Interest Rates and Insurance Company Investment Behavior *

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Abstract

Life insurance companies, the largest institutional holders of corporate bonds, tilt their portfolios towards higher-yield bonds when interest rates decline. This tilt seems to be primarily driven by an increase in duration rather than credit risk and insurers do not seem to increase the credit risk of their bonds as interest rates decline. Moreover, the duration gap between their assets and liabilities deviates from zero for extended periods of time both in negative and positive directions. These patterns cannot be explained by incentives to reach for yield. We propose a new model of duration-matching under adjustment costs that conforms with these patterns and test other implications of this model.

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1 Introduction

The effect of interest rates on financial institutions' investment behavior has been the center of attention of academics, policymakers, and the media. A particular financial stability concern has been that the low interest rate environment prevailing since the 2008 financial crisis may highten incentives of financial institutions to invest in riskier assets (Bernanke 2013; Stein 2013; Rajan 2013; Yellen 2014). We study how changes in interest rates affect the investment and risk-taking behavior of life insurance companies, the largest institutional holders of corporate bonds, using a new regulatory data that includes a long time series starting in 1994 and covers the whole universe of life insurance companies.

We show that insurance companies are tilting their portfolios towards higher-yield bonds when interest rates decline. At first, this seems to be consistent with "reaching for yield" in a low interest rate environment (Choi and Kronlund 2017). However, we find that the tilt towards higher-yield bonds seems to be primarily driven by an increase in duration rather than credit risk and insurers do not seem to increase their credit risk as interest rates decline.[1]

An alternative hypothesis that can explain this phenomenon is that the insurers hedge their risk through duration matching of assets and liabilities (Domanski, Shin, and Sushko 2017). The insurance company wants to adjust its portfolio to keep the duration gap between assets and liabilities close to zero in an effort to reduce the interest rate risk because of regulations that tie risk-based capital surcharges to interest rate risk (Lombardi, 2006) and because the demand for their products depend on their health and riskiness (Koijen and Yogo, 2015). Duration of liabilities react to changes in interest rates because of the behavior of policyholders. Many insurance products offer policyholders the option to contribute additional funds at their discretion or to close out (surrender) a contract in return for a predetermined payment. When interest rates change, it is more likely that policyholders will act on these options (Berends, McMenamin, Plestis, and Rosen, 2013). In particular, lower interest rates increase liability duration by decreasing the likelihood of surrender and increasing the likelihood of paid-up additions. Therefore, the duration gap decreases when interest rates fall to which the insurance company reacts by increasing the duration of its assets in order to pull the duration gap back to zero.

Under continuous duration matching, the equity of insurance companies should be close to zero. In contrast with this implication, we find that the duration of equity deviates from zero both in positive and negative directions for extended periods of time. Therefore, we propose a stylized model of duration matching with adjustment costs, in the spirit of capital adjustment costs that have been popular in the literature studying firms' investment decisions

[1] Choi and Kronlund (2017) study how the reaching for yield behavior of bond mutual funds is affected by interest rates.

since Abel and Eberly (1994). In the context of insurance companies, these adjustment costs may stem from the fact that selling and purchasing assets in large quantities may have greater marginal cost due to market frictions like price pressure or due to greater cost of effort by investment managers. This intuitive idea of frictions to portfolio adjustment is also confirmed in our discussions with regulators and conforms with the fact that the insurers engage in bond acquisitions and disposals intermittently.[2]

In our model, the duration of an insurer's assets varies over time in response to interest rate changes both because of nonzero convexity of bonds and because of the insurer's active adjustment to its duration through acquisitions and disposals. Our interest in the investment behavior of insurance companies requires us to isolate the second effect. To capture this effect, our model allows us to create a novel definition of *active duration adjustment*, measured as the difference between the duration of the insurer's total holdings at the end of a given period and the duration of its legacy assets (the hypothetical duration of the holdings if the insurer were not to make any changes to its portfolio) under the new interest rates.

Our model shows that an insurer's active duration adjustment is driven by the difference between the duration of its legacy assets and duration of its liabilities interacted with leverage. We call the latter the *target duration* in the spirit of the target leverage hypothesis in corporate finance. In the absence of adjustment costs, the insurer would always invest to set the duration of assets equal to the target duration. In the presence of adjustment costs, however, the insurer does not close this gap immediately at every period but rather gradually. The speed of this adjustment depends positively on the cost of carrying an interest rate risk due to deviations from a zero duration gap and negatively on the cost of adjustment. We show that the solution of our model leads to a reduced-form econometric model that can be directly estimated in the data using a standard regression approach, akin to econometric models used to test the target leverage hypothesis (for example, DeAngelo and Roll 2014).

Our model, while stylized, has several powerful implications which can be tested with our long and comprehensive cross-sectional data of insurance companies. Consistent with the implication that adjustment towards the target duration happens gradually, we find that it takes an insurance firm about 11 quarters to close half the duration gap leading to extended periods of exposure to interest rate risk. Moreover, consistent with the predictions of the model regarding the relationship between target duration, leverage, and interest rates, we find that the active duration adjustment is positively related to leverage, negatively related to the product of leverage and interest rate, and the interest rate does not have an additional

[2]Based on the quarterly observations, a typical insurance firm trades bonds about 2/3 of the quarters. One concern is that this observation may imply that life insurers rely on derivatives to manage interest rate risk. However, derivatives have traditionally not played a large role in risk management in the life insurance industry due to large costs of hedging (Berends, McMenamin, Plestis, and Rosen, 2013).

effect on active duration adjustment beyond its interaction with leverage.

The premise of our model lies in the argument that policyholders behavior reacts to interest rate changes. When interest rates are lower, policyholders have greater incentives to hold on to their insurance contracts due to lack of other high-yield investment opportunities. This implies that policy surrenders and lapses become less likely as interest rates decline, which increases target duration of the insurer.[3] Consistent with this argument, we find a positive relationship between interest rates and surrender/lapse rates and this association generates a negative relationship between surrender/lapse rates and active duration adjustment.

Overall, our results suggest that insurance companies tilt their portfolio towards higher duration assets in an effort to minimize their interest rate risk subject to adjustment costs. This poses challanges to financial stability that is separate from reaching for yield. In particular, reaching for yield in a low interest rate environment suggests that the central banks should raise interest rates to prevent financial institutions' excessive risk taking that can generate additional negative effects if the economy experiences adverse shocks. In comparison, duration matching under adjustment costs suggests that the insurance companies are exposed to interest rate risk for an extended period of time even if their goal is to minimize risk. In this framework, the central bank should take into account the sign of the duration gap when deciding to raise interest rates. If the duration gap is positive, then an increase in interest rates can reduce the target duration and hence increase the duration gap further, thereby increasing the interest rate risk of the insurance companies rather than reducing it. In the current environment, however, the equity duration (and hence duration gap) of the U.S. insurance companies is negative, thereby giving an additional incentive for the Federal Reserve to raise rates to reduce the duration mismatch faced by insurance companies due to adjustment costs.

Our results are also related to previous literature on insurance company investment behavior. The seminal paper in this literature, Becker and Ivashina (2015), studies how the reaching for yield behavior of insurance companies change before and during the financial crisis and find that insurance companies reach for credit risk before, but not during, the financial crisis. Our focus is understanding the drivers of the changes in excess yield on insurance companies' portfolio as interest rate changes. We find similar results as Becker and Ivashina (2015) for their time window 2004:Q3-2010:Q4; however, we find that the bulk of excess yield in insurance companies' bond holdings relative to the market can be attributed to changes in duration risk rather than credit risk over the 1996–2016 sample period.

[3] A lower surrender rate lengthens the duration of the payments insurance company has to make as the underlying risk will materialize in the future. A lower lapse rate increases target duration primarily by increasing the liabilities, and hence leverage, of the insurance company. See Section 5.3 for details.

