial banks’ shareholders strive to preserve their charter value.

III. Empirical Design

I test the model’s predictions using a sample of U.S. life insurance companies over 2004Q4 — 2014Q4. The main variables include measures of investment risk calculated from insurers’ asset holdings and market prices and measures of insurance underwriting as implied by financial reports. Appendix E provides details of data sources and compilation. This section discusses the construction of main measures and the identification strategy.

A. Construction of Measures

A.1. Investment Risk Measures

I construct three main measures of insurers’ investment risk: the percentage of total assets invested in corporate bonds and loans, $c_{Bond\_loan\_inv}$, the percentage held in corporate bonds that are below NAIC category 1 (i.e., below single-A rating), $c_{Bond\_non\_NAIC1}$, and the corporate bond portfolio’s next-year monthly index-adjusted return volatility, $c_{Bond\_adj\_vol\_lead}$, where the index is the investment-grade index constructed by Robertson and Spiegel (2017). Specifically,
I define the following:

\[
cBond_{loan\_inv} = \frac{\text{Total Carrying Value of Corporate Bonds and Loans}}{\text{Total Invested Assets}} \times 100\% ;
\]

\[
cBond_{non\_NAIC1} = \frac{\text{Total Carrying Value of Corporate Bonds Rated Below A}}{\text{Total Invested Assets}} \times 100\% ;
\]

\[
cBond_{adj\_vol\_lead} = \frac{\text{Lead Annual Index-adjusted Bond Portfolio Return Volatility}}{\text{Total Invested Assets}} \times 100\% .
\]

The first two measures are proxies for default risk. The third measure captures the residual risk: the volatility of the insurer’s corporate bond portfolio (more than 95% in investment-grade on average), adjusted for the fluctuations in the aggregate investment-grade index, should reflect its residual risk.

I also calculate the two-year lead volatility of the reported quarterly net investment yields as an additional measure of investment risk. This measure captures the market risk embedded in mostly non-bond investments because when insurers report investment income, only those volatile, liquid assets are marked to market, where gains and losses are immediately recognized. Most bond investments’ market value movements are recorded as unrealized gains or losses in “other comprehensive income”. Thus, this measure is particularly useful to capture volatility of investment yields caused by stock investments. Specifically,

\[
Rep\_y\_vol\_lead = sd(\text{Two-year Lead Reported Quarterly Net Investment Yields}) \times 100\%
\]

For measuring the asset risk of life insurers, my data sets have one limitation: I do not observe the holdings of private-label mortgage-backed securities. Yet it is worth noting that though life insurers do allocate a reasonable portion of their investment portfolio to private-label mortgage backed securities,\(^{29}\) the largest national life insurance groups (e.g., MetLife, Prudential) account for half of such holdings in aggregate, and more than one third of the investments are categorized as high quality, “zero-loss” securities.\(^{30}\) As will be shown in Section IV, the empirical results are largely driven by smaller insurers, which alleviates concerns associated with this data limitation. I also run robustness tests regarding this data limitation, which I discuss in Section IV.

\(^{29}\)The “Other Structured Securities” in Figure A1 include private-label mortgage backed securities and other asset-backed securities.

\(^{30}\)For a detailed discussion on insurers’ investments in private-label MBS please refer to the NAIC study at https://www.naic.org/documents/cipr_study_161208_private-label_mortgage_securitization.pdf
A.2. Other Key Measures

I use the change in the sum of total liabilities and reserve credits taken from affiliated reinsurance vehicles (liability reduction due to financial reinsurance) as a proxy for the growth in insurance underwriting. At each measuring time $t$, I record the lead growth of insurance underwriting from $t$ to $t + 1$ so that the timing is consistent with that in the model. This measure, labeled as $Ins\_growth\_lead$, is used to test if the model’s intuition for the effect of capital financing cost on asset risk is valid.

I construct a lead measure for corporate-bond-driven capital volatility ($c\text{Bond}\_cap\_vol\_lead$) to test Proposition 2 from the model indirectly. The measure is calculated as the next-year corporate bond portfolio return volatility (standard deviation, scaled by total invested assets) divided by the reported capital ratio. As a result, this measure excludes the capital volatility caused by insurance risk and risky investments other than corporate bonds.

State-level indicators of the legality of financial reinsurance vehicles is obtained according to state insurance law information (Appendix B) and labeled as $Fin\_re\_state$. I identify the first date on which an indicator changes from zero to one as the year-end right before the year of the law change, as I assume insurers make financial decisions at that year-end with considerations of the law change already. For example, if a law changes (effective date) in the year of 2010, the first date on which the indicator equals one is 2009Q4.

The full list of variable definitions is presented in Table I.

[B. Identification Strategy]

I exploit staggered changes in state laws that legalize in-state financial reinsurance vehicles (SPFVs) to obtain causal inferences. The events are reflected in the time series by the variable $Fin\_re\_state$ changing from zero to one. The complete list of quasi-experiments is in Appendix B. I now discuss the validity of this identification strategy.

First, the legalization of in-state financial reinsurance vehicles tends to reduce local life insurers’ costs of raising regulatory capital. Compared to standard debt and equity, financial reinsurance is arguably the option most preferred by shareholders for raising regulatory capital due to the
following reasons: (1) neither debt nor equity financing involves a transfer of insurance risk on the statutory basis; (2) financial reinsurance transactions can be completed quickly and immediately reflected on the ceding insurer’s balance sheet; (3) the required rate of return tends to be lower since the reinsurance industry is concentrated into a number of national companies that have expertise in evaluating insurance claims and can achieve better diversification of insurance risk than does the ceding insurer. In addition, it is plausible that SPFV arrangements legalized in the domicile jurisdiction of the ceding insurer are preferred by the underlying reinsurance company than those in foreign jurisdictions. This is because the domicile state has regulatory and legal enforcement power on the ceding insurer, which helps prevent it from committing fraud or taking excessive risk. In other words, reinsurance companies can “free-ride” domestic state regulators to limit counter-party risk. This should be particularly important when the ceding insurer is small or not financially robust. Moreover, the collateral requirements for domestic SPFVs may be lower than those for foreign SPFVs. An example is Texas — if a Texas life insurer arranges an SPFV under a foreign jurisdiction, then the SPFV is required to maintain 100% collateral pledged for assets admitted from third-party guarantees (e.g., bank letters of credit), regardless of the underlying reinsurer’s financial strength. In contrast, if this insurer arranges the SPFV under a domestic jurisdiction, such collateral requirements are waived, regardless of the underlying reinsurer’s financial strength.

Second, the enactment of captive insurance laws is not likely rooted in the insurance industry. As the North Carolina example given in Appendix B shows, the main purpose of such legal changes is to attract non-financial firms to establish captives for self-insurance and thus improve state government revenue and local employment. In fact, the formation of a captive insurance firm (non-reinsurance ones) is usually the result of insurance market friction because it typically insures its parent’s otherwise uninsurable risk. Additionally, captive insurance is a unique type of business and its legality is not likely bundled with other legislation incentives. For example, it has been verified that the enactments of captive insurance laws in the sample period do not coincide with state corporate tax reforms.

Lastly, the assignment of treatment is straightforward since life insurers are regulated at the state level — the regulator of an insurer’s domicile state assumes core responsibilities of regulating

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32 Source: https://capitol.texas.gov/tlodocs/85R/analysis/html/SB01070F.htm
its financial solvency.\textsuperscript{33}

I conduct analyses using both the full sample and a stacked-cohort difference-in-differences sample. The latter has a time window of 5 years, from year-end $t-2$ to $t+2$ ($t$ is the first post-treatment time). The reason that the sample is formed at the annual frequency for 5 years, instead of the quarterly frequency as in the full sample, is threefold: (1) loan holdings and reinsurance reserve credits are only observable at each calendar year end; (2) using only year-end observations avoids the impact of unobservable seasonality in life insurers’ interim decisions; (3) since the reduction of capital raising costs implied by legal changes in the sample is expected to have mid- to long-term effects, a five year time window appears appropriate. In forming the stacked-cohort difference-in-differences sample, I match each treated insurer with control insurers. Matching is performed separately for each treatment event (cohort) with replacements. For a given treated insurer in a given cohort, control insurers are obtained through the following steps. First, I eliminate insurers domiciled in a state (other than the event state) that experiences a similar law change during the 5 year window. Second, I sort the average pre-event regulatory capital ratio and size of all insurers left in the cohort into quintiles. Third, I calculate the percentage differences of regulatory capital ratio and size between each potential control insurer and the given treated insurer, and take the average. Finally, I sort all potential control insurers according to the average difference calculated in the previous step, eliminate insurers with a difference more than 25\%, and select the three insurers with the smallest average difference as controls.\textsuperscript{34} Finally, I require that each insurer in the sample has at least one observation both before and after time $t$.

\textbf{C. Full Sample}

I start my full sample from 2004Q4, though my data sets provide earlier observations, due to the fact that the coverage of the TRACE corporate bond data set turns 100\% only in 2005; my sample ends at 2014Q4 due to the availability of the EMAXX holdings data.\textsuperscript{35} The final full sample contains 18,250 quarterly observations of 619 unique life insurers from 2004Q4 to 2014Q4.

\textsuperscript{33}This is true for insurers whose businesses cross state borders as well — although regional insurers interact with other state regulators for proof of compliance, their financial solvency is mainly evaluated in their state of domicile, whose jurisdiction has the authority to initiate receiverships if an insurer is determined insolvent.

\textsuperscript{34}In unreported regressions, I confirm that there is no material change in results if the upper bound of average difference in capital ratio and size is changed to 20\% or 30\%.

\textsuperscript{35}Forward-looking measures, such as insurance underwriting growth and return volatilities, are obtained with no issue since both TRACE and SNL Financials data are available after 2014.
Panel A of Table II provides the summary statistics. On average, corporate bond and loan investments account for 45% of an insurer’s invested assets during the sample period. The sample confirms that life insurers tend to invest in safer assets; non-category-one corporate bonds constitute no more than 15% of invested assets on average. During the sample period, life insurers’ underwriting business seem to grow at a reasonable rate (4.80%).

D. Stacked-cohort Difference-in-Differences Sample

Panel B and Panel C of Table II give the summary statistics and pre-treatment differences between the treated and matched control group, respectively. There are 2,392 observations that belong to 498 firm-cohorts in total. Variable distributions in Panel B appear to be similar to those in Panel A of Table II. Overall, the matched difference-in-differences sample seems to represent the quarterly full sample in an unbiased way. The tests for pre-treatment differences for the difference-in-differences sample as shown in Panel C suggest that the treated and control groups are reasonably well matched for all dependent variables, though none of these variables are involved in the matching criteria.

