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# Essays on Institutional Investors in the Bond Market

Yu, Yifan

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# Essays on institutional investors in the bond market

Yifan Yu

A Dissertation
Presented to the Faculty
of Princeton University
in Candidacy for the Degree
of Doctor of Philosophy

Recommended for Acceptance
by the Department of
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# Abstract

This thesis consists of three chapters on institutional investors in bond market.

Chapter 1 examines duration hedging behavior in corporate bond market by studying investment decisions of life insurance companies, the largest institutional investors in this market. I find that life insurers are tilting their corporate bond portfolios towards bonds with higher duration as interest rates decrease to historical lows since the 2008 financial crisis. This hunt-for-duration behavior is due to life insurers' interest rate risk hedging to ensure better duration matching between their assets and liabilities. I further show that hunt-for-duration by life insurers can drive overpricing of corporate bonds when negative monetary policy surprises hit.

Chapter 2 investigates how the risk-based capital (RBC) reform in insurance industry initiated in year 1993 affects life insurers' investment behavior in corporate bonds, and how RBC-induced distortion in insurers' investment practices could have an impact on credit allocation, and ultimately real investment in the economy. Following the reform, I observe that insurers tilt their portfolios towards the lowest rated corporate bonds within a bond risk category defined by the RBC rule. Through shifting insurers' bond demand, I find that the RBC reform changes the credit supply conditions to a particular group of firms: those that have credit ratings barely fitting into a low-risk category and belong to industries where insurers hold more corporate bonds before the reform. Furthermore, I find that these firms take advantage of the more favorable credit allocation conditions to increase investment and employment after the reform. These results highlight a channel through which regulatory reform in insurance industry can bear real consequences.

Chapter 3 studies whether life insurers rebalance their bond portfolios during Quantitative Easing (QE) programs initiated by the Federal Reserve (Fed) since the 2008 financial crisis. I find that life insurers sell QE securities and replace them with corporate bonds over certain QE periods. Moreover, life insurers rebalance toward

corporate bonds in the lowest rating tier within a risk category defined by the RBC rule under which insurers are regulated. Overall, these findings show that QE's portfolio rebalancing channel can work through the life insurance sector.

# Acknowledgements

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I feel lucky to have met great classmates and friends at Princeton. I will cherish the precious time we have spent together.

Above all, I would like to express my deepest gratitude to my parents, Jing and Ting, for everything they have done for me. They have always been by my side, which has given me more courage and strength to face challenges and chase dreams. I am indebted to them for life.

To my parents.

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# Chapter 1

# Hunt-for-Duration in the Corporate Bond Market

[1]

## 1.1 Introduction

The U.S. corporate bond market is an institutional market, with institutional holdings accounting for around 75% of the amounts outstanding.[2] Given institutional investors' dominance, it is important to understand institution's investment behavior and how institutional trading affects prices in the corporate bond market.

Against the backdrop of the prolonged period of low interest rates since the 2008 financial crisis, I study the investment behavior of U.S. life insurance companies, the largest institutional holder of corporate bonds.[3] I find that as the interest rates drop

[1] My first presentation of ideas for Section 1.4 of this chapter on U.S. institutional investors' characteristics-based demand for corporate bonds was on February 26, 2019 during Bendheim Center for Finance Student Research Workshop at Princeton University.

[2] See https://www.federalreserve.gov/releases/z1/20200921/html/l213.htm.

[3] According to the U.S. Flow of Funds, in 2019 life insurance companies hold about 29% of the total amounts outstanding of corporate and foreign bonds. See https://www.federalreserve.gov/releases/z1/20200921/html/l213.htm.

to historical lows, life insurers tilt their corporate bond portfolios towards bonds with higher duration and such behavior can bear price implications.

Why would life insurers tilt their portfolios towards high duration when the interest rates decline? This can be explained by the liability-driven investment strategies of life insurance companies. To match the long-term payment commitments of their insurance products, life insurers invest largely in fixed income assets. As the interest rate falls, the values of liabilities and assets on the balance sheet of a life insurer both increase. The magnitude and speed of the increase depends on the duration and convexity of liabilities and assets. When a life insurer's balance sheet brings about negative convexity as the interest rate falls to a very low point, the duration of liabilities increases faster than assets, leading to a widening duration gap between liabilities and assets. To protect the balance sheet against further drop in the interest rate, life insurers need to increase the duration of their asset holdings. Borrowing the term from Domanski et al. (2017), throughout the paper, I call the duration hedging behavior "hunt-for-duration".

To quantify the extent to which life insurers engage in hunt-for-duration, I employ two approaches. The first approach adopts the characteristics-based demand model developed by Koijen and Yogo (2019) in the context of bonds. The model is micro-founded by investors with mean-variance preferences for returns, who consider that returns follow a factor structure and that both expected returns and factor loadings depend on assets' own characteristics. Under the above set-up, Koijen and Yogo (2019) prove that optimal portfolio weight depends on assets' observed characteristics and latent demand (unobserved characteristics to econometricians). Using security-level data on life insurers' bond portfolios, I estimate life insurers' characteristics-based demand model for corporate bonds, where portfolio weight is a logit function of bond characteristics including yield, duration, credit rating, liquidity, and latent demand. To address the issue of endogeneity of bond yield to latent

demand in estimating the characteristics-based demand model, I use an instrumental variable that exploits the fact that institutional investors have an investment universe predetermined by their investment mandate.[4] When a bond issuer whose bond issues are included in the investment universe of more and larger investors, it then has a larger exogenous component of demand, which generates higher prices and hence lower yields that are orthogonal to latent demand.

I harvest the estimated coefficients on bond duration from the characteristics-based demand model and use them to capture life insurers' hunt-for-duration behavior. A larger coefficient on bond duration indicates that life insurers are tilting their portfolio more towards bonds with higher duration. I find that over time from year 2002 to 2017, life insurers have a heavier tilt towards high duration bonds when the 1-year Treasury yield (used as the interest rate indicator throughout the paper) is low and the slope of the yield curve (measured as the difference between 30-year and 1-year Treasury yields) is steep.

In the second approach, I compare the duration of life insurers' corporate bond portfolio to that of the market portfolio. In particular, I construct the measure "excess duration" that captures the deviation of the duration of a life insurer's corporate bond portfolio from the bond-rating-matched benchmark, which is the average duration of all corporate bonds outstanding in the same rating group.[5] Constructing the measure in relative terms is important because the insurance companies are subject to risk-based capital charges based on the credit ratings of the bonds they invested in. As a consequence, life insurers have more discretion to engage in hunt-for-duration if they maintain the ratings of their holdings.