2 Data and Stylized Facts

2.1 Data Construction

We construct our dataset by combining data from several sources. The data for life insurance companies' corporate bond holdings comes from NAIC statutory filings. Schedule D of insurance filings has detailed information on investment by life, health, and property and causality (P&C) insurance companies, including corporate bonds, stocks, and municipal bonds. We obtain our data of insurance company holdings directly from NAIC through a special agreement with the Federal Reserve. The data has a complete coverage of all the NAIC-reporting insurance companies from 1994Q1 to 2016Q4. The Schedule D has both annual files with year end portfolio holdings information, and quarterly files which contain asset acquisition and disposal information within each quarter. The exact date and amount of each insurance company's acquisition/disposal transactions are documented, thus we know their portfolio rebalancing behavior at a very granular level.

The corporate bond pricing information comes from Mergent FISD bond transactions (1994-2002) and TRACE (2002-2016). The Mergent FISD consists of all transactions of publicly traded corporate bonds by life insurance companies , property and causality insurance companies, and health insurance companies beginning in January 1994. Previous research has shown the FISD data is representative of corporate bond transactions (Warga 2000, Campbell and Taksler 2003). The TRACE data has transaction reports for all corporate bonds back to July 2002. The data is cleaned using the filtering algorithm in Dick-Nielsen (2009). We obtain the bond issuance information from Mergent FISD which provides coupon, maturity, offering amount, and rating. The expected default frequency (EDF) information comes from Moody's Credit Edge, which starts in 1999.

Our sample covers a relatively high interest rate period from 1994 to 2000 and the post-recession low interest environment from 2010 to 2016. As far as we know, our sample has a longer time span compared to other papers that investigate investment behavior of financial institutions in the bond market. With a long sample of 23 years, we are able to study how insurance companies' investment behavior differs as interest rate changes.

2.2 Measuring Life Insurers' Tilt for Higher Yield Bonds

Insurance companies are the largest institutional holders of corporate and foreign bonds. According to the U.S. Flow of Funds Accounts, in 2015Q4, life insurers hold $2.36 trillion of corporate and foreign bonds, quantitatively similar to mutual and pension funds taken

together.[4] Insurance regulations require insurance companies to maintain minimum levels of capital on a risk-adjusted basis, called risk-based capital (RBC). To determine the capital requirement for credit risk, corporate bonds are sorted into six broad categories (National Association of Insurance Commissioners (NAIC) risk categories 1 through 6) based on their credit ratings, with higher categories subject to higher capital requirements.[5] As discussed in Becker and Ivashina (2015), due to the regulations and the presence of government guarantees, insurance companies may attempt to increase the yield in their bond portfolio by taking on extra priced risk, while leaving capital requirements unaffected. Therefore, we focus on corporate bond holdings of insurance companies, conditional on NAIC risk categories.

Our main hypothesis is that the incentives of insurance companies to invest in higher yield bonds within a given NAIC rating category is related with the level of interest rates. To measure this empirically, we compare the yield of insurance company corporate bond holdings with the yield of the aggregate corporate bond portfolio (Choi-Kronlund 2016), within each NAIC rating category.

We define excess yield $ExYld_{i,t}$ within NAIC1 category as the average yield of insurance company i's NAIC1 bond portfolio relative the the average yield of all the outstanding NAIC1 bonds in the market:

$$\begin{array}{rcccc} ExYld_{i,t} & = & \frac{\sum_j H_{i,j,t} y_{i,t}}{\sum_j H_{i,j,t}} & - & \frac{\sum_k A_{k,t} y_{k,t}}{\sum_k A_{k,t}} \\ & & \text{Avg yld on quarter end} & & \text{Avg yld on bonds} \\ & & \text{holding portfolio (NAIC1)} & & \text{outstanding (NAIC1)} \end{array}$$

where $H_{i,j,t}$ is the amount of bond j held by insurance company i and $A_{k,t}$ is the amount of bond k outstanding, both measured as face value at the end of quarter t.

This measure also gives the excess yield in the aggregate insurance sector when we let i be the universe of all insurance companies. Comparing the relative yield of an insurance company's portfolio to the market within an NAIC designation allows us to control for the unobservable factors that drives variation in the market yield. Similarly, we could also define the $ExYld_{i,t}$ in NAIC2 designation. The main results we present in the paper are based on NAIC1 designation.[6]

[4]Mutual funds and pension funds are the second and third largest institutional holders in US corporate bond market, with holdings of $1.74 and $0.7 trillion respectively

[5]The NAIC categories map into S&P ratings in the following way: $NAIC1 = \{AAA, AA, A\}, NAIC2 = BBB, NAIC3 = BB, NAIC4 = B, NAIC5 = CCC, NAIC6 = \{CC, C, D\}$

[6]Over 60% of corporate bond holdings of insurance companies is in NAIC1 category, with over an additional 30% in NAIC2 category. The robustness of our results using NAIC2 category bond holdings are available upon request. Since the holdings in the remaining NAIC categories are less than 10% of their total corporate bond holdings, we do not study other categories.

2.3 Stylized Facts

We document three stylized facts by examining how this excess yield is related with interest rates, and the underlying risk quantities insurance companies are loading on. We use 10-year Treasury Constant Maturity Rate as the interest rate variable because it has duration very comparable to both assets and liabilities of typical insurance companies, therefore should be the most relevant discount rate insurers use while making investment decision (Domanski-Shin-Sushko 2017, Hartley-Paulson-Rosen 2016). In later parts of the paper, we present a partial adjustment model of duration matching to rationalize these facts.

Stylized Fact1: *The excess yield of life insurers' corporate bond portfolio increases as interest rates decline.*

Figure 1 plots the excess yield of the bond portfolio for life insurance companies and the level of 10 year treasury yield (1994q1-2016q4). As the interest rate declines, life insurance companies tend to hold portfolios with higher yield relative to the rest of the market, within the same rating category. Insurance companies on average hold higher yield bonds than the market in the NAIC1 category, and hold bonds with similar yield to the market in the NAIC2 category. However, the negative relationship between excess yield and interest rate holds in both rating categories. In NAIC1 (NAIC2) category, a one percentage point decrease in 10 year treasury yield is associated with 10.9 (3.6) basis point increase in excess yield on insurance companies' bond portfolio.

One possible explanation of this pattern is "reaching for yield." The literature has argued that a financial institution's risk-taking appetite is stronger when interest rates are low (Choi and Kronlund 2017, Chodorow-Reich 2014, Barbu, Fricke and Moench 2016, Ma, Lian and Wang 2017, Di Maggio and Kacperczyk 2017). According to this view, insurance companies might have a tendency to take excess risk to generate additional returns because lower interest rate has reduced the expected return on their existing portfolio.

There are two major sources of risk in corporate bond market that insurers could load on in order to generate higher expected returns. The first source is credit risk. As argued in Becker and Ivashina (2015), one way for insurance companies to reach for yield is to increase their holdings of bonds with greater credit risk within the same NAIC rating category. The second source is duration risk. Lengthening the duration of insurance company's bond portfolio is an alternative way for insurers to increase the portfolio's expected return. In fact, if the excess yield on insurers' portfolio is driven by reaching for yield incentive, they will strategically choose between loading on credit or duration risk based on optimal risk-return trade-off.

In order to unpack the risk quantities of insurance companies' portfolio into these two

sources of risk, we come up with a matching algorithm. In particular, for every NAIC1 bond that insurance companies hold on their balance sheet in a given quarter, we find 10 bonds among all the remaining NAIC1 bonds outstanding with the closest duration to the bond we want to match with. Then we subtract the average yield of the 10 duration-matched bonds from the yield of the bond that insurers hold. We call this excess yield "duration-matched excess yield" of the bond. In our empirical design, we are always using market holdings of corporate bonds as the benchmark (control) group, following Becker-Ivashina and Choi-Kronlund. Similarly, we use only corporate bonds in duration matching, in line with Choi and Kronlund (2017) who use maturity buckets within the corporate bond universe. We aggregate this duration-matched excess yield to the whole insurance sector by value weighting the bond-level metric by the total par amount held by insurance sector. We repeat this exercise for the NAIC2 category.

This duration-matched excess yield captures how much of the excess yield remains on insurance sector's portfolio after we control for duration. By comparing the yield of insurance sector's bond holdings with a control group from all the bonds outstanding with similar duration in the same NAIC category, we can properly take care of any nonlinear relationship between duration and yield, which could not be fully controlled in a linear regression framework.