E. Empirical Specifications

With the quarterly full sample, I use the following regression specifications to test my model’s predictions:

\[
\text{Dependent}_i = \beta_{10} + \beta_{11} \cdot \text{Fin}_i + \beta_{12} \cdot \text{Size}_i + \alpha_i + \delta_i + \epsilon_i
\]

\[
\text{Dependent}_i = \beta_{20} + \beta_{21} \cdot \text{Fin}_i + \beta_{22} \cdot \text{Size}_i + \beta_{23} \cdot \text{Fin}_i \times \text{Size}_i + \alpha_i + \delta_i + \mu_i
\]

\[
\text{Dependent}_i = \beta_{30} + \beta_{31} \cdot \text{Fin}_i + \beta_{32} \cdot \text{Size}_i + \beta_{33} \cdot \text{Fin}_i \times \text{Low_fin_strength}_i + \alpha_i + \delta_i + \nu_i
\]

This does not take into account equity investments, which are very small, and private-label MBS investments, which are potentially riskier than category-one corporate bonds.
where \( i \) represents insurers and \( t \) time. The coefficients of interest are \( \beta_{j1} \) \((j = 1, 2, 3)\) and \( \beta_{k3} \) \((k = 2, 3)\). Based on model predictions, the conjecture is that when investment risk measures are the dependent variable, \( \beta_{j1} \) \((j = 1, 2, 3)\) and \( \beta_{33} \) should be negative, whereas \( \beta_{23} \) should be positive. When the lead insurance growth is the dependent variable, the conjectures are exactly the opposite. This is because a reduction in the cost of capital financing should lead to less average investment risk and more insurance underwriting, and such magnitude should be more prominent for insurers that are smaller or have lower financial strength because the larger or financially stronger an insurer is, the more likely it is reputable and has better access to capital financing resources, which implies the less impact legal changes in financial reinsurance may have. As the equations above suggest, firm and time fixed effects are controlled for in all regressions. Consequently, the coefficients of \( \text{Fin}_{-re}_{-state} \) are estimated largely based on its time-series variations.

I use the difference-in-differences sample to perform similar tests and achieve more reliable point estimates. The specifications are as follows:

\[
\begin{align*}
\text{Dependent}_{\text{var}}_{it} &= b_{10} + b_{11} \cdot \text{Treated}_i \times \text{Post}_t + a_{1ic} + d_{1t} + \epsilon_{it} \\
\text{Dependent}_{\text{var}}_{it} &= b_{20} + b_{21} \cdot \text{Treated}_i \times \text{Post}_t + d_{2t} \times \text{Small} \\
&+ b_{22} \cdot \text{Treated}_i \times \text{Post}_t \times \text{Small} + a_{2ic} + \mu_{it} \\
\text{Dependent}_{\text{var}}_{it} &= b_{30} + b_{31} \cdot \text{Treated}_i \times \text{Post}_t + d_{3t} \times \text{Low}_{-\text{fin}}_{-strength} \\
&+ b_{32} \cdot \text{Treated}_i \times \text{Post}_t \times \text{Low}_{-\text{fin}}_{-strength} + a_{3ic} + \nu_{it}
\end{align*}
\]  

where \( i \) represents insurers, \( ic \) insurer-cohort, and \( t \) time. The coefficients of interest are \( b_{m1} \) \((m = 1, 2, 3)\) and \( b_{s2} \) \((s = 2, 3)\). The specifications are generalized difference-in-differences tests, i.e., time and firm-cohort fixed effects are controlled for. The identifying assumption, besides the treatments being quasi-experiments, is that the marginal effect of the cost of raising regulatory capital on financial decisions is the same for insurers with similar size and regulatory capital ratio, after controlling for insurer and time fixed effects. Similarly, the conjecture is that when investment risk measures are the dependent variable, \( b_{j3} \) \((j = 1, 2, 3)\), \( b_{22} \), and \( b_{32} \) should all be negative, and when the lead insurance growth measure is the dependent variable, all conjectures are of the opposite sign.
IV. Results

In this section, I present the empirical results obtained using the specifications discussed in the previous section. Overall, the findings clearly support the model’s predictions that a reduction in the cost of raising regulatory capital leads life insurers to take less average investment risk and accelerate their insurance underwriting growth. The conjecture that the effect is more pronounced for smaller and financially less robust insurers is also confirmed by the results.

A. Investment Risk

In Table III, I test the effect of capital raising costs on the risk of life insurers’ investment portfolios using the full sample. In Panel A of Table III, I regress the total percentage of invested assets allocated to corporate bonds and mortgage loans on the $Fin_{re\_state}$ indicator and its interaction with size and the low-financial-strength indicator. The dependent variable mainly captures the default risk of the portfolio because the rest of the portfolio largely consists of high-quality assets. I control for size, firm fixed effects, and time fixed effects, to remove the effect of macroeconomic conditions and the time-invariant insurer characteristics that affect firm-level decisions. The standard errors are clustered at the state level. In column (1), the coefficient on $Fin_{re\_state}$ is negative and significant. The magnitude of $-3.59\%$, given the overall sample average of $cBond\_loan\_inv$, which is $44.87\%$, appears to be economically significant. The positive, significant coefficient on $Size$ is intuitive since larger insurers presumably have better resources for investment management and are thus able to take higher portfolio risk. In column (2), the magnitude of the coefficient on $Fin_{re\_state}$ significantly increases compared to column (1), and the interaction term with $Size$ has a positive and significant coefficient. This means the effect of capital raising costs on portfolio default risk is larger for smaller insurers. In column (3), the coefficient on the interaction term is of the expected sign, though insignificant statistically.

[Insert Table III Here]

In Panel B of Table III, I regress the total percentage of invested assets allocated to below-single-A assets on the $Fin_{re\_state}$ indicator and its interaction with size and the low-financial-strength indicator. The cutoff of the single-A rating follows the asset categorization of NAIC, which defines
assets rated at or above single A as category one, as illustrated in Figure 1. Results are consistent with those in Panel A. In column (1), the point estimate $-1.43$ means a decrease of 1.43% in the percentage of below-A investments, where the sample average is 13.17%. This appears to be economically significant. Note that the coefficient on the interaction of $\text{Fin}_\text{re}_\text{state}$ and $\text{Size}$ is insignificant, meaning larger insurers are equally likely to reduce non-category-one investments after a reduction in capital raising costs than smaller insurers.

In Panel C of Table III, the dependent variable is the index-adjusted lead volatility of the corporate bond portfolio returns. It mainly captures the residual risk of the corporate bond portfolio in addition to default risk. Although column (1) suggests a lack of overall effect, column (2) and column (3) suggest an effect on smaller and less financially robust insurers, which is consistent with the conjecture. In particular, if an insurer is of low financial strength (rated below A- or unrated by A.M. Best), column (3) indicates that a reduction in the cost of raising capital would lead to a decrease of 8 bps in its corporate bond investments’ index-adjusted volatility, where the overall sample average is 48 bps. Therefore, the effect is economically significant, though tiny in terms of absolute value.

In Table IV, I perform similar tests as those in Table III with the stacked-cohort difference-in-differences sample to achieve better identification and point estimates. Overall, the results are clearly consistent with those in Table III. In particular, in both Panel A and Panel B, the point estimate on $\text{Treated} \times \text{Post}$, $-3.28$ and $-1.34$, respectively, is close to the corresponding estimate in Table III, $-3.59$ and $-1.43$, respectively. The implication is that these estimates in the difference-in-difference setting, though obtained using a relatively small sample (number of observations is 2,392), appear to be reliable. Additionally, in Panel A, the coefficient on the triple interaction term in column (2) clearly indicates that the treatment effect of capital raising costs on the overall allocation to corporate bonds and loans is concentrated among smaller insurers.

In Panel C of Table IV, the significant coefficient on $\text{Treated} \times \text{Post}$ in column (1) suggests that there is indeed an overall treatment effect, though such effect is not found in the full sample. Since the difference-in-differences setting is meant to produce more accurate point estimates, it is plausible to conclude that the treatment effect of capital raising costs on the index-adjusted
volatility of insurers’ corporate bond investments is non-zero. In terms of magnitude, the 5 bps as identified in column (1) of Panel C appears to be meaningful, given the overall sample average of 48 bps. The significant coefficient on the triple interaction term in column (3) of Panel C confirms the corresponding result in Table III.

Next, in Table V, I examine if the portfolio risk associated with marked-to-market investments, mainly stocks and derivatives, changes after a reduction in capital financing costs. The non-results in both Panel A and Panel B clearly provides evidence that the results in Table III and Table IV are not likely driven by reallocation of investments from bonds to stocks and derivatives, which are arguably more risky. In other words, non-results in Table V help validate the interpretation of the findings previously discussed.

Therefore, the results presented in Tables III through V offer support for the model’s prediction that a reduction in the cost of raising regulatory capital leads life insurers to reduce average investment risk. Moreover, the decrease in average investment risk comes from both the default risk and residual risk of bond investments. The magnitude of the treatment effects appears to be economically meaningful.

B. Insurance Underwriting

I have now performed the main tests on the model’s prediction regarding investment risk. To further examine if the model’s predictions are valid, I conduct similar regression tests using the lead insurance underwriting measure as the dependent variable. The results are presented in Table VI.

In Panel A, the coefficients on Size are all negative and significant, which is intuitive since the larger the size of an insurer, the slower it tends to grow. In column (3) of Panel A, the negative coefficient on Fin_re_state appears to be in conflict with the conjecture, though the positive, significant coefficient on the interaction term indicates that my conjecture holds for less financially robust insurers. This should not be interpreted as evidence against the model predictions for two reasons. First, the calculation of insurance underwriting growth involves the reserve credits taken
from affiliated reinsurance, whose observations are available only at the annual frequency. As a result, the results obtained with the quarterly full sample are only suggestive, where point estimates tend not to be robust. Second, the corresponding test in Panel B with the difference-in-differences sample does not produce similar results, i.e., the first coefficient in column (3) of Panel B is positive and insignificant. In fact, both column (1) and column (3) of Panel B confirm the model predictions. The point estimate in column (1) of Panel B, 6.18%, is actually economically huge given the sample average of 5.07%. Admittedly, there is a possibility that this number is over-estimated — it is plausible that the state captive insurance law changes improve the local economy and household income, which then increase households’ participation in the life insurance market\footnote{See Krebs et al. (2015) for discussions on the relationship between household income and life insurance market participation.}. In other words, the estimate of 6.18% could contain a demand effect. Additionally, this result of increased insurance underwriting after a reduction in capital financing costs in the cross section is consistent with what Koijen and Yogo (2016) document for the aggregate.