[4]Corroborating evidence for institutional investors' time-invariant investment universe of stocks is shown in Koijen and Yogo (2019). I show in Section 1.4 that institutional investors indeed invest in bonds issued by a relatively fixed subset of bonds issuers.

[5]Ozdagli and Zhang (2019) and Choi and Kronlund (2018) have constructed the measures of reaching-for-yield in a similar spirit.

I document the negative correlation between the excess duration of life insurers' corporate bond portfolio and the interest rate with the specification that takes into account the dynamic changes in the excess duration following a shock to the interest rate. I also study the cross-sectional variation in hunt-for-duration, exploiting the differences in regulatory capital constraints faced by life insurers, as life insurers with higher asset-liability mismatch are charged a higher capital reserve. The results show that more regulatory-constrained insurers tend to hunt for duration more.

Evidence for hunt-for-duration is found not only from snapshots of life insurers' bond holdings, but also from their bond transaction activities. In a similar empirical setup as Becker and Ivashina (2015), I investigate life insurers' acquisitions of newly-issued bonds from the primary market and their trading in the secondary market. I separate the sample period into two sub-periods: a period with the 1-year Treasury yield higher than 1% (before year 2009) and a period with the yield at most 1% (after year 2009). The results show that life insurers buy (sell) more bonds that have higher (lower) excess duration. Furthermore, the correlation between life insurers' trade of a bond and its excess duration is even stronger over the sub-period of low interest rates.

The importance of life insurance companies' portfolio duration management lies in that it can explain other patterns found in the literature. For instance, without controlling for bond excess duration, during times of low interest rates, life insurers' propensity to invest in bonds is an increasing function of bond yield (which is reaching-for-yield in Becker and Ivashina (2015)). However, with inclusion of bond excess duration, the association between life insurers' trade of a bond and its yield weakens significantly, indicating that life insurers' inclination for buying bonds with higher yield in times of low interest rates is mainly prompted by increasing the duration of their bond portfolios for hunt-for-duration purposes.

To illustrate that hunt-for-duration is unique to life insurance companies due to their liability-driven portfolio management, I use other major bond investors as a comparison group. Specifically, I trace the evolution of portfolio duration of the mutual funds, who are the second largest participants in the corporate bond market. Different from life insurers, the investment strategies of mutual funds are asset-driven. Mutual fund managers are subject to short-term performance monitoring and hence are averse to holding long-term bonds that are volatile as the interest rates fluctuate. I find that mutual funds, in contrast with life insurers, are shifting their corporate bond portfolios toward lower duration as the interest rates decrease. Therefore, the comparison confirms that hunt-for-duration is not a general feature in the corporate bond market, but a specific one accounted for by the specific institutional setting of life insurance companies.

Having documented the hunt-for-duration behavior of life insurance companies, I investigate whether this behavior bears price impact on corporate bonds. To address this question, I examine the returns of bond purchases associated with hunt-for-duration. I consider bonds in the top two quintiles of excess duration bought by life insurers following a quarter with a negative monetary policy shock as bonds involved in hunt-for-duration-motivated trades. I find that during quarters following a negative monetary policy shock, in the top two quintiles of excess duration, bonds that are purchased most heavily by life insurers have abnormal returns significantly higher than bonds that are only lightly bought by life insurers, and the upward pattern in abnormal returns gradually reverses. Such price pattern is absent in other quarters. I also conduct the same examination on bonds in the bottom two quintiles of excess duration. There is no evidence of upward price pressure from life insurers buying over all quarters. Furthermore, I calculate the portfolio returns of an investment strategy that involves longing bonds acquired by life insurers for the purpose of hunt-for-duration. The strategy earns a significant negative alpha. Overall, the results provide

evidence corroborating that life insurers' hunt-for-duration behavior can engender price impacts.

This paper is related to the literature that studies the investment behavior of insurance companies. Ozdagli and Zhang (2019) proposes and validates a model of duration matching with adjustment costs to explain why life insurance companies don't fully close the duration gap between asset and liability as the interest rates decline. Domanski et al. (2017) study the hunt-for-duration behavior in the context of European life insurance companies and government bonds. Becker and Ivashina (2015) finds signs of reaching-for-yield (i.e., life insurers tilt towards the riskiest bonds within a bond rating group) over the pre-crisis period from 2004Q3 to 2007Q2. Ellul et al. (2011) find that in the event of corporate bond downgrades, regulatory-constrained insurance companies are forced to sell downgraded bonds, thereby creating a downward price pressure. Ellul et al. (2015) show that historical accounting rules, interacted with capital regulation can induce life insurers to resort to gains trading.

The rest of this chapter proceeds as follows. In Section 1.2, I discuss the institutional settings of life insurance companies and how the institutional features could lead life insurers to engage in hunt-for-duration as the interest rates decline. Section 1.3 discusses the data. In section 1.4, I estimate life insurers' demand for bond duration using the characteristics-based demand model. In sections 1.5 and 1.6, I construct the measure of excess duration of life insurers' portfolio and present the empirical results. In Section 1.7, I investigate the effects of hunt-for-duration on bond prices. Section 1.8 concludes.

## 1.2 Why hunt-for-duration in a low interest rate environment?

### 1.2.1 The institutional setting: life insurance companies

There are several unique institutional features that are crucial to life insurance companies' bond investment decisions. These features include life insurers' asset and liability characteristics, regulatory capital requirements, and accounting rules. These factors collectively explain why life insurers have an appetite for bonds with long duration in times of low interest rates.

The U.S. insurance industry is regulated under the National Association of Insurance Commissioners (NAIC) risk-based capital (RBC) system.[6] Under the RBC system, insurance companies are subject to a minimum capital requirement based on the amount of risk to which they are exposed. To determine the minimum level of capital an insurance company must maintain, the RBC formula considers four risks factors: asset risk, underwriting risk, interest rate risk, and all other business risk. One risk factor widely discussed in the literature (e.g., Becker and Ivashina (2015) and Ellul et al. (2011)) has to do with the asset risk. As bonds are a major investment vehicle for insurers, insurance companies are restricted from loading on excessive asset risk through holding bonds with low credit ratings. The restrictions are imposed by charging exponentially increasing capital requirements on bonds that belong to different NAIC risk categories. For each $100 invested, the capital charge for bonds in NAIC category 1 (bonds rated AAA/AA/A) is $0.30, whereas the capital charge for bonds in NAIC category 6 (bonds rated CC or below) is $19.50.[7]

[6] For a brief background on the RBC system: https://content.naic.org/cipr_topics/topic_risk_based_capital.htm

[7] See https://www.naic.org/documents/committees_e_capad_investment_rbc_wg_related_irbc_factors.pdf for the complete capital charge scheme for the six NAIC risk categories of bonds.