Stylized Fact 2: *After controlling for duration, the "duration-matched excess yield" does not react to interest rate changes.*

Figure 2 plots the duration-matched excess yield against 10-year Treasury yield. Unlike the excess yield, the duration-matched excess yield no longer increases when interest rate declines. In NAIC1 category, the "duration matched excess yield" is insensitive to changes in interest rate (Panel A), and in NAIC2 category, it even slightly declines in low interest rate environment (Panel B). When interest rates are high, the excess yield (scattered in orange) and duration matched excess yield (scattered in blue) are indistinguishable from each other, whereas their difference widens when interest rate declines. This pattern tells us that the negative association between insurers' excess yield and interest rate we see in Fact 1 can be attributed to the difference in duration profile of their portfolios relative to the market, suggesting that insurers may be increasing their asset portfolio duration as interest rate declines.

Indeed, this hypothesis is verified in Figure 2 Panel C. We calculate for NAIC1 category the "excess duration" of insurance sector's bond holdings (holding-weighted average duration of insurance company portfolio minus the average duration of the market). We see that, on

average, insurance companies hold higher duration bonds. Moreover, the excess duration varies a lot with interest rate. When interest rates are around 7%, the excess duration is almost zero, and it then increasee monotonically to around 2.5 when interest rates decline to 1.5%.[7] We observe a similar qualitative pattern in Panel D for NAIC2 category.

One might also wonder how much of the variation of the excess yield on insurance company's bond portfolio is driven by changes in credit risk profile of the portfolio. To shed light on this question, we adopt a similar matching algorithm for credit risk. For every bond held by insurance companies on their balance sheet in a given quarter, we find 10 bonds among all the bonds outstanding that have the closest distance-to-default (DD) to it. This allows us to compare, after controlling for credit risk characteristics, how much of the excess yield is left on insurance companies' bond portfolio. This approach also addresses the potential concern whether some of the pattern in Panels A and B in Figure 2 is driven by the correlation of duration and credit risk (i.e. by controlling for duration we also unwillingly controlled for credit risk).

Stylized Fact 3: *After controlling for credit risk, the "credit-risk-matched excess yield" still increases as interest rate decreases.*

As shown in Figure 3 (Panels A & B), the "DD-matched excess yield" still has a very negative correlation with the level of interest rate. In fact, the "DD-matched excess yield" is almost indistinguishable from the excess yield. This means the credit risk alone does not explain much of the changes in excess yield on insurers' bond portfolio in response to changes in interest rates. This is verified in Panels C & D of Figure 3 which examines the excess credit risk on insurance companies' bond portfolio.

To summarize, we show that insurance companies are tilting their portfolios towards higher-yield bonds when interest rates decline. At first, this seems to be consistent with "reaching for yield" in a low interest rate environment. However, we find that the tilt towards higher-yield bonds seems to be primarily driven by an increase in duration rather than credit risk and insurers do not seem to increase their credit risk as interest rates decline.

These patterns cannot be squared with a rational model in which insurance companies take on excessive risk to reaching for yield when interest rates are low because (i) exposure to credit risk does not react to changes in interest rates, and (ii) life insurance companies in general have longer liability duration than asset duration and increasing asset duration in response to interest rate declines would actually reduce their risk, rather than causing them

[7] We use modified duration, which is a price sensitivity measure. It's defined as the percentage change in the price of the bond when the yield increases by one percent.

to take on additional risk. In the next section, we propose an alternative explanation for these stylized facts: insurance companies are gradually adjusting their asset portfolio duration to meet a duration target that minimizes their interest rate risk subject to adjustment costs.

3 Duration Matching of Life Insurance Companies

3.1 Duration Gap

Understanding the concept of duration matching starts with understanding the concept of duration gap. We adopt the definition from Mishkin and Eakins (2012) and define duration gap as $G \equiv D_A - \frac{L}{A} D_L$, where D_A is the duration of assets, D_L is the duration of liabilities, and L/A is leverage (liabilities/assets). The definition is motivated by the fact that an insurance company with zero duration gap will have equity value immune to interest rate changes. To see this, note that $-\frac{\partial E}{\partial r} = -\frac{\partial (A-L)}{\partial r} = -A\frac{\partial \ln A}{\partial r} + L\frac{\partial \ln L}{\partial r} = A\left(D_A - \frac{L}{A} D_L\right) = A \times G$. Dividing both sides by equity value of an insurance company and noting that $D_E = -\frac{\partial \ln E}{\partial r}$, we get the identity $G = \frac{E}{A} D_E$. From a risk management perspective, it is optimal for insurance companies to keep a duration gap close to zero so that the equity value of insurers do not fluctuate too much as interest rate moves around. Indeed, life insurance companies use duration matching as a hedging tool to manage interest rate risk (Hartley, Paulson, and Rosen 2016).

Duration matching can also rationalize the fact that insurance companies have shorter duration of assets relative to their liabilities (EIOPA, 2014a, b, Graph 78), a fact hard to rationalize in a framework where insurance companies acquire high duration bonds to "reach for yield". In a framework where insurers reach for yield by acquiring higher duration assets, asset duration should exceed liability duration and lower interest rate environment would exacerbate this difference. Given that the life insurance sector has average modified asset duration less than 9 even in the highest quarter, and many policies (liabilities) have time spans of 10-30 years, this implication of reaching for yield is difficult to reconcile with the data. However, duration matching readily explains why $D_A > D_L$. Since the insurer's goal is to attain a zero duration gap, i.e. $D_A = \frac{L}{A} D_L$, we have $D_A < D_L$ because leverage $L/A < 1$.

In principle, life insurers could also use derivatives to manage their interest rate risk, in addition to adjusting asset duration. However, since using derivatives are expensive, it has traditionally played little role in risk management of the life insurance industry (Berends, McMenamin, Plestis, and Rosen, 2013). Therefore, we do not consider interest rate derivatives in the analysis and assume insurers have to rely on duration matching to manage their interest rate risk.

3.2 Do Insurers Always Maintain Zero Duration Gap?

We start our analysis with the simplest duration matching framework: insurers continuously rebalance to attain zero duration gap, so that equity is always immune to interest rate fluctuations. This is similar to the stylized example of duration matching as in Domanski, Shin and Sushko (2017). A few testable implications comes out directly from this framework.

Consider an insurance company aiming to always keep duration gap equal to zero, $G = 0$. As interest rate changes the duration gap can deviate from zero and hence the insurer needs to engage in dynamic hedging. How the insurance company rebalances its portfolio depends on dG/dr, the sensitivity of the current duration gap to interest rate. Our stylized fact implies that insurance companies increase duration of asset D_A after an interest rate decrease, which is consistent with a scenario that duration gap falls below zero and insurance companies have to lengthen asset duration to close the gap. This implies $dG/dr > 0$.

Therefore, the simplest duration-matching framework suggests $G = 0$ and $dG/dr > 0$. These are predictions testable using the duration and convexity of insurance company's equity. As discussed in the previous section, sensitivity of equity to interest rate is directly linked to duration gap: $-\frac{\partial E}{\partial r} = A \times G$. So if duration gap is equal to zero, the equity value must be perfectly immune to interest rate fluctuations. In other words, duration of equity $D_E \equiv -\frac{1}{E}\frac{dE}{dr} = 0$. Note that we have the mathematical result $\frac{dG}{dr} = \frac{d}{dr}\left(-\frac{1}{A}\frac{\partial E}{\partial r}\right) = -\frac{1}{A}\frac{d^2E}{dr^2} + \frac{dE}{dr}\frac{1}{A^2}\frac{dA}{dr}$. And when duration is perfectly matched, we have $\frac{dE}{dr} = 0$, which means $\frac{dG}{dr} = -\frac{1}{A}\frac{d^2E}{dr^2}$. So $dG/dr > 0$ implies $-\frac{d^2E}{dr^2} > 0$. This means the convexity of equity $C_E = \frac{1}{E}\frac{d^2E}{dr^2} < 0$. In sum, perfectly matched duration leads to the following predictions:

1. On average, insurers keep zero duration gap, thus $D_E = 0$

2. Insurance company actively increases D_A after an interest rate decrease, implying $C_E > 0$

The duration and convexity of equity could be directly estimated using the following regression (Campbell, Lo, and MacKinlay 1997):

$$Ret_{E,t} = Q - D_E \Delta y_{10,t} + \frac{C_E}{2}(\Delta y_{10,t})^2$$

We construct weekly equity returns using the SNL U.S. Insurance Life & Health Equity Index (1994-2017) and regress them on weekly changes in 10-year treasury yield. Table 1 reports the point estimates of the regression coefficients in the whole sample, which suggests that on average $D_E = -0.057$ and statistically significant. The convexity is not significantly different from zero. This rejects the predictions from the simplistic duration matching model, and hence the notion that insurers always maintain zero duration gap.