Figure 4 summarizes the treatment effects of staggered state law changes on investment risk and insurance underwriting. In creating the plots, time fixed effects have been removed, and difference in the means of the treated and control groups have been adjusted for. The plots appear to satisfy the parallel-trend requirement. I perform robustness tests specific for the the parallel-trend assumption later.

C. Capital Volatility and Likelihood of Default

Given the results presented above, a natural question that arises is what the increased insurance underwriting growth and decreased average portfolio risk together imply for capital volatility and likelihood of default. It is difficult to have accurate estimation because I do not observe nor can I conveniently estimate the capital volatility implied by insurance risk. But a first step can be taken to answer this question by using the corporate-bond-driven capital volatility measure I have constructed. It captures the contribution of insurers’ corporate bond investments to their total capital volatility. Examining the treatment effect of a reduction in capital financing costs on this
measure, if any, is at least qualitatively informative.

In Table VII, I use the measure $cBond\_cap\_vol\_lead$, the lead corporate-bond-driven capital volatility, as the dependent variable and perform regression tests similar to previous ones. In column (1) of Panel A, the coefficient on $Fin\_re\_state$ is -0.93, which translates to 93 bps reduction. Given the sample mean of 774 bps, this effect is economically meaningful. The coefficients on Treated $\times$ Post in Panel B are largely similar in magnitude, where the point estimate of -1.39 in column (1) is arguably the most reliable. Although the coefficients on interaction terms with Low $fin\_strength$ in column (3) of both panels are of the expected sign, neither of them are statistically significant.

[Insert Table VII Here]

To analyze further the potential effect of the state law changes I use as quasi-experiments on the treated life insurers’ likelihood of default, I obtain details of life insurers’ receivership cases that initiated during the 12-year time window around the event year (6 years before and 6 years in or after) from the GRID database provided by NAIC.\footnote{https://isiteplus.naic.org/grid/gridPA.jsp} I record all such receiverships, including conservations, rehabilitations, and liquidations, of life insurers domiciled in the 9 event states as listed in Appendix B. It turns out that within the 12-year time window around the event year, only Missouri and Texas have life insurer receivership cases initiated. For each case, I record the total negative impact on insurance claim liabilities, i.e., the total dollar amount of losses on insurance claims due to the underlying insurer’s default. Figure 5 shows the results.

[Insert Figure 5 Here]

Missouri has 2 life insurer receivership cases during the 6 years before its event year 2007 and 2 during the 6 years after; Texas has 4 life insurer receivership cases during the 6 years before its event year 2013 and zero during the 6 years after. The total pre-event insurance claim losses of the two states is $513 million, while the post-event amount is $131 million. The total claim losses for a given receivership could be zero due to the fact that insurance claims can be transferred to solvent third parties. Admittedly, these data points do not enable statistically reliable conclusions, but at
least they do not suggest that life insurers domiciled in the event states become easier to default after the treatment.

D. Robustness

D.1. Potential Reallocation to MBS

Since I do not observe my sample insurers’ holdings in private-label mortgage-backed securities, the decrease in investment risk measures could be the result of an increase in private-label MBS purchases. To test for this alternative explanation, I interact the $Fin_{re\_state}$ indicator with a post-crisis indicator, defined as date later than or equal to 2009Q4, and run the full-sample regressions. The rationale is that since both new issuances and trading of private-label MBS significantly decreases after the 2007—2009 financial crisis, with the private-label RMBS market nearly dormant from 2010 to 2015, the coefficient of the interaction term should be positive and statistically significant should the alternative explanation holds.

[Insert Table VIII Here]

Table VIII summarizes the results. First, coefficients on the $Post\_crisis$ indicator are statistically significant in all regressions. In column (1) of Panel A, this coefficient is 6.15, which suggests that life insurers on average increased their allocation to corporate bonds and mortgage by 6.15% after the crisis. Together with the point estimate of 6.54 in column (2), the result actually indicates that life insurers reallocated investments, most likely private-label MBS investments, to mortgage loans and below-A corporate bonds after the crisis because private-label MBS were widely downgraded. Second, coefficient estimates of the interaction term $Fin\_re\_state \times Post\_crisis$ are neither statistically significant nor economically meaningful in any regression. Therefore, it is implausible that the findings discussed previously are driven by reallocation of investments to private-label MBS.

D.2. Difference-in-Differences Parallel Trend

I have shown in Figure 4 that the parallel trend assumption for the difference-in-differences tests is likely satisfied. To test this assumption formally, I use the difference-in-differences sample and re-run the tests by interacting the $Treated$ indicator with all time indicators, as in Table IX.
There are five time indicators \((t - 2)\) to \((t + 2)\), and the interaction \(Treated \times (t - 2)\) is used as the benchmark. The dependent variable is the total percentage of assets invested in corporate bonds and loans \((cBond\_loan\_inv)\) in column (1), the percentage of invested assets held in corporate bonds that are below single A \((cBond\_non\_NAIC1)\) in column (2), the corporate bond portfolio’s next-year monthly index-adjusted return volatility in percentage \((cBond\_adj\_vol\_lead)\) in column (3), the lead growth of insurance underwriting in percentage \((Ins\_growth\_lead)\) in column (4), and the corporate-bond-driven capital volatility in percentage \((cBond\_cap\_vol\_lead)\) in column (5). In column (1) and column (3), the treatment effect starts at time \(t + 1\), whereas in column (2) and column (5), the treatment effect is not significant until time \(t + 2\). These results suggest that the treatment effects identified in this study kick in shortly after the event, which is reasonable given the fact that life insurers are able to quickly adjust their investment portfolios.

V. Conclusion

This paper studies the effect of the costs of raising regulatory capital on life insurers’ investment risk. Using both a simple model and empirical tests, I show that when regulatory capital becomes cheaper to acquire, life insurers lower the risk taken per unit of invested assets and increase the growth of their insurance underwriting business. These findings serve as novel evidence that the costs of raising regulatory capital play an essential role in the decision making of regulated financial institutions. Moreover, I show that a reduction in the cost of raising regulatory capital does not necessarily lead to higher likelihood of default for life insurers.

The findings in this paper challenge a standard thinking on financial regulation: relaxed regulatory standards lead to increased risk-taking incentives. As shown in the model and in the empirical tests, the reason why this standard thinking might not be the full picture is that the scale of financial institutions is not exogenous to regulation and that shareholders of these institutions may take efforts to preserve the charter value in stress scenarios instead of walking away. Indeed, insurers and banks in real life tend to target a capital buffer level and strive to comply with regulation, a characteristic that academic research on financial institutions and financial regulation usually fails to internalize. This paper argues that such considerations may be essential, especially for smaller,
less advantaged institutions that lack access to capital management resources.

While this paper focuses on the life insurance industry, the intuitions embedded in the findings can be tested in both the property and casualty insurance and commercial banking industry. For example, the liability securitization through catastrophe-linked bonds used by property and casualty insurers has similar functionalities as life insurers’ financial reinsurance programs. Thus, it would be interesting to see how the pricing of catastrophe-linked bonds affects property and casualty insurers’ investment choices. One can also identify exogenous variations in the cost of external equity or deposit insurance and test the resulting changes in commercial banks’ depository debt and lending decisions. It might be plausible that smaller, regional commercial banks’ behaviors are akin to those of life insurers studied in this paper.
REFERENCES


Lawsky, Benjamin M, 2013, Shining a light on shadow insurance: A little-known loophole that puts insurance policyholders and taxpayers at greater risk, *Unpublished Manuscript, New York State Department of Financial Services*.


Figure 1. RBC Requirements for Life Insurers’ Investments

Figure 1 depicts the capital requirements for security investments according to the NAIC as of 2016, with an exception of private-label mortgage-backed securities, whose capital requirements have been specified using model estimations instead of credit rating starting from 2010. The numbers at the end of the bars are the risk factors used to multiple the corresponding assets’ carrying values. The sum of these products, adjusted for covariance with interest rate risk, is the amount of minimum capital a life insurer is required to hold for its investments.

Figure 2. Quasi-experiments

Figure 2 visualizes the states whose legalization of financial reinsurance in the form of Special Purpose Financial Vehicles is used as quasi-experiments (colored green) for the sample period over 2004 — 2014. For any such state, the year next to its abbreviation on the map is the year of law change.
Figure 3 visualizes the model’s predictions that life insurers’ private cost of financial regulation is positively (negatively) associated with their asset risk (profitability). The intuition is that when regulatory capital becomes cheaper to acquire, life insurers would scale up their insurance business and prudentially reduce average portfolio investment risk. “Risky Investments” corresponds to the percentage value of $x$, “Insurance Liabilities” the percentage value of $D_0/\left[ W_0 + (1 + m)D_0 \right]$, and “Expected Return on Capital” the percentage value of $(E[V_3] - V)/W_0$. 
Figure 4. Difference-in-Differences: Treatment Effects

Figure 4 visualizes the impact of staggered state insurance law changes that reduces life insurers’ private costs of regulation on their asset risk taking, insurance underwriting, and implied capital volatility in the difference-in-differences estimation. The treatment happens in between time $-1$ and time 0 (the dashed vertical line), namely year-end 0 is the first treated. The values on the plots are group averages that have been adjusted for time fixed effects and the difference in the overall mean of the treated group and that of the control group.
Figure 5 visualizes the default cases of life insurers in event states during the 12-year time window around the corresponding events (6 years before and 6 years in or after). Among the 9 states that are used as quasi-experiments, only Missouri and Texas have life insurer receivership cases during the time window. The top chart shows the total number of receivership cases; the bottom chart shows the total dollar amount of insurance claim losses associated with these receivership cases. The total claim losses for a given receivership could be zero due to the fact that insurance claims can be transferred to solvent third parties. Data is collected from the GRID database provided by NAIC.
### Table I
**Definition of Variables**

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>cBond_Loan_inv</td>
<td>The percentage of invested assets in corporate bonds and mortgage loans.</td>
</tr>
<tr>
<td>cBond_non_NAIC1</td>
<td>The amount of corporate bond investments that have a lower credit rating than NAIC Category 1, i.e., below single A rating; scaled by total invested assets, in percentage.</td>
</tr>
<tr>
<td>cBond_adj_vol_lead</td>
<td>The expected index-adjusted volatility of an insurer’s corporate bond portfolio’s value-weighted monthly returns, where the index is investment-grade bond index and expected volatility is calculated using next-year realized returns; scaled by total invested assets.</td>
</tr>
<tr>
<td>Rep_y_vol_lead</td>
<td>The standard deviation of an insurer’s reported quarterly investment yields for the next 2 years, annualized, which reflect the risk of asset classes that marked to market for income reporting (common stock, derivatives, etc.).</td>
</tr>
<tr>
<td>cBond_cap_vol_lead</td>
<td>The lead investment-driven capital volatility calculated using an insurer’s corporate bond portfolio’s next-year return volatility divided by its current capital ratio.</td>
</tr>
<tr>
<td>Ins_growth_lead</td>
<td>The next-year percentage growth in outstanding insurance claims. The amount of outstanding insurance claims is defined as the sum of total liabilities and the amount of reserve credit taken from affiliated reinsurance arrangements.</td>
</tr>
<tr>
<td>Low_fin_strength</td>
<td>An indicator that equals 1 if the A.M. Best financial strength rating is below A- and zero otherwise (and zero for unrated insurers).</td>
</tr>
<tr>
<td>Leverage</td>
<td>One minus the reported capital ratio.</td>
</tr>
<tr>
<td>Size</td>
<td>Logarithm of total book assets.</td>
</tr>
<tr>
<td>Fin_re_state</td>
<td>An indicator that is equal to one if the state in which an insurer is domiciled allows in-state financial reinsurance vehicles.</td>
</tr>
</tbody>
</table>
Table II
Summary Statistics