The risk factor related with this paper is the interest rate risk. Given that life insurance is a liability-driven business supported by investments in fixed-income assets, life insurers are vulnerable to interest rate movements. To contain life insurers' exposure to interest risk, NAIC imposes capital charges on mismatch in asset and liability cash flows. Asset and liability can be gravely mismatched as interest rates drop to historical lows. As an interest risk strategy to ensure better matching between assets and liabilities, life insurance companies increase the duration of their assets (i.e., hunt for duration) during times of persistently low interest rates.[8] Details on a liability-driven investment strategy that attempts to hedge against interest rate risk is presented in Section 1.2.2.

One concern could be that bonds with longer duration are subject to greater market value movements as the interest rate changes. However, according to NAIC guidelines, insurance companies report their bond holdings using historical cost accounting (HCA). That is, bonds are valued at amortized cost rather than market value (Ellul, Jotikasthira, Lundblad, and Wang 2017). Therefore, even though prices of longer-duration bonds are more volatile in a changing interest rate environment, unless the bonds are sold, HCA shields insurance companies from market value fluctuations of their bond holdings.

### 1.2.2 Stylized example of duration-matching

The balance sheet identity states that a company's equity value is determined by the difference in the value of its asset and liability. A change in the interest rate can affect the values of asset and liability, and hence the equity value. The sensitivity of value to interest rate is measured by duration. When the duration of a company's asset differs significantly from that of its liability, the company has a duration mismatch, which puts the company at risk to interest rate changes. To protect its equity from

[8]For a brief overview of the impact of low interest rates on life insurers: https://content.naic.org/cipr_topics/topic_low_interest_rates.htm

fluctuations in interest rate, a company engages in duration-matching to ensure that the duration of its asset aligns well with that of its liability. Domanski, Shin, and Sushko (2017) provide a stylized description of duration-matching in the context of life insurance companies. For illustrative purpose, I summarize the explanation in this section.

Life insurance companies sell long-term products, such as annuities, with a guaranteed level of income over the life of the policy. To fulfill the long-term payment commitments to their policyholders, life insurance companies invest largely in bonds with long maturities. To capture the above characteristics of a life insurer's balance sheet, think of the liability of a life insurer as a growing perpetuity with a first payment of $C$ and growth rate $g$. On the asset side, the life insurer holds y units of T-year risk-free zero-coupon bond with principal amount 1 and yield $r$.

The first row of Table 1.1 gives the value of the life insurer's liability and asset using yield $r$ as the discount rate. When the interest rate $r$ decreases, the values of liability and asset both increase, but with different sensitivities. The sensitivities to interest rate of asset and liability, as measured by modified duration, are presented in the second row of Table 1.1. The left panel of Figure 1.1 plots the duration of liability and asset against the interest rate. Notice that as the interest rate $r$ approaches zero, the duration of liability is larger than that of asset. Furthermore, the duration mismatch between liability and asset widens at an increasing rate. As shown in the last row of Table 1.1 and Panel B of Figure 1.1, this is due to the fact that the convexity of liability, which measures how the duration of liability responds to interest rate changes, exceeds that of asset. To summarize, since the liability value increases faster the asset value during times of low interest rates, to protect its balance sheet against interest rate risk, the life insurer needs to increase the duration of its asset. As in Domanski, Shin, and Sushko (2017), I call this duration hedging behavior "hunt-for-duration" throughout the paper.

Table 1.1: Value, duration, and convexity of asset and liability

| | Asset | Liability |
|---|---|---|
| Value ($V$) | $\frac{1}{(1+r)^T}$ | $\frac{C}{r-g}$ |
| Modified duration $(-\frac{1}{V}\frac{dV}{dr})$ | $\frac{T}{1+r}$ | $\frac{1}{r-g}$ |
| Convexity $(\frac{1}{V}\frac{d^2V}{dr^2})$ | $\frac{T(T+1)}{(1+r)^2}$ | $\frac{2}{(r-g)^2}$ |

Notes: This table lists the value, modified duration, and convexity of a life insurance company's asset and liability. As in Domanski, Shin, and Sushko (2017), the assumption is that asset consists of T-year risk-free zero coupon bonds, and that liability is a growing perpetuity with coupon $C$ and growth rate $g$. The discount rate $r$ is the yield of the T-year risk-free zero coupon bond.

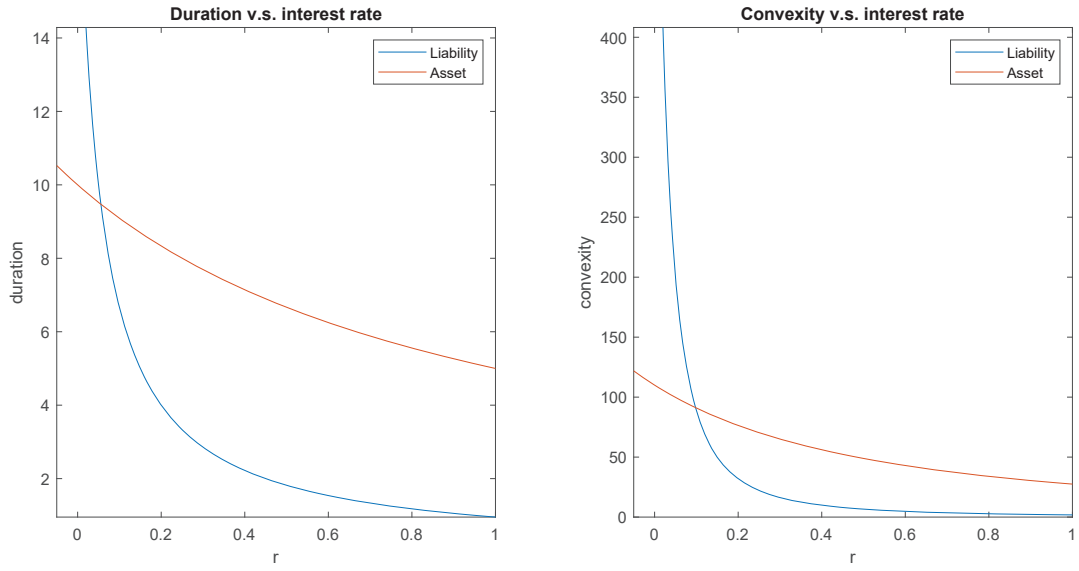
## 1.3 Data

Data used in this empirical study come from multiple sources: National Association of Insurance Commission (NAIC) Schedule D filings, Morningstar, enhanced Trade Reporting and Compliance Engine (TRACE), and Mergent Fixed Income Securities Database (FISD). The data period spans from 2002 to 2017.[9]

NAIC Schedule D filings consist of transaction and year-end position data of life insurance companies and P&C insurance companies. Part 1 of NAIC Schedule D provides insurers' year-end bond holding information including bond identification, holding size, and other accounting items. Part 3 to 5 include insurers' transaction records with transaction date, bond identification, trade size, price, direction, and counter-parties. One important thing to notice is that the transaction data records

[9]I am thankful to Lunyang Huang and Simon Schmickler for our efforts together on processing bond holdings data of insurance companies and mutual funds.