To better understand the reason behind the failure of the simplest duration matching

model, we run the same regression over 2-year rolling windows and study evolution of D_E and C_E. From Figure 4 we see that the lower interest rates in recent years may have pushed the insurers towards $D_E < 0$. As we will discuss in later sections of the paper, on reason might be that the increase in the duration of liabilities due to the implicit options in some insurance contracts, for example pre-determined withdrawal/surrender value of life insurance products and annuities, which are out of the money in the low interest rate environment. This effect is similar to the effect of prepayment option in the context of mortgages and banks.

The results also suggest that insurance companies do not fully adjust their asset duration to perfectly match with liability every period. More realistically, insurance company's duration matching behavior is better described by a "partial adjustment" framework. This framework introduces market frictions: adjusting a large fraction of portfolio in corporate bond market in a short period of time is costly, due to price pressure and illiquidity of the market. When liability duration increases, insurance companies try to rebalance their portfolio to increase D_A, but can only do so gradually over time. Moreover, when interest rate continues to decline and further widens this gap, insurance companies will adjust their asset portfolio duration to chase a "time-varying target".

4 Duration Matching with Adjustment Costs: The Target Duration Hypothesis

In this section, we provide the theoretical foundations of dynamic duration matching under adjustment costs. We show how the solution of a simple theoretical model leads to a reduced-form model that can be directly estimated in the data using a standard regression approach. Since this reduced-form model turns out to be analogous to econometric models of the target leverage hypothesis in corporate finance (for example, DeAngelo and Roll 2014), we call our framework the target duration hypothesis.

4.1 The Model

The insurance company wants to adjust its portfolio to keep the duration gap close to zero in an effort to reduce the interest rate risk because of regulations that tie risk-based capital surcharges to interest rate risk (Lombardi, 2006) and because the demand for their products depend on their health and riskiness (Koijen and Yogo, 2015). However, there are costs of rebalancing the firm's asset portfolio to make large adjustments in asset duration. For example, selling and purchasing assets in large quantities may have greater marginal cost

due to market frictions like price pressure or due to greater cost of effort by investment managers. This intuitive idea of frictions to portfolio adjustment is also confirmed in our discussions with regulators and conforms with the fact that the insurers do not engage in bond acquisitions and disposals in every period.[8]

The firm is trying to balance between its desire to minimize the cost of having a duration gap different from zero and its desire to minimize the cost of adjustments to its portfolio duration. As a result, the firm's objective function at date t is given by

$$\max -\left[\frac{\phi}{2}\left(G_t\right)^2+\frac{\psi}{2}\left(\Delta D_{A,t}\right)^2\right],$$

where G is the duration gap and ΔD_A is how much the firm adjusts its asset duration. The first term in this objective function captures the cost of deviating from zero duration gap, a deviation that increases interest rate risk regardless of the direction of the deviation. The second term captures increasing marginal cost of adjusting duration regardless of the direction of duration adjustment.[9]

The duration gap is defined as in Mishkin and Eakins (2012), $G \equiv D_A - \frac{L}{A} D_L$, where D_A is the duration of assets, D_L is the duration of liabilities, and L/A is leverage (liabilities/assets). The new asset duration after the firm's portfolio adjustment is given by $D_{A,t} = D^0_{A,t} + \Delta D_{A,t}$ where $D^0_{A,t}$ is the duration of legacy assets at time t, that is, $D^0_{A,t}$ is what would be the asset duration if the firm were not to make any portfolio adjustment ($\Delta D_{A,t} = 0$) but rather keep the same portfolio as in the beginning of the period. Moreover, since keeping the duration gap close to zero means that the firm should keep duration of assets (D_A) close to $\frac{L}{A} D_L$, we define $D^*_A \equiv \frac{L}{A} D_L$, as the target asset duration. Putting this information together, the objective function of the firm becomes to choose the optimal adjustment to its portfolio duration

$$\max_{\Delta D_{A,t}} -\left[\frac{\phi}{2}\left(D^0_{A,t}+\Delta D_{A,t}-D^*_{A,t}\right)^2+\frac{\psi}{2}\left(\Delta D_{A,t}\right)^2\right].$$

Duration of liabilities react to changes in interest rates because of the behavior of the policyholders. Many insurance products offer policyholders the option to contribute additional funds at their discretion or to close out (surrender) a contract in return for a predetermined payment. When interest rates change, it is more likely that policyholders will act on these

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[9] We have chosen quadratic cost functions for ease of derivation of first-order conditions. Alternatively, the first-order condition of this model can be seen as a linear approximation to the first-order condition of a model with more general cost functions.

options (Berends, McMenamin, Plestis, and Rosen, 2013). In particular, lower interest rates increase liability duration by decreasing the likelihood of surrender and increasing the likelihood of paid-up additions. We can capture this relationship by allowing the duration target to depend on interest rates, $D_A^*(r)$. Furthermore, as a result of the non-zero convexity of the bonds, the duration of legacy assets are affected by changes in interest rates. We can express this dependence as $D_{A,t}^0 = D_A^0(r_t)$. As a result, the objective function of the firm becomes

$$\max_{\Delta D_{A,t}} -\left[\frac{\phi}{2}\left(D_A^0(r_t) + \Delta D_{A,t} - D_A^*(r_t)\right)^2 + \frac{\psi}{2}\left(\Delta D_{A,t}\right)^2\right].$$

The FOC of this problem is given by

$$\Delta D_{A,t} = -\frac{\phi}{\psi+\phi}\left[D_A^0(r_t) - D_A^*(r_t)\right].$$

This expression is familiar to empirical researchers working with the target leverage hypothesis in corporate finance, e.g. DeAngelo and Roll (2014). In particular, this expression captures how fast the firm reacts to imbalances in the duration of its legacy assets in relation to its target duration, $D_A^0(r_t) - D_A^*(r_t)$. In analogy with the target leverage hypothesis, $0 < \frac{\phi}{\psi+\phi} < 1$ is the speed of adjustment to the target duration. The speed of adjustment is positively related to the cost of missing the duration target, ϕ, and negatively related to the adjustment cost, ψ.

4.2 Testing the Model

Our data provides comprehensive information regarding the holdings of every insurance company, which we aggregate at the firm-quarter level. We can calculate the duration of legacy assets at the end of a given quarter t, $D_A^0(r_t)$, from the data directly because we observe the holdings of the insurer at the end of the last quarter. Similarly, we can calculate the active adjustment to duration as the difference between the duration of the holdings and the duration of the legacy assets at the end of quarter t, $\Delta D_{A,t} = D_{A,t} - D_{A,t}^0$.

The duration of liabilities is hard to measure because liabilities of insurance companies do not have the same level of detail as its assets. Therefore, we model the dependence of the liabilities on interest rate as a linear function so that the target duration is given by $D_A^*(r) = \frac{L}{A}(a + b \times r)$, where $a > 0$ and $b < 0$ because the duration of liabilities is positive and decreasing function of interest rates. Plugging this expression into the first

order condition of the model,

$$\Delta D_{A,t} = -\frac{\phi}{\psi+\phi}\left[D_A^0(r_t) - D_A^*(r_t)\right]$$

we obtain the following expression that can be estimated using a linear regression,

$$\begin{aligned} ActiveDurationAdjustment &= -\frac{\phi}{\psi+\phi} \times LegacyDuration + \frac{\phi}{\psi+\phi} \times Leverage \times (a + b \times r) \\ &= -\frac{\phi}{\psi+\phi} \times LegacyDuration + \frac{\phi}{\psi+\phi} a \times Leverage \\ &\quad + \frac{\phi}{\psi+\phi} b \times Leverage \times r. \end{aligned}$$

It is customary in empirical work to put the uninteracted terms into a regression when interacted terms are present. Therefore, our final regression also includes the uninteracted (stand-alone) interest rate, r, as follows

$$\begin{aligned} ActiveDurationAdjustment_{i,t} &= const_i + \alpha \times LegacyDuration_{i,t} + \beta \times Leverage_{i,t-1} \\ &\quad + \gamma \times Leverage_{i,t-1} \times r_t + \delta \times r_t + error_{i,t} \end{aligned}$$

where each observation is at the level of firm i and quarter t. Since the dependent variable is the *adjustment* in duration, the firm fixed effect, $const_i$, controls for any trend in the duration of the holdings that may be correlated with interest rates.