Panel A: Full Sample
(Quarterly Data; Annualized Values; 2004Q4 — 2014Q4)

<table>
<thead>
<tr>
<th></th>
<th>No. of Obs.</th>
<th>Mean</th>
<th>SD</th>
<th>p25</th>
<th>p50</th>
<th>p75</th>
</tr>
</thead>
<tbody>
<tr>
<td>cBond_loan_inv (%)</td>
<td>18,250</td>
<td>44.87</td>
<td>26.78</td>
<td>24.35</td>
<td>43.25</td>
<td>60.70</td>
</tr>
<tr>
<td>cBond_non_NAIC1 (%)</td>
<td>18,250</td>
<td>13.17</td>
<td>11.07</td>
<td>4.04</td>
<td>10.77</td>
<td>19.75</td>
</tr>
<tr>
<td>cBond_adj_vol_lead (%)</td>
<td>18,249</td>
<td>0.48</td>
<td>0.44</td>
<td>0.19</td>
<td>0.37</td>
<td>0.62</td>
</tr>
<tr>
<td>Rep_y_vol_lead (%)</td>
<td>17,631</td>
<td>0.56</td>
<td>0.73</td>
<td>0.15</td>
<td>0.29</td>
<td>0.63</td>
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<tr>
<td>cBond_cap_vol_lead (%)</td>
<td>18,236</td>
<td>7.94</td>
<td>10.57</td>
<td>1.33</td>
<td>4.06</td>
<td>10.22</td>
</tr>
<tr>
<td>Ins_growth_lead (%)</td>
<td>17,554</td>
<td>4.79</td>
<td>39.54</td>
<td>-4.42</td>
<td>2.38</td>
<td>10.47</td>
</tr>
<tr>
<td>Low_fin_strength</td>
<td>18,250</td>
<td>0.13</td>
<td>0.34</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Leverage</td>
<td>18,236</td>
<td>0.71</td>
<td>0.25</td>
<td>0.57</td>
<td>0.82</td>
<td>0.90</td>
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<tr>
<td>Size</td>
<td>18,250</td>
<td>12.59</td>
<td>2.67</td>
<td>10.48</td>
<td>12.49</td>
<td>14.49</td>
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<td>Fin_re_state</td>
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<td>0.18</td>
<td>0.38</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

No. of Firms: 619

Panel B: Stacked-cohort Difference-in-Differences Sample
(Annual Year-end Data; t − 2 to t + 2)

<table>
<thead>
<tr>
<th></th>
<th>No. of Obs.</th>
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<th>SD</th>
<th>p25</th>
<th>p50</th>
<th>p75</th>
</tr>
</thead>
<tbody>
<tr>
<td>cBond_loan_inv (%)</td>
<td>2,392</td>
<td>45.39</td>
<td>25.56</td>
<td>27.51</td>
<td>44.38</td>
<td>60.30</td>
</tr>
<tr>
<td>cBond_non_NAIC1 (%)</td>
<td>2,392</td>
<td>13.32</td>
<td>10.42</td>
<td>4.96</td>
<td>11.32</td>
<td>19.72</td>
</tr>
<tr>
<td>cBond_adj_vol_lead (%)</td>
<td>2,392</td>
<td>0.45</td>
<td>0.39</td>
<td>0.19</td>
<td>0.35</td>
<td>0.60</td>
</tr>
<tr>
<td>Rep_y_vol_lead (%)</td>
<td>2,130</td>
<td>0.55</td>
<td>0.68</td>
<td>0.16</td>
<td>0.30</td>
<td>0.62</td>
</tr>
<tr>
<td>Inv_cap_vol_lead (%)</td>
<td>2,392</td>
<td>7.74</td>
<td>9.59</td>
<td>1.46</td>
<td>4.21</td>
<td>10.28</td>
</tr>
<tr>
<td>Ins_growth_lead (%)</td>
<td>2,113</td>
<td>5.07</td>
<td>27.61</td>
<td>-3.57</td>
<td>2.73</td>
<td>8.74</td>
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<tr>
<td>Low_fin_strength</td>
<td>2,392</td>
<td>0.18</td>
<td>0.38</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Leverage</td>
<td>2,392</td>
<td>0.71</td>
<td>0.24</td>
<td>0.56</td>
<td>0.82</td>
<td>0.90</td>
</tr>
<tr>
<td>Size</td>
<td>2,392</td>
<td>12.50</td>
<td>2.48</td>
<td>10.69</td>
<td>12.41</td>
<td>14.14</td>
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No. of Firm-cohorts: 498

Panel C: Difference-in-Differences Pre-treatment Sample Means and Medians
(Treated (T) vs. Control (C); t − 2 to t − 1)

<table>
<thead>
<tr>
<th></th>
<th>T_Mean</th>
<th>C_Mean</th>
<th>T_Med</th>
<th>C_Med</th>
<th>t-test</th>
<th>Rank-Sum p</th>
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<td>cBond_loan_inv (%)</td>
<td>45.93</td>
<td>44.94</td>
<td>44.87</td>
<td>42.53</td>
<td>0.52</td>
<td>0.31</td>
</tr>
<tr>
<td>cBond_non_NAIC1 (%)</td>
<td>13.39</td>
<td>12.28</td>
<td>10.88</td>
<td>10.53</td>
<td>1.52</td>
<td>0.24</td>
</tr>
<tr>
<td>cBond_adj_vol_lead (%)</td>
<td>0.42</td>
<td>0.41</td>
<td>0.33</td>
<td>0.33</td>
<td>0.38</td>
<td>0.78</td>
</tr>
<tr>
<td>Rep_y_vol_lead (%)</td>
<td>2.130</td>
<td>0.55</td>
<td>0.68</td>
<td>0.16</td>
<td>0.30</td>
<td>0.62</td>
</tr>
<tr>
<td>cBond_cap_vol_lead (%)</td>
<td>6.38</td>
<td>6.68</td>
<td>3.69</td>
<td>3.90</td>
<td>-0.51</td>
<td>0.48</td>
</tr>
<tr>
<td>Ins_growth_lead (%)</td>
<td>3.16</td>
<td>6.88</td>
<td>1.50</td>
<td>3.47</td>
<td>-1.71</td>
<td>0.33</td>
</tr>
<tr>
<td>Low_fin_strength</td>
<td>0.20</td>
<td>0.16</td>
<td>0</td>
<td>0</td>
<td>1.21</td>
<td>0.23</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.71</td>
<td>0.72</td>
<td>0.82</td>
<td>0.83</td>
<td>-0.79</td>
<td>0.60</td>
</tr>
<tr>
<td>Size</td>
<td>12.44</td>
<td>12.48</td>
<td>12.35</td>
<td>12.41</td>
<td>-0.23</td>
<td>0.88</td>
</tr>
</tbody>
</table>
This table shows results of regressing investment risk measures of life insurers' investments on the Fin_re_state indicator, size, and low-financial strength indicator (Low_fin_strength) using the quarterly full sample. A Fin_re_state indicator of 1 represents a reduction in the cost of raising regulatory capital; the Low_fin_strength indicator equals 1 if the insurer is rated below A- by A.M. Best and zero otherwise. The dependent variable is the total percentage of assets invested in corporate bonds and loans (cBond_loan_inv) in Panel A, the percentage of invested assets held in corporate bonds that are below single-A rating (cBond_non_NAIC1) in Panel B, and the corporate bond portfolio's next-year monthly index-adjusted return volatility in percentage (cBond_adj_vol_lead) in Panel C. Firm and time fixed effects have been controlled for in all regressions (the variable Low_fin_strength is absorbed by the firm fixed effects); standard errors are clustered at the state level. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

### Panel A: Percentage of Risky Investments

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin_re_state</td>
<td>-3.59**</td>
<td>-17.47***</td>
<td>-3.39**</td>
</tr>
<tr>
<td></td>
<td>(1.58)</td>
<td>(4.90)</td>
<td>(1.36)</td>
</tr>
<tr>
<td>Size</td>
<td>3.61**</td>
<td>3.28*</td>
<td>3.61**</td>
</tr>
<tr>
<td></td>
<td>(1.64)</td>
<td>(1.64)</td>
<td>(1.64)</td>
</tr>
<tr>
<td>Fin_re_state × Size</td>
<td>1.101***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fin_re_state × Low_fin_strength</td>
<td>-2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.86)</td>
<td></td>
<td></td>
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<tr>
<td>Observations</td>
<td>18,250</td>
<td>18,250</td>
<td>18,250</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.097</td>
<td>0.100</td>
<td>0.090</td>
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</table>

### Panel B: Percentage of Below-single-A Investments

<table>
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<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin_re_state</td>
<td>-1.43***</td>
<td>-5.72*</td>
<td>-1.51***</td>
</tr>
<tr>
<td></td>
<td>(0.51)</td>
<td>(2.88)</td>
<td>(0.56)</td>
</tr>
<tr>
<td>Size</td>
<td>1.93***</td>
<td>1.83***</td>
<td>1.93***</td>
</tr>
<tr>
<td></td>
<td>(0.67)</td>
<td>(0.65)</td>
<td>(0.67)</td>
</tr>
<tr>
<td>Fin_re_state × Size</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fin_re_state × Low_fin_strength</td>
<td>-0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>18,250</td>
<td>18,250</td>
<td>18,250</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.219</td>
<td>0.220</td>
<td>0.210</td>
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</table>

### Panel C: Lead Index-adjusted Return Volatility of Bond Investments

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<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin_re_state</td>
<td>-0.02</td>
<td>-0.25***</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.06)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Size</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Fin_re_state × Size</td>
<td>0.02***</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fin_re_state × Low_fin_strength</td>
<td>-0.08**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
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<td>18,249</td>
<td>18,249</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.290</td>
<td>0.291</td>
<td>0.290</td>
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</tbody>
</table>