Figure 1.1: Duration and convexity against interest rate




Notes: This figure plots the modified duration (left graph) and convexity (right graph) listed in Table 1.1 as a function of interest rate $r$. The parameters used are $T = 10$ and $g = -0.05$, where $g$ is calibrated by Domanski, Shin, and Sushko (2017) using $D_{L,t} = 1/(r_t^{T=25} - g)$, where $D_{L,t}$ and $r_t^{T=25}$ are the duration of liability and 25-year zero-coupon euro swap rate in year $t$, respectively. To obtain $g$, year 2013 numbers are used: $r_{t=2013}^{T=25} = -0.12\%$, and $D_{L,t=2013} = 20.5$, according to EIOPA (2014).

all trades that result in change of bond holding positions, including market buy and sell transactions as well as non-market transactions such as calls and maturities.[10]

Holding positions at the end of a given quarter in year $t$ can be backed out through combining the reported year-end positions of year $t-1$ with transactions up until the end of the given quarter. I need both market and non-market transactions to infer quarter-end positions. However, when studying the trading activities of insurance companies, I use only market transactions.

[10]Transaction type can be identified in the counter-party field. Non-market transactions are those with counter-party field listed as call, cancel, conversion, direct, exchange, maturity, pay-down, put, redemption, sinking fund, tender, transfer, etc.

Quarterly snapshots of bond holdings of mutual funds are obtained from Morningstar. I choose funds whose prospectus objective stated in Morningstar is corporate bond, since my focus is on funds that invest in corporate bonds.

I collect data on bond characteristics from Mergent FISD. This dataset contains bond-specific information such as coupon rate and payment frequency, maturity date, issue amount outstanding, option features, bond type, and industry. In addition, Mergent FISD records historical bond-level credit ratings issued by S&P, Moody's, or Fitch. I determine a bond's rating by the following rule.[11] When all three rating agencies rate a bond, I use the middle rating. If two agencies rate a bond, I use the lower rating. If only one agency rates a bond, that single rate is used. Each letter rating is assigned to a number. Specifically, $AAA$ corresponds to 1, $AA+$ corresponds to 2, ..., $C$ corresponds to 21, and $D$ corresponds to 22. Bonds with numerical ratings from 1 to 10 are investment-grade ($AAA+$ to $BBB-$). Non-investment-grade bonds ($BB+$ or lower) have numerical ratings above 10.

Price data of corporate bonds are from enhanced TRACE. TRACE dataset reports transaction-level information including date, size, and price of corporate bond trades. I follow Dick-Nielson (2009) and Bessembinder et al. (2009) to clean up the price data. I delete trades that are cancelled, adjust trades that are corrected or reversed, and remove double-counting of agency trade. Quarter/month-end price of a bond is obtained by weighting prices by size of all trades taking place on the last day during which the bond is traded in the quarter/month. Bond yield in quarter/month $t$ is calculated using its quarter/month-end price and detailed cash flow information from Mergent FISD. Modified duration, which reflects price sensitivity to change in yield, is then computed based on bond price, yield, and cash flow data. Quarterly/monthly

[11] https://www.bbhub.io/indices/sites/2/2017/03/Index-Methodology-2017-03-17-FINAL-FINAL.pdf, p.25.

returns of a bond in quarter/month $t$ is calculated as relative change in price from quarter/month $t-1$ to $t$, factoring in accrued interest and coupon payment.[12]

I restrict my sample to fixed-rate U.S. dollar corporate debentures and medium-term notes in the industrial, financial, and utility sectors. I exclude convertible bonds since this option feature makes returns of convertible and nonconvertible incomparable. Furthermore, I remove bonds with time to maturity less than one year because this criterion is applied to major corporate bond indices such as the Bloomberg Barclays U.S. Corporate Bond Index and the Bank of America (BofA) Merrill Lynch U.S. Corporate Master Index.

To verify the self-calculated bond yields and returns based on TRACE transaction prices, In Figure II, I compare the average of TRACE bond yields to BofA Merrill Lynch US Corporate Index Effective Yield. I also compare the average of TRACE bond returns to those implied by BofA Merrill Lynch Total Bond Return Index Values. To make the figure concise, I only plot two broad rating groups: investment and speculative grade. The results are similar for more detailed rating and maturity groups. This comparison indicates that my self-complied bond yields and returns using TRACE data are close to BofA bond indices.[13]