This regression allows us to test the following predictions of our model:

1. The coefficient of $LegacyDuration$ ($\alpha = -\frac{\phi}{\psi+\phi}$) satisfies $-1 < \alpha < 0$.
2. The coefficient of $Leverage$ ($\beta = \frac{\phi}{\psi+\phi} a$) is positive.
3. The coefficient of $Leverage \times r$ ($\gamma = \frac{\phi}{\psi+\phi} b$) is negative.
4. The coefficient of stand-alone interest rate r (δ) is zero.

As an additional test, we note that our model allows us to estimate the duration gap as

$$\begin{aligned} G &= D_A - D_A^*(r) \\ &= D_A - Leverage \times (a + b \times r) \\ &= D_A - Leverage \times \left(-\frac{\beta}{\alpha} - \frac{\gamma}{\alpha} \times r\right) \\ &= D_A + Leverage \times \left(\frac{\beta}{\alpha} + \frac{\gamma}{\alpha} \times r\right). \end{aligned}$$

As a final test, we check if the surrender behavior of the policyholders is consistent with our results. Since the positive link between the policy surrender and interest rate generates a link between the liability duration and interest rates, we test the following two-stage regression

$$\begin{aligned} SurrenderRatio_{i,t} &= \theta_i + \eta \times r_t + \varphi \times LegacyDuration_{i,t} + \varepsilon_{i,t} \\ ActiveDurationAdjustment_{i,t} &= const_i + \alpha \times LegacyDuration_{i,t} + \beta \times SurrenderRatio_{i,t} + error_{i,t} \end{aligned}$$

where we expect $\eta > 0$, $\alpha < 0$, and $\beta < 0$. We estimate similar regressions where the surrender ratio is replaceed by lapse ratio.

In the next section, we show that these predictions of the model is confirmed in the data suggesting that the target duration hypothesis is a good representation of the investment decisions of the insurance companies.

5 Results

5.1 Interest Rate and the Option to Surrender and Lapse

We collect data for the amount of policy surrendered and lapsed by each insurance company every year. By dividing these variables by the total amount of policy in force we get a ratio of policy surrendered and lapsed. These ratios are capturing the tendency of policy holders to surrender or lapse their policy. Figure 5 plots the surrender rate and lapse rate against the 10 year treasury yield. We see a strong positive association. In higher interest rate environment there's also high tendency for policy holders surrender or lapse their policy. As interest rate declined from 6.5% to 2%, the surrender rate decreased from 1.8% to 0.8%, and the lapse rate decreased from 7.7% to 4.7%. This is because when interest rates are high, there are better alternative investment opportunities that policy holders can substitute into. On the other hand, since many life insurance and annuity products have embedded guarantees, policy holders would prefer to receive the minimum guaranteed rate on these products in a low interest rate environment.

An increase in surrender rate and lapse rate will influence the target duration of an insurance company. Increase in surrender rate will reduce the liability duration D_L because the future liabilities become current liabilities (cash liability). How lapse affect target duration is less straightforward. If a policy holder stops paying premium, life insurance policies (whole life, variable universal life, and universal life insurance policies) with existing cash values will use its account value to pay for the unpaid premium. If the account value is insufficient to pay for the policy holder's premium, then the policy will be consid-

ered lapsed. Recall that the target duration is equal to $D_A^* = \frac{L}{A} D_L$. Suppose an insurance company have two policies with payouts L_1 and L_2 (so that total liability $L = L_1 + L_2$), and duration of the two payouts are D_{L1} and D_{L2}. The target duration of the insurer is $D_A^* = \frac{L}{A} \frac{L_1 D_{L1} + L_2 D_{L2}}{L_1 + L_2} = \frac{L_1 D_{L1} + L_2 D_{L2}}{A}$. Suppose, without loss of generality, policy 1 is lapsed; the target duration becomes $D_{A,Lapse}^* = \frac{L_2}{A} D_{L2} < D_A^*$. This means more lapse will also reduce the target duration of an insurance company.

When interest rates are low, the surrender rate and lapse rate are also low because investors will prefer to hold their policy with guaranteed payment. This mechanism will increase the target duration of insurance companies. As a result, insurance companies will actively increase their duration in order to reduce the duration gap.

5.2 Estimating Parameters in the Partial Adjustment Model

As illustrated in the previous section, we run the following regression:

$$\begin{aligned} ActiveDurationAdjustment_{i,t} &= const_i + \alpha \times LegacyDuration_{i,t} + \beta \times Leverage_{i,t-1} \\ &\quad + \gamma \times Leverage_{i,t-1} \times r_t + \delta \times r_t + error_{i,t} \end{aligned}$$

The regression allows us to test the predictions from the model by estimating the parameters. For all insurance companies we have book leverage measured using liability divided by total assets, from insurance company's quarterly filings. And for public insurance companies, we can get market leverage using $1 - \frac{E}{A}$ where E is the market capitalization of stocks, and A is the total asset. Panel A and B in Table 2 reports the estimation results with book and market leverage respectively.

The estimation supports all four predictions from the model:

1. The coefficient of legacy duration $\alpha = -0.0625$ is significant and satisfies $-1 < \alpha < 0$. Note that $-\alpha = \frac{\phi}{\psi + \phi} = 0.0625$ is the speed of adjustment. The point estimate implies the time to close half of the duration gap is about 11 quarters (Half Life=$\frac{\ln(1/2)}{\ln(1-0.0625)}$), assuming the target does not change. This suggests that the duration adjustment is gradual and there are barriers to adjust asset portfolio immediately.

2. The coefficient of leverage $\beta = 0.340$ is positive and significant. The point estimate implies the coefficient $a = \frac{\beta}{\phi/(\psi+\phi)} = \frac{0.340}{0.0625} = 5.44$.

3. The coefficient of leverage interacted with interest rate is $\gamma = -2.981$ is negative and significant. This implies a negative coefficient of $b = \frac{\gamma}{\phi/(\psi+\phi)} = \frac{-2.981}{0.0625} = -47.70$. Remember that $D^*(r) = \frac{L}{A}(a + b \times r)$, this means there's a negative long-run relationship between interest rate and duration target. If 10 year treasury yield goes down by 1 percentage point,

the target duration goes up by 0.477×0.9 for the average firm with leverage of 0.9. This is economically meaningful.

4. The coefficient of the stand-alone interest rate r is $\delta = 0.452$ and statistically indistinguishable from zero.

5.3 Active Duration Adjustment and Option to Surrender and Lapse

The mechanism in our model is that interest rate changes affect policy holder's surrender and lapse behavior, thus affecting the target duration of insurance companies, which then transmits into active duration adjustment on asset side. For the mechanism to work, any surrender or lapse caused by interest rate fluctuations should lead to active duration adjustment. The mechanism (for the case of surrenders) is testable using the following two-stage instrumental variable regression:

$$\begin{aligned} SurrenderRatio_{i,t} &= \theta_i + \eta \times r_t + \varphi \times LegacyDuration_{i,t} + \varepsilon_{i,t} \\ ActiveDurationAdjustment_{i,t} &= const_i + \alpha \times LegacyDuration_{i,t} \\ &\quad + \beta \times \widehat{SurrenderRatio}_{i,t} + error_{i,t} \end{aligned}$$

where $\widehat{SurrenderRatio}_{i,t}$ is the first stage regression estimate, which we use in the second stage regression.