40
Table IV  
Capital Raising Costs and Investment Risk: Difference-in-Differences

This table shows results of regressing investment risk measures of life insurers’ investments on the treatment indicator using the stacked-cohort difference-in-differences sample. The time window is from year $t-2$ to $t+2$, where the first post-treatment time is year-end $t$. The dependent variable is the total percentage of assets invested in corporate bonds and loans ($cBond_{loan-inv}$) in Panel A, the percentage of invested assets held in corporate bonds that are below single-A rating ($cBond_{non-NAIC1}$) in Panel B, and the corporate bond portfolio’s next-year monthly index-adjusted return volatility in percentage ($cBond_{adj_vol_lead}$) in Panel C. Each treated observation is matched to three control observations using pre-event size and capital ratio, forming a “matched group”. The Small indicator equals one for firms whose average pre-event size is below the median of their corresponding cohorts and zero otherwise; the Low_fin_strength indicator equals one if the insurer is rated below A- by A.M. Best and zero otherwise. In column (1) of all panels, time and firm-by-cohort fixed effects are controlled for; in columns (2) and (3) of all panels, time-by-subgroup (subgroups formed according to Small or Low_fin_strength) and firm-by-cohort fixed effects are controlled for. Standard errors are clustered at the matched-group level. Robust standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

### Panel A: Percentage of Risky Investments

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated $\times$ Post</td>
<td>-3.28***</td>
<td>-1.40</td>
<td>-3.39**</td>
</tr>
<tr>
<td></td>
<td>(1.20)</td>
<td>(1.37)</td>
<td>(1.31)</td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Small</td>
<td>-3.79*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Low_fin_strength</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.90)</td>
</tr>
<tr>
<td>Observations</td>
<td>2,392</td>
<td>2,392</td>
<td>2,392</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.012</td>
<td>0.023</td>
<td>0.015</td>
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</table>

### Panel B: Percentage of Below-single-A Investments

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated $\times$ Post</td>
<td>-1.34*</td>
<td>-1.15*</td>
<td>-1.30*</td>
</tr>
<tr>
<td></td>
<td>(0.68)</td>
<td>(0.61)</td>
<td>(0.77)</td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Small</td>
<td>-0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Low_fin_strength</td>
<td>-0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.72)</td>
</tr>
<tr>
<td>Observations</td>
<td>2,392</td>
<td>2,392</td>
<td>2,392</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.039</td>
<td>0.048</td>
<td>0.044</td>
</tr>
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</table>

### Panel C: Lead Index-adjusted Return Volatility of Bond Investments

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
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<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated $\times$ Post</td>
<td>-0.05*</td>
<td>-0.04</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Small</td>
<td>-0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Low_fin_strength</td>
<td>-0.16**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.08)</td>
</tr>
<tr>
<td>Observations</td>
<td>2,392</td>
<td>2,392</td>
<td>2,392</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.079</td>
<td>0.129</td>
<td>0.087</td>
</tr>
</tbody>
</table>
Table V  
Capital Raising Costs and Risk of Reported Investment Yields

This table shows results of regressing the standard deviation of quarterly reported investment yields for the next two years ($Rep_{y_{vol_{lead}}}$), which reflects the lead volatility of marked to market investments, mostly non-bonds, on the Fin_re_state indicator, size, and low-financial strength indicator. A Fin_re_state indicator of 1 represents a reduction in the cost of raising regulatory capital; the Low_fin_strength indicator equals 1 if the insurer is rated below A- by A.M. Best and zero otherwise. Panel A shows the results with the full sample. In Panel A, firm and time fixed effects are controlled for in all regressions (the indicator Low_fin_strength is absorbed by firm fixed effects); standard errors are clustered at the state level. Panel B shows results with the stacked-cohort difference-in-differences sample. The time window is from year $t - 2$ to $t + 2$, where the first post-treatment time is year-end $t$. Each treated observation is matched to three control observations using pre-event size and capital ratio, forming a “matched group”. The “Small” indicator equals one for firms whose average pre-event size is below the median of their corresponding cohorts and zero otherwise. In column (1) of Panel B, time and firm-by-cohort fixed effects are controlled for; in columns (2) and (3) of Panel B, time-by-subgroup (subgroups formed according to Small or Low_fin_strength) and firm-by-cohort fixed effects are controlled for. Standard errors are clustered at the matched-group level. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

<table>
<thead>
<tr>
<th>Panel A: Full Sample</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td><strong>Fin_re_state</strong></td>
<td>0.03</td>
<td>-0.12</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.22)</td>
<td>(0.04)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>-0.02</td>
<td>-0.03</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td><strong>Fin_re_state × Size</strong></td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fin_re_state × Low_fin_strength</strong></td>
<td></td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>17,631</td>
<td>17,631</td>
<td>17,631</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.059</td>
<td>0.059</td>
<td>0.060</td>
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<table>
<thead>
<tr>
<th>Panel B: Difference-in-Differences</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td><strong>Treated × Post</strong></td>
<td>-0.02</td>
<td>-0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.09)</td>
<td>(0.07)</td>
</tr>
<tr>
<td><strong>Treated × Post × Small</strong></td>
<td></td>
<td>-0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td><strong>Treated × Post × Low_fin_strength</strong></td>
<td></td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.16)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>2,130</td>
<td>2,130</td>
<td>2,130</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.001</td>
<td>0.005</td>
<td>0.004</td>
</tr>
</tbody>
</table>

42
Table VI
Capital Raising Costs and Insurance Underwriting Growth

This table shows regressions that test the effect of capital raising costs on the lead growth of insurance underwriting (Ins_growth_lead, in percentage). A Fin_re_state indicator of 1 represents a reduction in the cost of raising regulatory capital. Panel A presents results with the full sample, Panel B shows the stacked-cohort difference-in-differences tests, and Panel C the robustness check. The time window for the difference-in-differences is from year \( t - 2 \) to \( t + 2 \), where the first post-treatment time is year-end \( t \). In Panel A, time and firm fixed effects are controlled for (the indicator Low_fin_strength is absorbed by the firm fixed effects); in Panel B column (1), time and firm-by-cohort fixed effects are controlled for; in Panel B columns (2) and (3), time-by-subgroup (subgroups formed according to Small or Low_fin_strength) and firm-by-cohort fixed effects are controlled for. Standard errors are clustered at the state level for Panel A and the matched-group level for Panel B. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

<table>
<thead>
<tr>
<th>Panel A: Full Sample</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin_re_state</td>
<td>-0.57</td>
<td>-11.19</td>
<td>-2.23*</td>
</tr>
<tr>
<td></td>
<td>(1.66)</td>
<td>(9.98)</td>
<td>(1.18)</td>
</tr>
<tr>
<td>Size</td>
<td>-12.08***</td>
<td>-12.31***</td>
<td>-12.07***</td>
</tr>
<tr>
<td></td>
<td>(1.94)</td>
<td>(1.93)</td>
<td>(2.02)</td>
</tr>
<tr>
<td>Fin_re_state × Size</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fin_re_state × Low_fin_strength</td>
<td></td>
<td></td>
<td>8.50**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(3.28)</td>
</tr>
<tr>
<td>Observations</td>
<td>17,554</td>
<td>17,554</td>
<td>17,554</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.019</td>
<td>0.019</td>
<td>0.019</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Difference-in-Differences</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated × Post</td>
<td>6.18**</td>
<td>2.66</td>
<td>3.25</td>
</tr>
<tr>
<td></td>
<td>(2.84)</td>
<td>(3.11)</td>
<td>(2.85)</td>
</tr>
<tr>
<td>Treated × Post × Small</td>
<td>7.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated × Post × Low_fin_strength</td>
<td></td>
<td></td>
<td>14.53*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(8.15)</td>
</tr>
<tr>
<td>Observations</td>
<td>2,113</td>
<td>2,113</td>
<td>2,113</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.013</td>
<td>0.018</td>
<td>0.017</td>
</tr>
</tbody>
</table>
Table VII
Capital Raising Costs and Corporate-bond-driven Capital Volatility

This table shows regressions that test the effect of capital raising costs on corporate-bond-driven capital volatility ($cBond\_cap\_vol\_lead$, in percentage). A $Fin\_re\_state$ indicator of 1 represents a reduction in the cost of raising regulatory capital; the $Low\_fin\_strength$ indicator equals 1 if the insurer is rated below A- by A.M. Best and zero otherwise. Panel A presents results with the full sample; Panel B shows the stacked-cohort difference-in-differences tests. The time window for the difference-in-differences is from year $t - 2$ to $t + 2$, where the first post-treatment time is year-end $t$. Each treated observation is matched to three control observations using pre-event size and capital ratio, forming a “matched group”. The “Small” indicator equals one for firms whose average pre-event size is below the median of their corresponding cohorts and zero otherwise. In Panel A, time and firm fixed effects are controlled for (the indicator $Low\_fin\_strength$ is absorbed by the firm fixed effects); in Panel B column (1), time and firm-by-cohort fixed effects are controlled for; in Panel B columns (2) and (3), time-by-subgroup (subgroups formed according to Small or $Low\_fin\_strength$) and firm-by-cohort fixed effects are controlled for. Standard errors are clustered at the firm level for Panel A and the matched-group level for Panel B. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

### Panel A: Full Sample

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Fin_re_state$</td>
<td>-0.93**</td>
<td>-2.58</td>
<td>-0.72</td>
</tr>
<tr>
<td></td>
<td>(0.46)</td>
<td>(1.87)</td>
<td>(0.43)</td>
</tr>
<tr>
<td>Size</td>
<td>3.07****</td>
<td>3.03****</td>
<td>3.07</td>
</tr>
<tr>
<td></td>
<td>(0.52)</td>
<td>(0.52)</td>
<td>(0.58)</td>
</tr>
<tr>
<td>$Fin_re_state \times Size$</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Fin_re_state \times Low_fin_strength$</td>
<td></td>
<td></td>
<td>-1.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.59)</td>
</tr>
<tr>
<td>Observations</td>
<td>18,236</td>
<td>18,236</td>
<td>18,236</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.204</td>
<td>0.204</td>
<td>0.204</td>
</tr>
</tbody>
</table>

### Panel B: Difference-in-Differences

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated $\times$ Post</td>
<td>-1.39***</td>
<td>-1.25**</td>
<td>-0.91**</td>
</tr>
<tr>
<td></td>
<td>(0.40)</td>
<td>(0.58)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Small</td>
<td>-0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.83)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated $\times$ Post $\times$ Low_fin_strength</td>
<td></td>
<td>-2.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.77)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>2,392</td>
<td>2,392</td>
<td>2,392</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.069</td>
<td>0.097</td>
<td>0.078</td>
</tr>
</tbody>
</table>
Table VIII