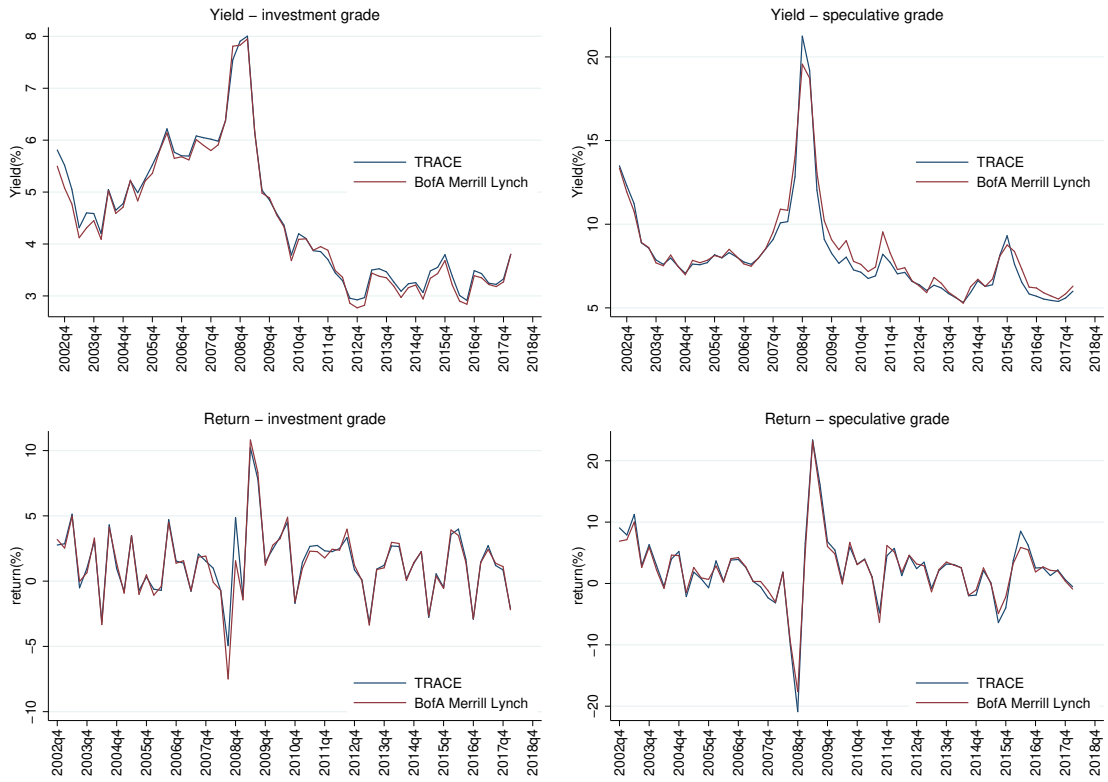
[12]Specifically,

$$r_{i,t} = \frac{P_{i,t} + AI_{i,t} + C_{i,t}}{P_{i,t-1} + AI_{i,t-1}} - 1, \tag{1.1}$$

where $P_{i,t}$ is bond $i$'s price at the end of quarter/month $t$, $AI_{i,t}$ is accrued interest, and $C_{i,t}$ is coupon payment, if any, during quarter/month $t$.

[13]BofA bond indices are available at https://fred.stlouisfed.org/categories/32348?t=baml&ob=pv&od=desc.

Figure 1.2: Corporate bond yields and returns, 2002 to 2018




Notes: For both investment and speculative grade corporate bonds, I compare the average of bond yields calculated based on TRACE transaction prices to BofA Merrill Lynch US Corporate Index Effective Yield. I also compare the average of TRACE bond returns with the return implied by BofA Merrill Lynch Total Bond Return Index Values.

## 1.4 Detecting hunt-for-duration: The characteristics-based demand model approach

### 1.4.1 Empirical specification of demand for bond characteristics

Investors (i.e., life insurers) are indexed by $i$. Time periods are indexed by $t$. Bonds are indexed by $n$. I focus the analysis on the fixed-rate U.S. dollar corporate bonds that are corporate debentures or medium-term notes. Investor $i$'s time $t$ investment in corporate bond $n$ is denoted by $B_{it}(n)$. There is also an outside asset indexed as the zeroth asset, which includes all other bonds (which are not fixed-rate U.S. dollar corporate debentures or medium-term notes) reported on life insurers' Schedule D Part 1. I use $B_{it}(0)$ to represent all wealth invested in the outside asset by investor $i$ at time $t$. Investor $i$'s portfolio weight on corporate bond $n$ at time $t$ is then

$$w_{it}(n) = \frac{B_{it}(n)}{B_{it}(0) + \sum_n B_{it}(n)},$$

and the portfolio weight on the outside asset is

$$w_{it}(0) = 1 - \sum_n w_{it}(n).$$

Investor $i$'s relative demand for corporate bond $n$ at time $t$, $\delta_{it}(0) = \frac{w_{it}(n)}{w_{it}(0)}$, is modelled as

$$\ln \delta_{it}(0) = c_{it} + \beta_{0,it} y_t(n) + \beta_{1,it} d_t(n) + \beta_{2,it}^{'} x_t(n) + \epsilon_{it}(n), \tag{1.2}$$

where $y_t(n)$ is the yield of bond $n$ at period $t$ over the closest benchmark Treasury bond, $d_t(n)$ is the bond's duration, and $x_t(n)$ stands for bond characteristics including

credit rating, issue size, and turnover. Credit rating is the numerical rating converted from the letter rating discussed in Section 1.3. Bond issue size is measured by the log of total par amount outstanding. Turnover, as a measure of liquidity, is the total trading volume over the current period scaled by par amount outstanding. The error term $\epsilon_{it}(n)$, referred to as the latent demand in Koijen and Yogo (2019), captures investor $i$'s demand for unobserved (by the econometrician) characteristics of bond $n$ at period $t$.

Equation (1.2) is referred to as characteristics-based demand because portfolio weights are specified as a function of yield, duration, and other observed and unobserved bond characteristics. Koijen and Yogo (2019) provide a theoretical model for equation (1.2). There are three key elements in the model. First, investors have mean-variance preferences for returns. Second, returns have a factor structure. Third, expected returns and factor loadings depend on assets' own characteristics.

### 1.4.2 Identification strategy with instrument variables

To estimate equation (1.2), I assume that $E[\epsilon_{it}(n)|x_t(n)] = 0$, that is, bond rating, size, and turnover are exogenous to latent demand. However, I don't assume that bond yields are orthogonal to latent demand because price-taking may not be credible in the context of life insurance companies, who are the largest institutional investors in the U.S. corporate bond market. Higher latent demand can result in higher prices and therefore lower yields. To address the endogeneity of bond yields, I use an instrumental variable strategy similar in spirit to that in Koijen and Yogo (2019).

Construction of the instrumental variable for bond yields relies on defining the investment universe of an investor. Institutions are considered to have an investment universe: They are allowed to hold a subset of bonds issued by a particular group of corporations. The investment universe is practically defined by an investment

mandate, which is probably most clearly stated in corporate bond index funds.[14] Insurance companies also have investment mandates, although they are usually not publicly available.[15]

The identification assumption is that each institution's investment universe is exogenous, as it is predetermined by an investment mandate that is exogenous to current demand shocks. Since a bond issuer can have several bond issues outstanding at the same time, I consider the investment universe at the bond issuer (rather than the bond issue) level. When a bond issuer whose bond issues are included in the investment universe of more investors, particularly when those investors are large, it then has a larger exogenous component of demand, which generates higher prices and hence lower yields that are orthogonal to latent demand. Incorporating the above idea into a mathematical expression, the instrument for the yield of bond issued by bond issuer $b$ at time $t$ for estimating investor $i$'s bond demand is specified as

$$\hat{y}_{it}(b) = \log\Big(\sum_{j\neq i} A_{jt}\frac{\mathbf{1}_{jt}(b)}{1+\sum_{m=1}^{B}\mathbf{1}_{jt}(m)}\Big), \tag{1.3}$$

where $A_{jt}$ is investor $j$'s (other than investor $i$) time $t$ asset under management (AUM), $\mathbf{1}_{jt}(b)$ is an indicator for whether bond issuer $b$ is in the investment universe of investor $j$ at time $t$.

### 1.4.3 Validity of the instrument

Before estimating the characteristics-based demand equation (1.2), I conduct several checks for validating the proposed instrument (1.3).