This mechanism creates two predictions:

1. In the first stage regression, we have $\eta > 0$. When interest rate is higher, there will be more policy surrender.

2. In the second stage regression, we have $\beta < 0$. Companies with higher (lower) surrender ratio will have to actively decrease (increase) the asset duration.

Similarly, we could test the effect of lapse on active duration adjustment by replacing the surrender ratio with lapse ratio in the regression.

Table 3 reports the estimation for the two stage regressions. For both surrender ratio and lapse ratio, we find strong support for $\eta > 0$ and $\beta < 0$. In the first stage regression, a one percentage point decrease in interest rate is associated with 0.30 percentage point decrease in surrender ratio and 0.68 percentage point decrease in lapse ratio. In the second stage, a one percentage point decrease in predicted surrender ratio is associated with positive quarterly active duration adjustment of 0.0795. And a one percentage point decrease in lapse ratio is associated with quarterly active duration adjustment of 0.035. A one standard deviation

change in surrender ratio (0.07) corresponds to a change in active duration adjustment of 0.56 (=7.95*0.07), and a one standard deviation change in lapse ratio (0.10) corresponds to a quarterly change in active duration adjustment of 0.345 (=3.45*0.10). The magnitudes are economically meaningful and comparable to one standard deviation change in active duration adjustment (0.55).

6 Conclusion

In this paper, we document three stylized facts about interest rate and life insurance companies' investment behavior. As interest rate declines, life insurance companies increase the excess yield on their corporate bond portfolio (relative to the market). Using a matching algorithm to unpack the risk quantities of insurance companies' portfolio, we find that most of the excess yield is driven by "duration tilt" rather than "credit risk tilt". We propose a "target duration hypothesis" to explain insurance companies' investment behavior which is consistent with the stylized facts. According to the hypothesis, insurance companies adjust asset duration to match a time-varying "duration target". When interest rate changes, policy holders strategically close out a contract in return for a predetermined payment. This changes insurers' "duration target", which then transmits into active duration adjustment. Finally, we test several predictions from the target duration model.

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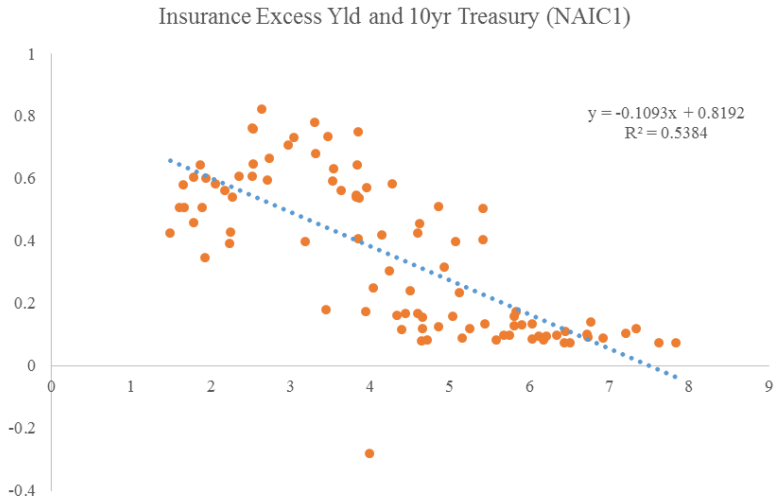
Figure 1. Interest Rate and Excess Yield on Insurance Sector's Bond Portfolio

The figure plots the excess yield on life insurance sector's corporate bond portfolio against the 10-year yield on US treasury. The excess yield is first constructed at bond-quarter level, for NAIC category 1 and 2 separately. For every bond held by the life insurance sector, we compute the excess yield by subtracting the market average yield (i.e. average yield on all bonds outstanding for a given NAIC category) from the bond yield. Then we aggregate the bond level excess yield to insurance sector level weighting by amount held by the insurance sector. Panel A reports for bonds in NAIC1 category, and Panel B for NAIC2 category.

Panel A



Panel B

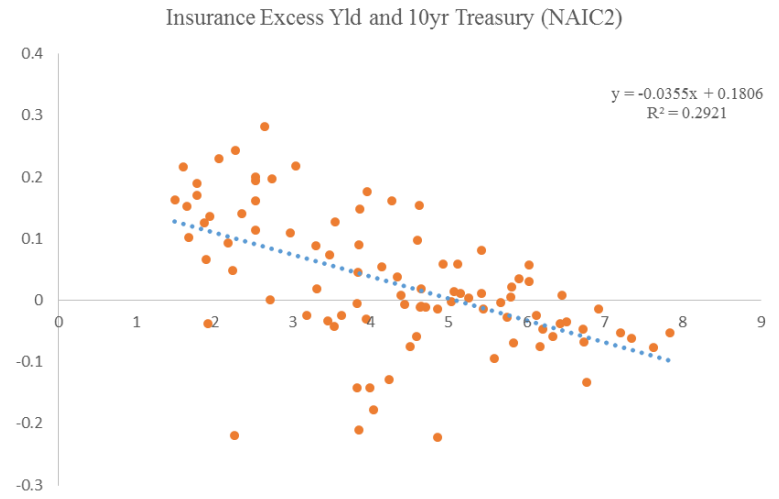
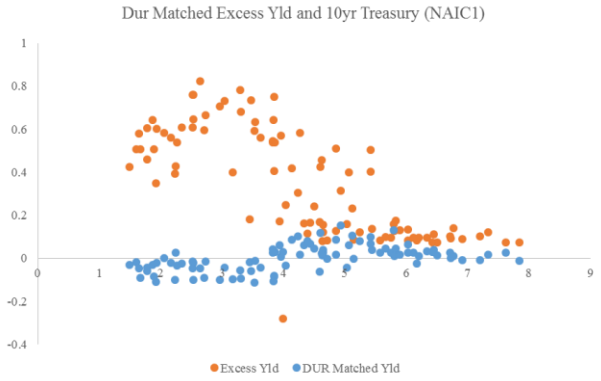


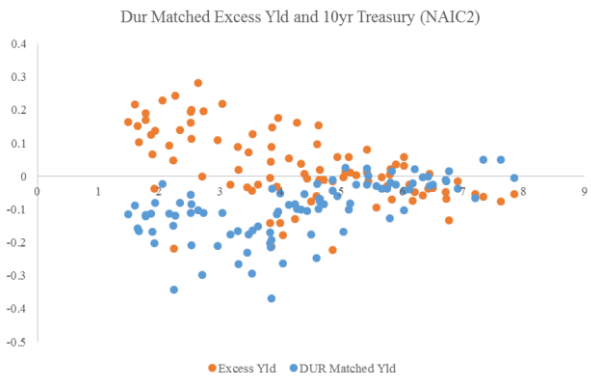
Figure 2. Interest Rate and Duration Tilt on Insurance Sector's Bond Portfolio

Panel A and Panel B plots the duration matched excess yield against the 10-year yield on US treasury (blue scatters) for NAIC category 1 and 2 respectively. As a comparison, we also plot the excess yield shown in Figure 1 (orange scatters). The duration matched excess yield is the difference between bond yield and average yield of 10 bonds with close duration from the market. Panel C and Panel D reports the excess duration (duration tilt) of insurance sector's corporate bond portfolio, which is the different between insurer's bond portfolio duration and average duration of all bonds in the market. We do this for bonds with NAIC category 1 (Panel C) and 2 (Panel D) separately.