Capital Raising Costs and Investment Risk: Before and After the Crisis

This table shows regressions that test if there is a difference in the effect of capital raising costs on life insurers’ investment risk taking before and after the 2007 — 2009 financial crisis (date later than or equal to 2009Q4), during which a significant amount of structured securities were downgraded. A *Fin_re_state* indicator of 1 represents a reduction in the cost of raising regulatory capital. The interaction term of *size* and the *Fin_re_state* indicator captures the heterogeneity in the treatment effect. The dependent variable is the total percentage of assets invested in corporate bonds and loans (*cBond_loan_inv*) in column (1), the percentage of invested assets held in corporate bonds that are below single A (*cBond_non_NAIC1*) in column (2), the corporate bond portfolio’s next-year monthly index-adjusted return volatility in percentage (*cBond_adj_vol_lead*) in column (3), and the standard deviation of quarterly reported investment yields for the next two years (*Rep_y_vol_lead*), which reflects the lead volatility of marked to market investments, mostly non-bonds, in column (4). Firm and time fixed effects have been controlled for in all regressions (the indicator *Low_fin_strength* is absorbed by the firm fixed effects); standard errors are clustered at the state level. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fin_re_state</strong></td>
<td>-3.73**</td>
<td>-1.42</td>
<td>-0.06</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(1.81)</td>
<td>(1.01)</td>
<td>(0.04)</td>
<td>(0.07)</td>
</tr>
<tr>
<td><strong>Post_crisis</strong></td>
<td>6.15***</td>
<td>6.54***</td>
<td>-0.16***</td>
<td>-0.57***</td>
</tr>
<tr>
<td></td>
<td>(1.51)</td>
<td>(0.68)</td>
<td>(0.02)</td>
<td>(0.05)</td>
</tr>
<tr>
<td><strong>Fin_re_state × Post_crisis</strong></td>
<td>0.18</td>
<td>-0.01</td>
<td>0.05</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(2.05)</td>
<td>(1.08)</td>
<td>(0.05)</td>
<td>(0.07)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>3.61**</td>
<td>1.93***</td>
<td>0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(1.50)</td>
<td>(0.57)</td>
<td>(0.03)</td>
<td>(0.05)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>18,250</td>
<td>18,250</td>
<td>18,250</td>
<td>17,631</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.097</td>
<td>0.219</td>
<td>0.599</td>
<td>0.060</td>
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</table>
Table IX
Difference-in-Differences Robustness Tests

This table shows results of regressions to check for pre-treatment trend using the stacked-cohort difference-in-differences sample. The time window is from year \( t - 2 \) to \( t + 2 \), where the first post-treatment time is year-end \( t \). The dependent variable is the total percentage of assets invested in corporate bonds and loans (\( cBond\_loan\_inv \)) in column (1), the percentage of invested assets held in corporate bonds that are below single A (\( cBond\_non\_NAIC1 \)) in column (2), the corporate bond portfolio’s next-year monthly index-adjusted return volatility in percentage (\( cBond\_adj\_vol\_lead \)) in column (3), the lead growth of insurance underwriting in percentage (\( Ins\_growth\_lead \)) in column (4), and the corporate-bond-driven capital volatility in percentage (\( cBond\_cap\_vol\_lead \)) in column (5). Each treated observation is matched to three control observations using pre-event size and capital ratio, forming a “matched group”. Time and firm-by-cohort fixed effects have been controlled for in all regressions; standard errors are clustered at the matched-group level. Robust standard errors are reported in parentheses; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

<table>
<thead>
<tr>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated × (t-1)</td>
<td>-0.85</td>
<td>-0.20</td>
<td>-0.02</td>
<td>-0.59</td>
<td>-0.11</td>
</tr>
<tr>
<td></td>
<td>(1.01)</td>
<td>(0.43)</td>
<td>(0.02)</td>
<td>(3.27)</td>
<td>(0.32)</td>
</tr>
<tr>
<td>Treated × t</td>
<td>-2.23</td>
<td>-1.09</td>
<td>-0.03</td>
<td>7.01</td>
<td>-1.09</td>
</tr>
<tr>
<td></td>
<td>(1.49)</td>
<td>(0.84)</td>
<td>(0.03)</td>
<td>(4.28)</td>
<td>(0.67)</td>
</tr>
<tr>
<td>Treated × (t+1)</td>
<td>-3.75**</td>
<td>-1.23</td>
<td>-0.08**</td>
<td>4.39</td>
<td>-1.17</td>
</tr>
<tr>
<td></td>
<td>(1.52)</td>
<td>(0.83)</td>
<td>(0.04)</td>
<td>(3.58)</td>
<td>(0.77)</td>
</tr>
<tr>
<td>Treated × (t+2)</td>
<td>-5.24***</td>
<td>-2.04**</td>
<td>-0.08**</td>
<td>6.63</td>
<td>-2.10***</td>
</tr>
<tr>
<td></td>
<td>(1.78)</td>
<td>(0.86)</td>
<td>(0.04)</td>
<td>(5.05)</td>
<td>(0.75)</td>
</tr>
<tr>
<td>Observations</td>
<td>2.392</td>
<td>2.392</td>
<td>2.392</td>
<td>2.113</td>
<td>2.392</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.015</td>
<td>0.041</td>
<td>0.041</td>
<td>0.013</td>
<td>0.070</td>
</tr>
</tbody>
</table>
Appendix A: 
Life Insurers’ Institutional Details

Terminologies

Table A1: Key Terminologies for the Life Insurance Industry

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>Proceeds that insurees pay to an insurer</td>
</tr>
<tr>
<td>Reserve</td>
<td>The amount of liabilities recognized for outstanding insurance policies</td>
</tr>
<tr>
<td>Surplus</td>
<td>Equity capital</td>
</tr>
<tr>
<td>Invested Assets</td>
<td>The amount of book assets invested in financial markets</td>
</tr>
<tr>
<td>Financial Reinsurance</td>
<td>Reinsurance arrangements in which reinsurers provide the ceding insurer with capital relief, which is typically in the form of affiliated special purpose financial vehicles</td>
</tr>
<tr>
<td>Reinsurance Assets</td>
<td>The amount of assets transferred from the reinsurance company to the ceding insurer under a reinsurance arrangement</td>
</tr>
<tr>
<td>Reserve Credit</td>
<td>The amount of liability reduction due to reinsurance arrangements.</td>
</tr>
</tbody>
</table>

Invested Asset Composition

Figure A1. Life Insurers’ Aggregate Asset Mix as of Year-end 2010

Figure A1 depicts the breakdown of asset holdings in life insurers’ investment portfolios as of year-end 2010, data provided by the NAIC. In the aggregate, corporate bonds account for more than 40% of assets and high-quality assets (agency MBS, government and municipal bonds, cash) around 20%. “Other structured securities” include private-label MBS and ABS, the majority of which are held by national large insurance groups and of the “zero-loss” category determined by the NAIC.
A Simple Life Insurer Example

The following example substantiates the industry background discussed in Section I by illustrating the insurance sales procedure, the main source of liability risk, the RBC calculation, and the financial reinsurance mechanism.

Suppose a life insurer starts with a cash amount of 30 at $t = 0$ and then sells a simple term life insurance policy that matures in 5 years and offers a death benefit of 200,000 if the insured person dies within 5 years. Suppose the policy is priced at an annual premium of 140. Right after the sales of the policy, the insurer collects the first premium payment, which equals 140, estimates the present value of the promised benefit using a pre-specified mortality table (annual probabilities), and recognizes reserves (liabilities) that are equal to this present value net of the present value of future premium collections. The mortality table used for this example is as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.05%</td>
</tr>
<tr>
<td>2</td>
<td>0.06%</td>
</tr>
<tr>
<td>3</td>
<td>0.07%</td>
</tr>
<tr>
<td>4</td>
<td>0.08%</td>
</tr>
<tr>
<td>5</td>
<td>0.09%</td>
</tr>
</tbody>
</table>

Figure A2 shows the balance sheet at $t = 0$, where the discount rate is normalized to zero.

Figure A2. Initial Balance Sheet

Figure A2 shows the life insurer’s initial balance sheet. The life insurer starts with capital of 30, sells a simple-life policy with a maturity of 5 years, death benefit of 200,000, and an annual premium of 140, and calculates the corresponding liability using the projected mortality rates in Table A2. The discount rate is normalized to zero.
Suppose the insurer invests 100 in NAIC Category 1 bonds and 70 in Category 2 bonds, the insurance risk factor is 2%, interest rate risk is negligible, and there is no other risk. Then at $t = 0$, the regulatory capital benchmark, termed the “Company Action Level”, is calculated as follows:

$$\sqrt{(100 \times 0.4\% + 70 \times 1.3\%)^2 + (139 \times 2\%)^2} = 9.44.$$ 

If the insurer’s capital falls below 150% of this benchmark, the state regulator will start to intervene. As of $t = 0$, the insurer in the example has capital of 30.97, which is 328% of the benchmark and can be considered well-capitalized.

At $t = 0.5$, an unexpected shock to the mortality table arrives, which is a uniform increase in projected mortality rates of 0.002%, as shown below:

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>0.052%</td>
<td>0.062%</td>
<td>0.072%</td>
<td>0.082%</td>
<td>0.092%</td>
</tr>
</tbody>
</table>

As shown in Figure A3, the shock considerably reduces the insurer’s regulatory capital ratio, from 18.22% to 6.49%. After the shock, the new RBC benchmark is:

$$\sqrt{(100 \times 0.4\% + 70 \times 1.3\%)^2 + (159 \times 2\%)^2} = 11.83.$$ 

Figure A3. Impact of Mortality Rate Shock

Figure A3 depicts the impact of a tiny, uniform shock (0.002%) to projected mortality rates on the life insurer’s balance sheet in the example, where all the insurer sells is a simple-life policy with a maturity of 5 years, death benefit of 200,000, and an annual premium of 140. The shock changes the insurer’s capital amount from 30.97 to 11.03, corresponding to a capital ratio change from 18.22% to 6.49%.
As a result, the mortality rate shock as shown in Figure A3 implies that the insurer is obliged
to raise regulatory capital in order to avoid regulatory action because its post-shock capital level,
11.03, is way below 150% of the new benchmark, which is

\[ 11.83 \times 150\% = 17.74 \, . \]