To verify that institutional investors indeed invest in bonds issued by a fixed subset of bond issuers, i.e., that they have a predetermined investment universe, I tabulate in Table 1.2 the percentage of bond issuers whose bonds are held in the current year-end

[14] See for example, https://investor.vanguard.com/mutual-funds/profile/VLTCX.
[15] https://www.naic.org/capital_markets_archive/110826.htm.

that are ever held in the previous 1 to 3 years. Institutions are separated into groups first by their type and then by their AUM. For life insurance company with median AUM, 83.8% of bond issuers whose bonds are held in current year-end were also in the previous year-end. This indicates that at least 83.8% of bond issuers in the investment universe this year were also part of the investment universe in the previous year. This percentage increases at a very slow pace to 85.0% going 3 years before. The persistence of bond issuers held increases with an institution's size. For life insurer with 90th percentile AUM, 92.3% of bond issuers that are currently held were also held in the previous 3 years. The same patterns also apply to property/casualty (PC) insurance companies and corporate bond mutual funds. Hence, Table 1.2 provides supporting evidence consistent with the fact that institutions have investment mandates, as they invest in a relatively fixed subgroup of bond issuers over time. Accordingly, the investment universe for each institution at each date is defined as the subset of bond issuers that are currently or ever held in the portfolio all the way up to the previous 3 years.

The validity of the instrument (1.3) relies not only on the existence of exogenous investment universe verified above, but also on the variation in the investment universe across the investors. The last two columns of Table 1.3 show that there is cross-sectional variation in the investment universe, since the institutions have their investment universe concentrated on a small subset of bond issuers. For example, in years 2014 to 2017, life insurers have a median of 186 bond issuers in the investment universe, whereas the 90th percentile includes 559 bond issuers.

The last check is for verifying that the instrument (1.3) is not a weak instrument. In particular, I calculate the Cragg–Donald F-statistic for equation (1.2) fitted via generalized method of moments (GMM) with $[y_{it}(n), d_{it}(n)]'$ instrumented by $[\hat{y}_{it}(n), m_{it}(n)]'$, where $m_{it}(n)$ is years to maturity. $m_{it}(n)$ is added for identification purpose, since $d_{it}(n)$ is also endogenous through $y_{it}(n)$. Based on the results in Table

Table 1.2: Persistence of the set of bond issuers held in portfolio

| Institution | Years | AUM percentile | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Life | 1 | 84.3 | 83.3 | 83.3 | 84.0 | 83.8 | 85.0 | 86.4 | 88.3 | 88.1 | 91.3 |
| | 2 | 84.7 | 83.9 | 84.3 | 84.3 | 84.7 | 85.9 | 87.2 | 88.9 | 88.9 | 91.8 |
| | 3 | 85.3 | 84.6 | 84.6 | 84.8 | 85.0 | 86.5 | 87.7 | 89.4 | 89.6 | 92.3 |
| PC | 1 | 78.9 | 80.0 | 78.9 | 78.6 | 78.8 | 79.7 | 80.4 | 80.6 | 81.1 | 82.8 |
| | 2 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 81.4 | 81.3 | 82.1 | 84.0 |
| | 3 | 80.0 | 80.5 | 80.0 | 80.0 | 80.6 | 81.0 | 82.0 | 81.9 | 82.9 | 84.6 |
| Mutual | 1 | 95.6 | 94.4 | 94.4 | 94.8 | 94.2 | 93.4 | 94.9 | 94.0 | 94.4 | 95.1 |
| | 2 | 96.4 | 95.0 | 95.1 | 95.2 | 94.9 | 94.1 | 95.4 | 94.7 | 95.2 | 95.4 |
| | 3 | 96.6 | 95.3 | 95.5 | 95.8 | 95.0 | 94.7 | 95.7 | 95.0 | 95.7 | 95.7 |
| All | 1 | 80.0 | 80.0 | 79.4 | 80.0 | 80.5 | 81.3 | 81.8 | 83.1 | 84.8 | 87.9 |
| | 2 | 80.3 | 81.0 | 80.0 | 80.6 | 81.3 | 82.1 | 82.5 | 84.0 | 85.7 | 88.8 |
| | 3 | 82.1 | 82.6 | 82.2 | 83.8 | 84.6 | 84.9 | 86.2 | 88.0 | 88.4 | 90.3 |

Notes: This table reports the percentage of bond issuers held in the current year-end that were ever held in the previous 1, 2, and 3 years. Each cell corresponds to a pooled median across time in an AUM percentile of an institution type. The sample period is from 2002 to 2017.

1.2, in calculating the instrument (1.3), the aggregation is over institutions with at 85% of currently held bond issuers also on the portfolio in the previous 3 years.

As shown in Table 1.3, institutions hold a relatively small number of bonds in their portfolio. Estimation based on the cross-sectional holdings of an individual institution might not be accurate. Therefore, the estimation scheme is that whenever there are more than 1000 holdings in the cross section, I estimate by the individual institution. For institutions with less than 1000 holdings, I pool them together with those that share similarity in regulatory constraints. Specifically, I group the life insurance companies by the A.M. Best's financial strength rating (FSR)[16] and then

[16]FSR provides an opinion of an insurer's financial strength and ability to meet its ongoing obligations to policyholders. The scale of FSR ranges from A++ to D, which corresponds to superior to poor financial strength. See http://www.ambest.com/ratings/guide.pdf for FSR category definitions.