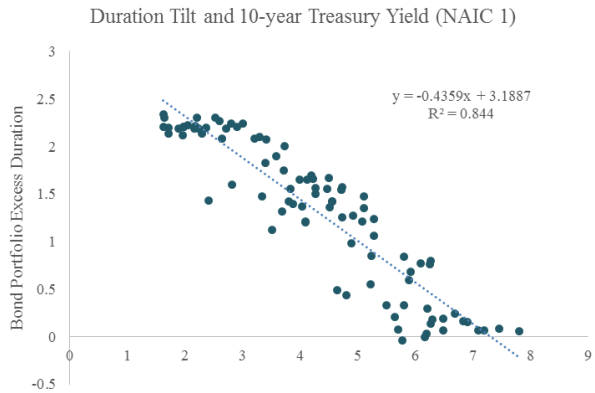
Panel A



Panel B



Panel C



Panel D

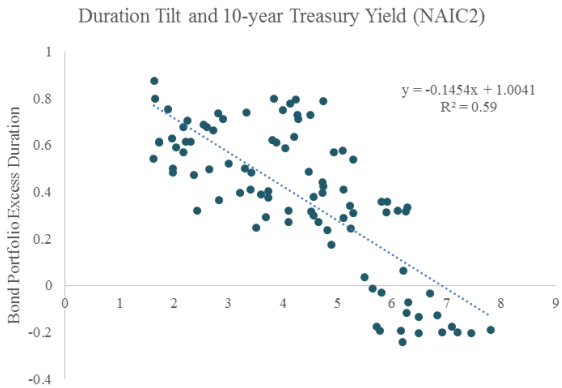
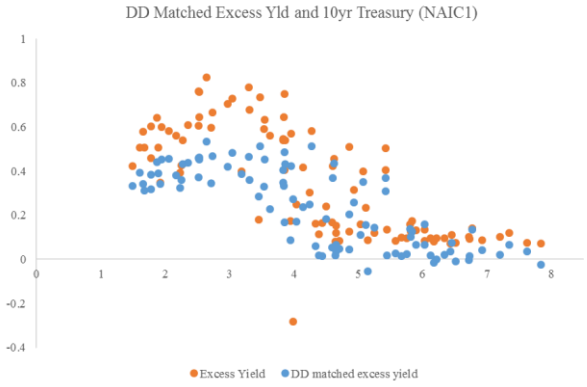


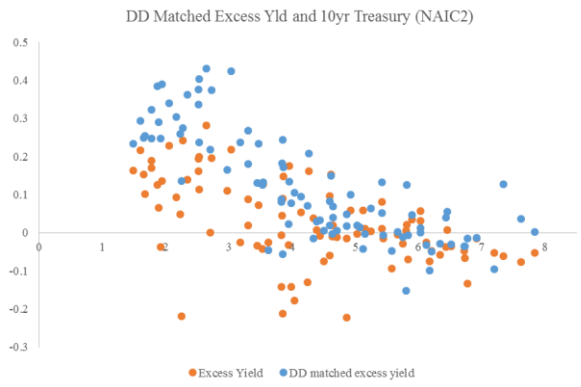
Figure 3. Interest Rate and Credit Risk Tilt on Insurance Sector's Bond Portfolio

Panel A and Panel B plots the distance-to-default (DD) matched excess yield against the 10-year yield on US treasury (blue scatters) for NAIC category 1 and 2 respectively. As a comparison, we also plot the excess yield shown in Figure 1 (orange scatters). The duration matched excess yield is the difference between bond yield and average yield of 10 bonds with close duration from the market. Panel C and Panel D reports the excess duration (duration tilt) of insurance sector's corporate bond portfolio, which is the different between insurer's bond portfolio duration and average duration of all bonds in the market. We do this for bonds with NAIC category 1 (Panel C) and 2 (Panel D) separately.

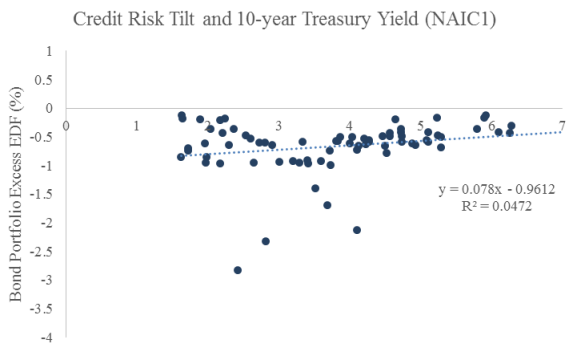
Panel A



Panel B



Panel C



Panel D

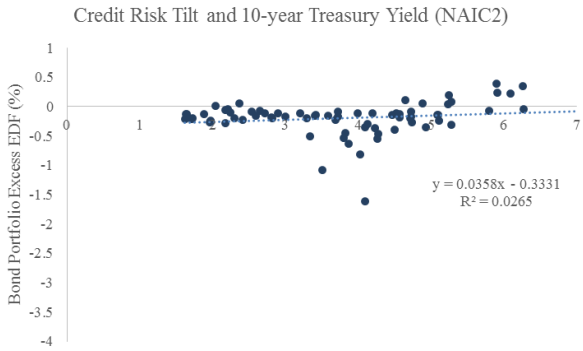
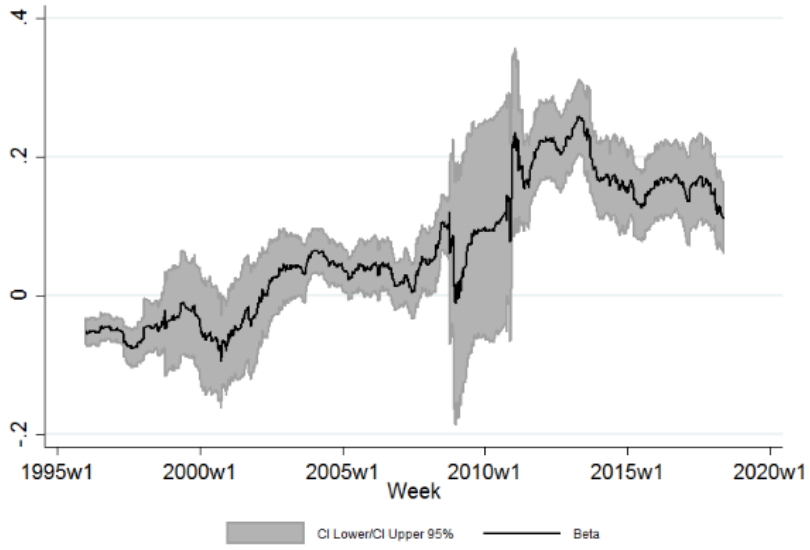


Figure 4. Time Varying Duration and Convexity of the Life Insurance Sector's Equity

The figures plots the 2-year rolling estimation of coefficients in the regression $Ret_{E,t} = Q - D_E\, \Delta y_{10,t} + \frac{C_E}{2}\left(\Delta y_{10,t}\right)^2$ from 1994 to 2016. The shadow area indicates the 95% confidence interval of the estimated coefficient. Panel A plots the rolling estimation of the coefficient $-D_E$ and Panel B plots the rolling estimation of coefficient$C_E/2$.

Panel A. 2 year rolling estimate of $-D_E$



2 year rolling estimate of $\frac{C_E}{2}$

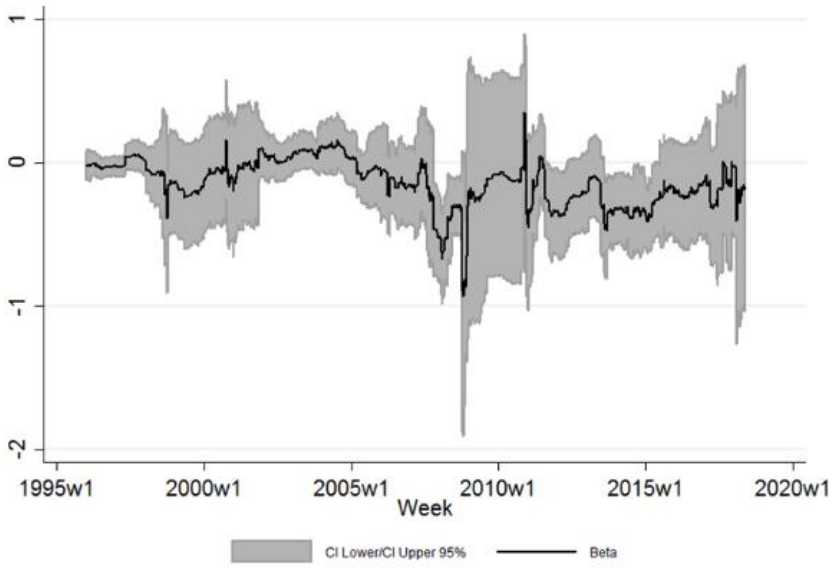
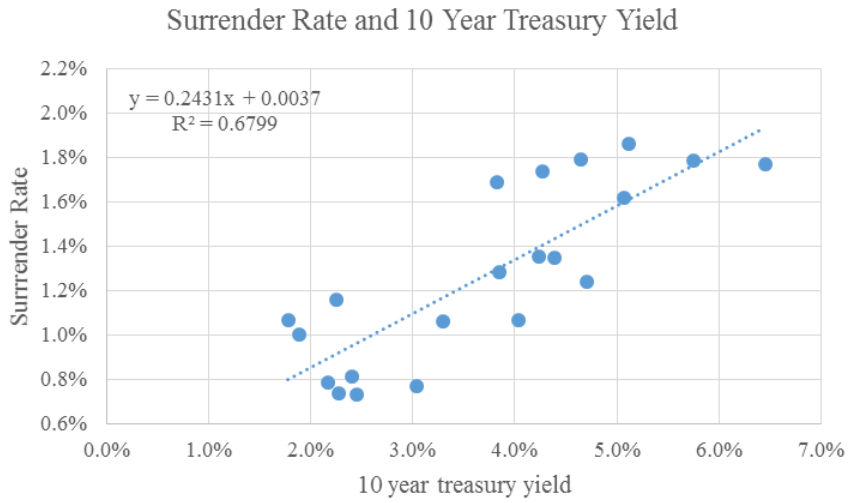