Suppose the insurer plans to raise regulatory capital through financial reinsurance, where the capital
requirement of 2% for insurance risk would be lowered to 1% for the amount reinsured. A typical
financial reinsurance deal in the United States involves the insurer establishing an affiliated special
purpose financial vehicle (SPFV) with a reinsurance company and ceding part of its outstanding
liabilities to the SPFV. Assume that the ceded amount is 38.97 and the amount retained 120. At
the same time, the insurer cedes bonds to the SPFV in the amount of 30 and the reinsurer injects
reinsurance assets of 10, resulting in the SPFV’s balance sheet having 40 in total assets, 38.97 in
total liability, and 1.03 in capital. The new RBC benchmark is:

\[
\sqrt{(100 \times 0.4\% + 70 \times 1.3\%)^2 + (120 \times 2\% + 38.97 \times 1\%)^2} = 9.50 \, .
\]

And the new RBC for the consolidated insurer is 21.03, which is 221% of the benchmark, a well-
capitalized level. In reality, there is a small amount of fees the ceding insurer needs to pay the
reinsurance company upfront, which is omitted here. Figure A4 visualizes this reinsurance example.
Figure A4. Raising Regulatory Capital with Financial Reinsurance

Figure A4 depicts the change in a life insurer’s statutory balance sheet brought by the use of financial reinsurance, where the reinsurer provides an asset commission and assumes part of the ceding insurer’s liabilities through a special purpose vehicle and thus relieves the ceding insurer’s capital strain. The amount of financing will be reimbursed to the reinsurer with part of the future cash flows from the ceded insurance claims.
Appendix B:
State-level Captive Insurance Regulation Changes

The table below shows the list of changes in state insurance laws that unambiguously imply a reduction in the financing cost of life insurance companies domiciled in the corresponding states for the period of 2004—2014. The ones with an asterisk are used as quasi-experiments in the stacked-cohort difference-in-differences analysis, where the event time $t$ is assumed to be the last calendar year-end prior to the year of change (i.e., assuming that asset investment decisions for year $t + 1$ are made at year-end $t$) and the time window is from $t−2$ to $t+2$.

<table>
<thead>
<tr>
<th>State</th>
<th>Year of Change</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delaware*</td>
<td>2007</td>
<td><a href="http://captive.delaware.gov">http://captive.delaware.gov</a></td>
</tr>
<tr>
<td>Kentucky*</td>
<td>2010</td>
<td><a href="http://insurance.ky.gov">http://insurance.ky.gov</a></td>
</tr>
<tr>
<td>Missouri*</td>
<td>2007</td>
<td><a href="http://insurance.mo.gov">http://insurance.mo.gov</a></td>
</tr>
<tr>
<td>Nebraska*</td>
<td>2007</td>
<td><a href="https://doi.nebraska.gov">https://doi.nebraska.gov</a></td>
</tr>
<tr>
<td>North Carolina*</td>
<td>2013</td>
<td><a href="http://www.ncdoi.com">http://www.ncdoi.com</a></td>
</tr>
<tr>
<td>Ohio</td>
<td>2014</td>
<td><a href="https://insurance.ohio.gov">https://insurance.ohio.gov</a></td>
</tr>
<tr>
<td>Oklahoma</td>
<td>2004</td>
<td><a href="http://www.oklegislature.gov">http://www.oklegislature.gov</a></td>
</tr>
<tr>
<td>South Carolina</td>
<td>2004</td>
<td><a href="http://captives.sc.gov">http://captives.sc.gov</a></td>
</tr>
<tr>
<td>Tennessee*</td>
<td>2011</td>
<td><a href="https://www.tn.gov/commerce/insurance">https://www.tn.gov/commerce/insurance</a></td>
</tr>
<tr>
<td>Texas*</td>
<td>2013</td>
<td><a href="http://www.tdi.texas.gov">http://www.tdi.texas.gov</a></td>
</tr>
</tbody>
</table>

The following excerpt from the legal news for North Carolina on October 24, 2013 provides an example for the legislation incentives:

‘The North Carolina Captive Insurance Act...allowing for the formation of captive insurance companies in the state...“Entering the captive insurance market will provide economic opportunities for North Carolina and help accommodate the needs of businesses in our state,” said Insurance Commissioner Wayne Goodwin.’
Appendix C: Details of Model Solutions

The Scenario of Interest: \( \frac{m}{\rho} < 1 - \frac{1}{pR} < \frac{m}{\rho^2} \)

First, it is straightforward to see that any \( I_1 \) satisfying

\[
I_1 < W_0 - (\rho - m)D_0
\]

cannot be optimal because it is always possible to increase \( I_1 \) marginally to improve the expected profit. Hence, we restrict our attention to the following two cases.

Case 1: \( W_0 - (\rho - m)D_0 \leq I_1 < W_0 + (\rho + m)D_0 \)

In this case, financing costs are incurred if and only if both the risky asset return and liability shock result in losses. The maximization problem becomes:

\[
\max_{I_1} \quad (pR - 1)I_1 + mD_0 - \frac{1}{2}(1-p) \cdot \frac{1}{2}c(pD_0 + I_1 - W_0 - mD_0)^2 \cdot \mathbb{1}_{(pD_0 + I_1 \geq W_0 + mD_0)}
\]

\[
\text{s.t.} \quad W_0 - (\rho - m)D_0 \leq I_1 < W_0 + (\rho + m)D_0
\]

The first-order condition for an interior solution gives:

\[
I_1 = \frac{2(pR - 1)}{(1-p)c} + W_0 - (\rho - m)D_0
\]

(C2)

For this solution to be valid, \( D_0 \) needs to satisfy:

\[
D_0 > \frac{pR - 1}{(1-p)c}
\]

(C3)

Plug in the interior solution as in equation (C2) to the maximization problem (C1), we obtain:

\[
E[V_3] = V + \frac{(pR - 1)^2}{(1-p)c} + pR \cdot W_0 + [pRm - (pR - 1)\rho]D_0
\]

(C4)

By assumption of the scenario, we have

\[
pRm - (pR - 1)\rho < 0
\]

Hence \( D_0 \) should be as small as possible to maximize the expected shareholder value. Hence either \( D_0 \) should approach \( \frac{pR - 1}{(1-p)c} \) or the optimal \( I_1 \) is not an interior solution, both conditions imply that the optimal \( I_1 \) should approach \( W_0 + (\rho + m)D_0 \). As a result, the equilibrium should be reached in the next case.
Case 2: $W_0 + (\rho + m)D_0 \leq I_1 \leq W_0 + (1 + m)D_0$

In this case, both financing cost terms in equation (3) exist in the maximization problem. The first-order condition for an interior solution of $I_1$ is given by:

$$I_1 = \frac{pR - 1}{(1-p)c} + W_0 + mD_0$$  \hfill (C5)

For this solution to be valid, $D_0$ needs to satisfy:

$$D_0 \leq \frac{pR - 1}{(1-p)c}$$  \hfill (C6)

Plug in the interior solution as in equation (C5) to the maximization problem, we obtain:

$$E[V_3] = V + \frac{(pR - 1)^2}{2c(1-p)} + pR \cdot W_0 + pR \cdot mD_0 - \frac{1}{2} \rho^2 D_0^2$$  \hfill (C7)

The interior solution for $D_0$ is given by:

$$D_0 = \frac{pR \cdot m}{(1-p)\rho c^2}$$  \hfill (C8)

By assumption of the scenario, we have

$$\frac{pR \cdot m}{(1-p)\rho c^2} = \frac{pR - 1}{(1-p)c} \cdot \frac{pR}{pR - 1} \cdot \frac{m}{\rho} < \frac{pR - 1}{(1-p)c}$$

Hence, there is a unique equilibrium:

$$D_0^* = \frac{pR \cdot m}{(1-p)\rho c^2}$$

$$I_1^* = \frac{pR - 1}{(1-p)c} + W_0 + mD_0^*$$  \hfill (C9)

$$= \left[ \frac{(pR - 1)\rho^2}{pR \cdot m} + m \right] D_0^* + W_0$$

By assumption of the scenario, we have

$$\left[ \frac{(pR - 1)\rho^2}{pR \cdot m} + m \right] D_0^* + W_0 < (1 + m)D_0^* + W_0,$$  \hfill (C10)

which means the solution is valid. The expected shareholder value in equilibrium is:

$$E[V_3^*] = V + pR \cdot W_0 + \frac{\rho^2(pR - 1)^2 + p^2R^2 \cdot m^2}{2\rho^2c(1-p)}$$  \hfill (C11)
Therefore, we have the following comparative statics:

\[
\frac{\partial D_0^*}{\partial c} < 0 \tag{C12}
\]
\[
\frac{\partial I_1^*}{\partial c} < 0 \tag{C13}
\]
\[
\frac{\partial E[V_3^*]}{\partial c} < 0 \tag{C14}
\]

Now denote the equilibrium weight of the risky asset at \( t = 1 \) as \( x_1^* \). Then

\[
x_1^* = \frac{I_1^*}{W_0 + (1 + m)D_0^*}, \tag{C15}
\]

and we have

\[
\frac{\partial x_1^*}{\partial c} = \frac{\partial x_1^*}{\partial D_0^*} \cdot \frac{\partial D_0^*}{\partial c}
\]
\[
= \frac{(pR - 1)\rho^2 - pR \cdot m}{pR \cdot m} \cdot \frac{W_0}{[W_0 + (1 + m)D_0^*]^2} \cdot \frac{\partial D_0^*}{\partial c}
\]
\[
= \frac{pR \cdot m - (pR - 1)\rho^2}{pR \cdot m} \cdot \frac{W_0}{[W_0 + (1 + m)D_0^*]^2} \cdot \frac{pR \cdot m}{(1 - p)\rho^2} \cdot \frac{1}{c^2}
\]
\[
= \frac{[pR \cdot m - (pR - 1)\rho^2](1 - p)\rho^2 W_0}{[(1 - p)\rho^2 W_0 \cdot c + (1 + m)pR \cdot m]^2}
\]
\[
> 0
\]

where the last inequality holds by assumption of the scenario.

**The Maximum-insurance Scenario:** \( \frac{m}{\rho} \geq 1 - \frac{1}{pR} \)

This scenario can be analyzed similarly. When \( \frac{m}{\rho} \) does not equal \( 1 - \frac{1}{pR} \), for Case 1, the solution under this scenario would be to sell insurance to the maximum allowed by regulation:

\[
D_0^* = \frac{W_0}{\rho - m}, \tag{C17}
\]

and the optimal amount invested in the risky asset is constant:

\[
I_1^* = \frac{2(pR - 1)}{(1 - p)c} \tag{C18}
\]

For Case 2, it is easy to verify that the solution as specified in equation (C8) violates the condition as in equation (C6), leading the analysis back to Case 1.

If \( \frac{m}{\rho} = 1 - \frac{1}{pR} \), it can be verified that the equilibrium \( I_1 \) is still reached under Case 1 as specified in equation (C2), and the amount of insurance sales \( D_0 \) can be any value that is at least \( \frac{pR-1}{(1-p)c} \).

55
For simplicity, I pick the maximum-insurance solution from this infinite number of equilibrium as the equilibrium of interest.