Table 1.3: Summary of institutions

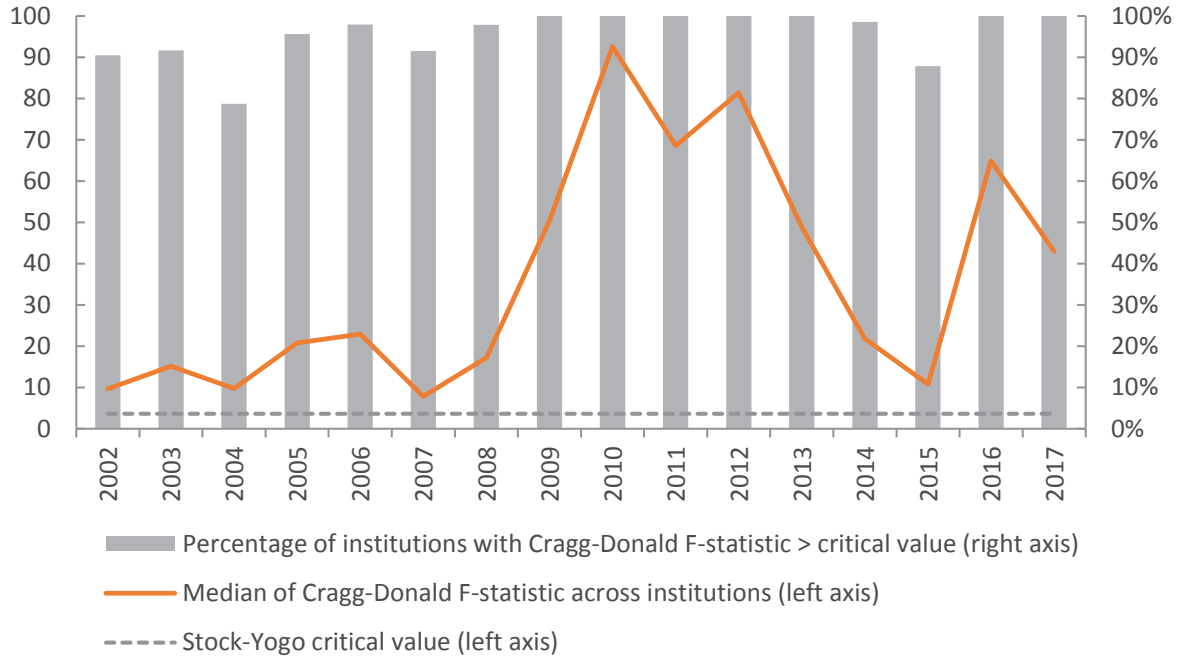
| | | | | AUM ($ million) | | Number of bonds held | | Number of bond issuers in investment universe | |
|---|---|---|---|---|---|---|---|---|---|
| Institution | Period | Number of Institutions | Market share held (%) | Median | 90th percentile | Median | 90th percentile | Median | 90th percentile |
| Life | 2002-2006 | 682 | 29 | 270 | 6359 | 86 | 431 | 126 | 461 |
| | 2007-2009 | 595 | 23 | 315 | 7330 | 95 | 513 | 132 | 490 |
| | 2010-2013 | 565 | 24 | 409 | 9553 | 124 | 625 | 160 | 523 |
| | 2014-2017 | 533 | 20 | 455 | 11610 | 150 | 748 | 186 | 559 |
| PC | 2002-2006 | 1427 | 5 | 80 | 902 | 22 | 100 | 41 | 143 |
| | 2007-2009 | 1479 | 4 | 86 | 1047 | 23 | 96 | 39 | 138 |
| | 2010-2013 | 1614 | 5 | 87 | 1100 | 33 | 132 | 52 | 167 |
| | 2014-2017 | 1603 | 4 | 88 | 1100 | 40 | 170 | 66 | 203 |
| Mutual | 2002-2006 | 444 | 5 | 226 | 1545 | 86 | 226 | 142 | 303 |
| | 2007-2009 | 401 | 4 | 261 | 1862 | 103 | 240 | 173 | 324 |
| | 2010-2013 | 365 | 5 | 445 | 2758 | 118 | 310 | 207 | 361 |
| | 2014-2017 | 369 | 4 | 449 | 3530 | 119 | 332 | 190 | 357 |
| All | 2002-2006 | 2552 | 39 | 128 | 1847 | 37 | 214 | 66 | 289 |
| | 2007-2009 | 2475 | 31 | 139 | 1994 | 39 | 221 | 63 | 290 |
| | 2010-2013 | 2544 | 34 | 146 | 2385 | 52 | 279 | 79 | 315 |
| | 2014-2017 | 2504 | 28 | 149 | 2805 | 62 | 329 | 96 | 342 |

Notes: This table reports the time-series mean of each summary statistics within the given period. The sample period is from 2002 to 2017. While the Schedule D data cover all life and PC insurance companies, the data collected from Morningstar for mutual funds include only those classified as corporate bond mutual fund by Morningstar. It's about 1/3 of the number of mutual funds in the literature (e.g., Choi and Kronlund (2017)) that uses a broader classification rule for bond mutual funds.

by the A.M. Best's capital adequacy ratio (BCAR) relative to the guideline for the current FSR.[17]

Figure 1.3 reports, at each date, the median F-statistics across all life insurance companies and the percentage of the pooled estimations with F-statistics above the critical value of 3.63 for rejecting the null of weak instrument listed in Table 5.2 of Stock and Yogo (2005). For a majority of the estimations over the sample period, the null hypothesis of weak instrument is rejected at the 5% significance level.

Figure 1.3: Cragg-Donald F-statistics on the instrument for bond yield




Notes: This figure plots the median Cragg-Donald F-statistics across all life insurance companies and the percentage of the pooled estimations with F-statistics above the critical value of 3.63 for rejecting the null of weak instrument listed in Table 5.2 of Stock and Yogo (2005).

[17]BCAR is the ratio of total adjusted capital to required risk-based capital, where both the available capital and the required capital are computed using A.M. Best's formula. Insurance companies with higher BCAR are considered to be better capitalized. See http://www.ambest.com/ratings/bcar_lh.pdf for details on how BCAR is calculated. The BCAR guideline for each FSR is listed in http://www3.ambest.com/ambv/ratingmethodology/openpdf.aspx?ubcr=1&ri=1112