Figure 5. Interest Rate and the Option to Surrender and Lapse

The figures plots the surrender rate (Panel A) and lapse rate (Panel B) against the 10-year treasury yield. The surrender rate is the amount of insurance policy surrendered each year as a fraction of total insurance contract in force. We aggregate the data from company level to the whole life insurance sector. The lapse rate is constructed similarly.

Panel A



Panel B

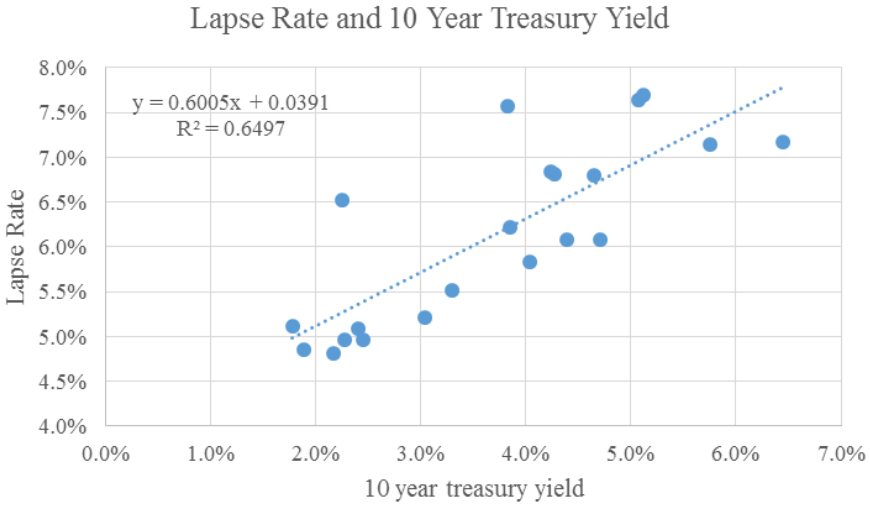


Table 1. Estimated Equity Duration and Convexity of the Life Insurance Sector

The table reports the estimated coefficient from the regression $Ret_{E,t} = Q - D_E\, \Delta y_{10,t} + \frac{C_E}{2}\left(\Delta y_{10,t}\right)^2$ (1994 to 2016, weekly data)

	Q	$-D_E$	$C_E/2$
Coeff	0.004	0.057***	-0.092
t-stat	-3.04	-3.42	(-0.88)

Table 2. Estimating Parameters in Partial Adjustment Model

The table reports the estimated coefficients in the partial adjustment model from the regression $ActiveDurAdj_{i,t} = con_i + \alpha \times LegacyDur_{i,t} + \beta \times Leverage_{i,t} + \gamma \times Leverage_{i,t} \times r_t^{10} + \delta \times r_t^{10} + \varepsilon_{i,t}$. The standard errors are double clustered by firm and quarter. Panel A runs the regression using book leverage constructed using insurance company's quarterly filings. Panel B runs the regression using the subset of insurance companies whose parents are publicly listed firms. The book leverage is the book value of liability divided by total asset $\frac{L}{A}$. The market leverage is constructed using $1 - \frac{E}{A}$ where E is the market capitalization at every quarter end.

Panel A. Book Leverage	
VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	-0.0625***
	(0.00458)
$BkLeverage_{i,t-1}$	0.340***
	(0.0560)
r_t^{10}	0.452
	(0.766)
$BkLeverage_{i,t-1} * r_t^{10}$	-2.981***
	(0.961)
Observations	59,559
R-squared	0.053
firm FE	YES
quarter FE	YES

Panel B. Market Leverage	
VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	-0.0596***
	(0.00972)
$MktLeverage_{i,t-1}$	0.242**
	(0.104)
r_t^{10}	2.104
	(1.775)
$MktLeverage * r_t^{10}$	-4.876**
	(2.260)
Observations	12,001
R-squared	0.054
firm FE	YES
quarter FE	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Active Duration Adjustment and Option to Surrender and Lapse (Quarterly)

The table reports the estimation result of the two stage regressions, which studies how interest rate changes transmits to the active duration adjustments on the asset side of insurance companies. The first stage regresses the surrender ratio on interest rate and legacy duration. The second stage regresses the quarterly active duration adjustment on predicted surrender ratio and legacy duration.

Panel A. Active Duration Adjustment and Surrender Ratio

1st Stage		2nd Stage	
VARIABLES	$SurrenderRatio_{i,t}$	VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	0.000043	$LegacyDur_{i,t}$	-0.0640***
	(0.000326)		(0.00547)
r_t^{10}	0.295***	$\widehat{SurrenderRatio}_{i,t}$	-7.945***
	(0.0654)		(2.353)
Observations	51,520	Observations	51488
R-squared	0.576		
firm FE	YES	firm FE	YES
quarter FE	YES	quarter FE	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B. Active Duration Adjustment and Lapse Ratio

1st Stage		2nd Stage	
VARIABLES	$LapseRatio_{i,t}$	VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	-0.000482	$LegacyDur_{i,t}$	-0.0660***
	(0.000614)		(0.00529)
r_t^{10}	0.679***	$\widehat{LapseRatio}_{i,t}$	-3.450***
	(0.101)		(0.894)
Observations	51,520	Observations	51,488
R-squared	0.488		
firm FE	YES	firm FE	YES
quarter FE	YES	quarter FE	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Active Duration Adjustment and Option to Surrender and Lapse (Annual)

The table reports the estimation result of the two stage regressions, which studies how interest rate changes transmits to the active duration adjustments on the asset side of insurance companies. The first stage regresses the surrender ratio on interest rate and legacy duration. The second stage regresses the annual active duration adjustment on predicted surrender ratio and legacy duration.

Panel A. Active Duration Adjustment and Surrender Ratio

1st Stage		2nd Stage	
VARIABLES	$SurrenderRatio_{i,t}$	VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	0.000028	$LegacyDur_{i,t}$	-0.253***
	(0.000286)		(0.0229)
r_t^{10}	0.304***	$\widehat{SurrenderRatio}_{i,t}$	-32.94***
	(0.0692)		(10.16)
Observations	12,909	Observations	12,889
R-squared	0.586		
firm FE	YES	firm FE	YES
quarter FE	YES	quarter FE	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B. Active Duration Adjustment and Lapse Ratio

1st Stage		2nd Stage	
VARIABLES	$LapseRatio_{i,t}$	VARIABLES	$ActiveDurAdj_{i,t}$
$LegacyDur_{i,t}$	-0.000474	$LegacyDur_{i,t}$	-0.261***
	(0.000609)		(0.0236)
r_t^{10}	0.698***	$\widehat{LapseRatio}_{i,t}$	-14.31***
	(0.116)		(3.669)
Observations	12,909	Observations	12,889
R-squared	0.482		
firm FE	YES	firm FE	YES
quarter FE	YES	quarter FE	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1