Therefore, in this scenario, the weight of the risky asset is decreasing in the cost of raising capital. The intuition is similar to that of Lemma 1 — when the scale of insurance business is fixed (having reached maximum in this scenario), a lower cost of raising capital leads to a higher percentage allocation to risky investments. There is no meaningful interaction between the asset and liability risk management in this scenario. Empirically, regulatory constraints are usually slack for life insurance companies, which makes this maximum-insurance scenario less relevant.

The Maximum-risky-investment Scenario: \( \frac{m}{\rho^2} \leq 1 - \frac{1}{pR} \)

The analysis of this scenario is again similar to that of the previous ones. In particular, the equilibrium is reached in Case 2. By assumption of the scenario, the solution of \( I^*_1 \) as in equation system (C9) is equal to or higher than \( W_0 + (1 + m)D_0 \), which means the equilibrium percentage allocation to the risky asset is 100%. Given this condition, it can be easily verified that the equilibrium \( D_0 \) should maximizes the following:

\[
(pR - 1 + pR \cdot m)D_0 - \frac{1}{2}(1 - p)(1 + \rho^2)c \cdot D_0^2,
\]

which gives the following unique solution:

\[
D_0^* = \frac{pR - 1 + pR \cdot m}{(1 - p)(1 + \rho^2)c}.
\]

Given that \( \rho^2 > 0 \) and \( 0 < \rho < 1 \), we have

\[
1 - \rho > \rho^2(\rho - 1),
\]

which implies

\[
\frac{1}{\rho} - 1 + \rho > \rho^2.
\]

Thus, we have

\[
\frac{m}{\rho^2} > \frac{m}{\frac{1}{\rho} - 1 + \rho} = \frac{m\rho}{1 - \rho + \rho^2}.
\]

By assumption of the scenario, we have

\[
\frac{pR - 1}{pR} \geq \frac{m}{\rho^2} > \frac{m\rho}{1 - \rho + \rho^2},
\]

which implies

\[
\frac{pR - 1 + pR \cdot m}{1 + \rho^2} < \frac{pR - 1}{\rho}.
\]
As a result, the solution of $D_0^*$ as specified in equation (C20) satisfies the condition (C6), which means it indeed characterizes the equilibrium. Therefore, in this scenario, the equilibrium percentage allocation to the risky asset is fixed at 100%, and the equilibrium amount of insurance underwriting is decreasing in the cost of raising capital. Empirically, most life insurers hold a considerable amount of high-quality, safe investment assets, which makes this scenario less relevant.

**Graphical Illustration**

Figures C1 and C2 summarize the analyses above for the equilibrium amount of insurance underwriting and risky investments in the model, respectively.

**Figure C1. Equilibrium Insurance Underwriting**

Figure C1 depicts the equilibrium insurance underwriting ($D_0^*$) in the model under the complete parameter space.
Figure C2. Equilibrium Risky Investments

\[ I_1^* = \frac{(pR-1)}{(1-p)c} \]

\[ \frac{\partial x^*}{\partial c} < 0 \]

Scenario of Interest

\[ \frac{\partial x^*}{\partial c} > 0 \]

Max-risky-investments Scenario

\[ I_1^* = (1 + m)D_0^* + W_0 \]

Full allocation to the risky asset

\[ I_1^* = \frac{m}{\rho} \]

Risk-adjusted return premium on insurance underwriting

\[ \frac{m}{\rho^2} \]

Risky asset’s return premium

Figure C2 depicts the equilibrium risky investments (dollar amount \( I_1^* \) and weight \( x^* \)) in the model under the complete parameter space.

Appendix D: Numerical Example of the Model

Parameter values in the model are set as follows:

\[ m = 2 \times 10^{-5} \]
\[ \rho = 0.025 \]
\[ p = 0.99 \]
\[ R = 1.02 \]
\[ W_0 = 1000 \]
\[ c \in [0.0001, 0.0005] \]

The low value of \( m \) represents the fact that the expected total proceeds from life insurance contracts are initially priced close to the actuarial value, where the life insurers earn a rate close to the risk-free rate (which is zero in the model). \( \rho \) captures the liability risk that stems from shocks to projected mortality rates. The high value of \( p \) and moderate value of \( R \) reflect the fact that investment-grade corporate bonds account for the majority of life insurers’ risky investments, whose expected yield in this case is 198 bps above the risk-free rate. The range of \( c \) implies a cost coefficient from 0.005% to 0.025%. To provide intuition into the magnitude from the model parameters, suppose the insurer needs to finance an additional 20% of its initial capital, which is 200, then the total financing cost ranges from 1 to 5, namely 0.5% to 2.5%, which is arguably a reasonable range of a lender’s required rate of return in excess of the risk-free rate. It can be easily verified that these values satisfy the inequalities in (4).
Appendix E: Data Details

Raw Data

First, I obtain life insurers’ balance sheet data from SNL Financials, which compiles quarterly statutory reports of life insurance companies starting from 1994. I restrict my attention to domestic stock life insurers (excluding insurers domiciled in Puerto Rico). The NAIC reporting ID is used as the firm-level identifier\(^{39}\). Main variables include: NAIC ID, state of domicile, total net assets, total liabilities, capital ratio, net investment income, net investment yield, financial strength rating by A.M. Best, and reserve credits taken from affiliated reinsurance vehicles. All variables are observed at the quarterly frequency except for reinsurance, which is at the annual frequency. I drop all observations with missing NAIC ID or total net assets. Then I take the logarithm of total net assets as the variable “size”. I use the net investment yield and net investment income to back out the amount of invested assets, which is less than or equal to total net assets.\(^{40}\) It is important to note that net investment yields do not reflect the true returns or current risk associated with the investment portfolio for the sample period because, for life insurers in the sample period, unrealized gains or losses of most investments are not reflected in income statements. The A.M. Best rating is used to identify insurers with weak financial strength, defined as having a rating below A-, which serves as a measure to capture cross-sectional differences in the costs of raising regulatory capital.\(^{41}\)

Then I use Thomson Lipper EMAXX corporate bond data to retrieve life insurers’ asset holdings in corporate bonds. EMAXX reports corporate bond holdings for institutional investors at the security-account-quarter level, where each account is uniquely mapped to an institution. The database covers all publicly traded and private placement bonds from 1998Q2 to 2014Q4. I mainly use the following data items: security CUSIP, credit rating, coupon rate, holdings, account ID, and institution name. I drop all observations that miss CUSIP. In addition, convertible bonds are dropped because their yields are difficult to measure and the importance of them in life insurers' investments is minimal: the holdings of hybrid securities are as low as 1% of life insurers’ investment portfolio in aggregate.\(^{42}\)

Next, I extract from SNL Financials life insurers’ calendar-year-end mortgage and contract loan holdings, where the amount outstanding, yield, and non-performing status are observed. These loans are typically issued by insurance companies and not publicly traded. Since the majority of other variables are at the quarterly frequency, I backfill quarterly loan variable values using the most-recent year-end value.

In fact, SNL Financials does report life insurers’ holdings in common stocks and preferred stocks, but I exclude them from my sample because the average percentage of stock holdings by insurers

\(^{39}\)As discussed in Section I, this corresponds to the level at which risk-based capital needs to be reported and is lower than the insurance group level, since the NAIC does not define risk-based capital for insurance groups.

\(^{40}\)An example of non-invested assets is deferred tax assets. The median percentage of assets invested for the sample firms is 94.67%.

\(^{41}\)For insurers that do not have a reported rating, I assume they are of low financial strength since their access to public capital markets is likely limited.

\(^{42}\)Source: https://www.naic.org/capital_markets_archive/110819.htm
is very small, no more than 2% of the total portfolio. The implicit assumption is that the risk of equity investments for most of the sample firms is tiny and largely constant, thus unlikely to affect regressions where firm fixed effects are controlled for. I provide robustness tests for this assumption, which will be discussed later.

Finally, I obtain bond market data to make possible market-based risk measures of life insurers' investment portfolio. Bond issuance data from 1968 to 2014 are acquired from Thomson SDC Platinum, where promised yield, principal amount, issuance date and maturity date are the main variables to use. Corporate bond trading data are from TRACE, which starts to report secondary market bond transactions in July, 2002. To clean the raw data of TRACE, I use the code provided by Jens Dick-Nielsen on his website and follow Edwards, Harris, and Piwowar (2007) in addition to reach the full set of trade-volume weighted transaction prices (clean prices that exclude accrued interests) from July, 2002 to the end of year 2015. With the clean prices of bond transactions, I locate month-end prices for each security, following Bai, Bali, and Wen (2018). In the processed TRACE sample, for each security at each quarter end, I keep the 8-digit CUSIP, quarter-end price, and the month-end prices for the next 12 months.

Data Compilation

The data compilation process is as follows. First, I map life insurers’ balance sheet data to mortgage holdings data using NAIC ID and reporting quarter, where the success rate is 100%. Next, I manually match the account ID reported in EMAXX and the NAIC ID reported in SNL Financials using institution names, where the success rate is 81%. Having combined the institutional variables with security-level holdings data, I then use 8-digit CUSIP and quarter to augment TRACE price data and keep the full data set since not all securities are covered by TRACE. I augment the merged data set with SDC bond issuance data using the 8-digit CUSIP. For the securities not mapped to TRACE, I use their promised yields for market-based risk measures and set the volatility of prices to zero. Finally, I drop all securities that mature within one year and all reinsurance company observations.

---

43 Other reasons why stock holdings are excluded are: (1) data mapping to CRSP using the CUSIP reported by SNL Financials turns out very unsatisfactory, i.e., the current prices for common stocks held cannot be reliably retrieved; (2) the absolute majority of preferred-stock observations do not report the par value.

44 Coupon rates and credit rating are also fetched from SDC Platinum but those reported by EMAXX are prioritized due to data quality.

45 For private placement bonds that are rated, I use the value-weighted average current yield of all public bonds with the same credit rating; for private placements bond without a credit rating, I assume constant yields and an issuance price at par.

46 The unique identifier used by Thomson cannot be mapped to data sets compiled by S&P, such as SNL Financials.

47 Private placements and insurer-issued loans are not covered by TRACE since they are typically not traded on secondary markets. The percentage of observations mapped is around 65%.

48 When 8-digit CUSIP is not available or does not generate a match, I map the data sets to an offer yield that is calculated using the value-weighted offer yield of all bonds issued by the same issuer (6-digit CUSIP) that have the same issuance and maturity year. The weights are determined by the principal amount as reported in SDC. The overall success rate is around 85%.

49 Bonds that mature within one year are subject to price fluctuation that is independent of their fundamentals, i.e., due to institutional investors’ preference. See Bai et al. (2018) for detailed discussions.