### 1.4.4 Estimated demand for bond duration and other characteristics

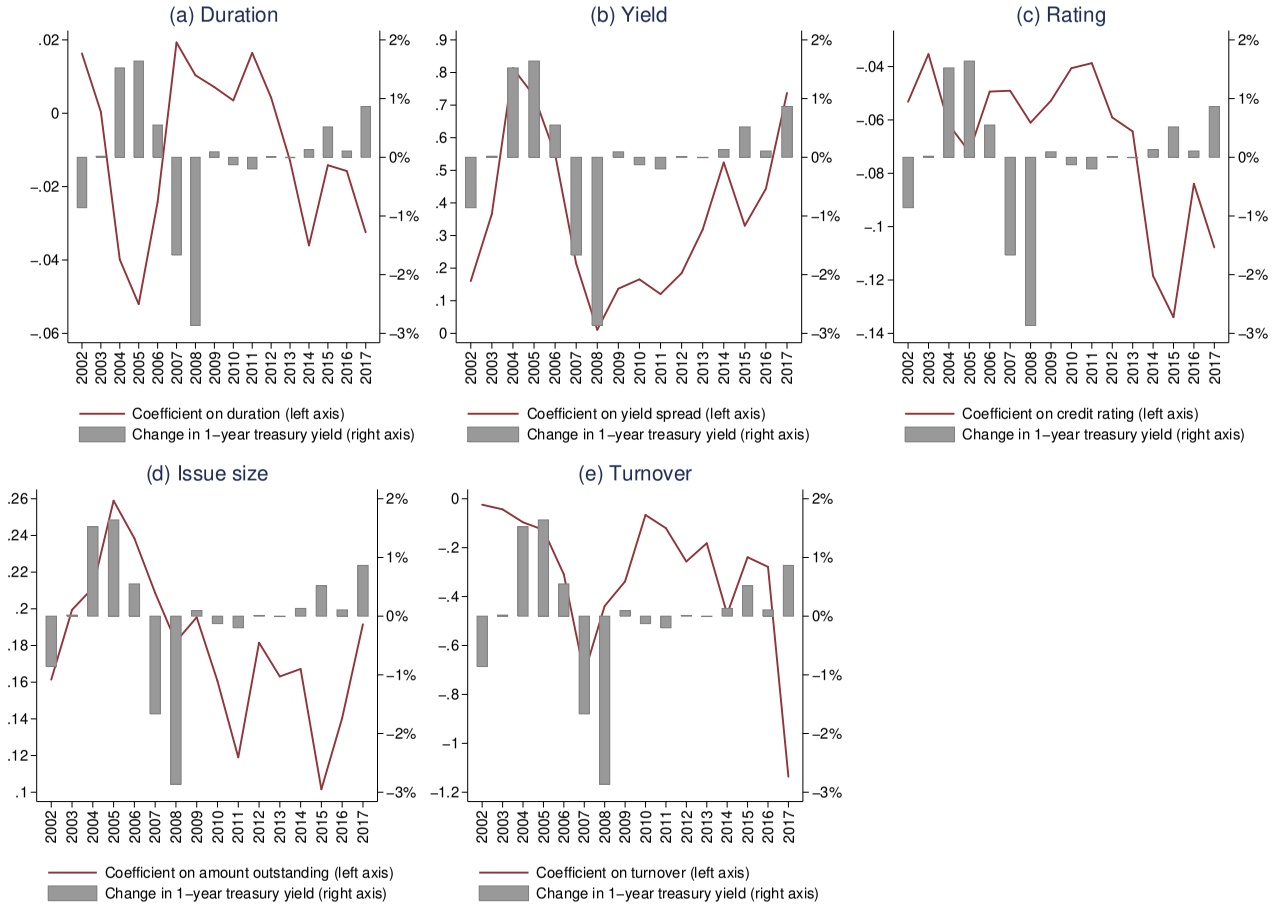
Figure 1.4 provides a summary of the estimated coefficients of life insurance companies' characteristics-based demand equation (1.2) fitted via generalized method of moments (GMM) with $[y_{it}(n), d_{it}(n)]'$ instrumented by $[\hat{y}_{it}(n), m_{it}(n)]'$. Each panel of Figure 1.4 plots, against the change in 1-year Treasury yield, the average of the estimated coefficient on a bond characteristic across life insurers weighted by their AUM.

Life insurers' demand for duration is captured in Panel (a) of Figure 1.4. A positive and larger coefficient on duration indicates a heavier tilt in the portfolio towards bonds with higher duration. I observe that hunt-for-duration coincides with episodes of low interest rates. With the 1-year Treasury yield dropping to a historical low as the 2007-2008 financial crisis unfolds, life insurers are tilting their portfolios towards bonds with higher duration. Therefore, this finding is consonant with what's discussed in Section 1.2.2, that is, life insurers have heightened needs for duration-matching as the interest rate falls to a very low point.

Panel (b) of Figure 1.4 depicts life insurers' demand for yield spread. A positive and larger coefficient implies a stronger tilt in the portfolio towards bonds with higher yield spread. Notice that higher demand for yield spread is concurrent with periods of high interest rates. In the pre-crisis period over 2004 to 2006 when interest rates are high and the post-crisis period since 2014 when the interest rates gradually increase after the Federal Reserve (the Fed) tapers Quantitative Easing (QE), life insurers shift their portfolios towards bonds with higher yield spread. This finding is in line with the procyclical pattern in reaching for yield among life insurers found by Becker and Ivashina (2015).

Life insurers' demand for other characteristics, including credit rating, size, and liquidity, are shown in the rest panels of Figure 1.4, respectively. The findings are in

Figure 1.4: Coefficients on bond characteristics




Notes: This figure plots, against the change in 1-year Treasury yield, the estimated coefficients of life insurance companies'characteristics-based demand equation (1.2) fitted via generalized method of moments (GMM) with $[y_{it}(n), d_{it}(n)]'$ instrumented by $[\hat{y}_{it}(n), m_{it}(n)]'$. Each panel corresponds to the average of the estimated coefficient on a bond characteristic across life insurers weighted by their AUM.

agreement with life insurers' institutional features discussed in Section 1.2.1. Consistent with the RBC requirements, life insurers demand bonds with better credit rating.[18] Life insurers exhibit tolerance for illiquidity,[19] which is compatible with their long-term liability structure.

Table 1.4: Life insurers' demand for duration and the interest rates

| Dep. Var: Coefficient on duration from characteristics-based demand model | | | | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| ΔTY1 | -0.005* | -0.005** | - | - |
| | [0.002] | [0.002] | - | - |
| Low | - | 0.011*** | - | 0.006* |
| | - | [0.003] | - | [0.003] |
| ΔTY1 × Low | - | -0.014** | - | - |
| | - | [0.006] | - | - |
| Δ(TY30 - TY1) | - | - | 0.004** | 0.007*** |
| | - | - | [0.002] | [0.001] |
| Δ(TY30 - TY1) × Low | - | - | - | -0.006** |
| | - | - | - | [0.002] |
| Insurer FE | Yes | Yes | Yes | Yes |
| $N$ | 7688 | 7688 | 7688 | 7688 |
| $R^2$ | 0.18 | 0.19 | 0.18 | 0.18 |

Notes: This table reports the relationship between life insurers' demand for duration and the interest rates. The dependent variable is the coefficient on duration estimated from the characteristics-based demand equation (1.2). $\Delta TY1$ is the change in 1-year Treasury yield from year-end $t-1$ to year-end $t$. $\Delta(TY30 - TY1)$ is the change in the difference between 30-year and 1-year Treasury yields from year-end $t-1$ to year-end $t$. *Low* is an indicator variable that equals one when the Federal funds rate is smaller than or equal to 1%, and zero otherwise. All regressions include insurer fixed effects. Standard errors clustered at the year level are reported in brackets. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

[18] As defined in Section 1.3, a higher numerical rating corresponds to a lower letter rating. Therefore, the negative coefficient on rating implies that life insurers demand bonds with better credit ratings.

[19] Higher turnover indicates greater liquidity. Hence, the negative coefficient on turnover indicate that life insurers demand less liquidity.

Table 1.4 examines in further details the loadings on duration with respect to interest rates. In particular, I regress the coefficient on duration estimated from the characteristics-based demand equation (1.2) on interest rate variables including change in the level (1-year Treasury yield, $\Delta TY1$) and slope (30-year minus 1-year Treasury yield, $\Delta(TY30-TY1)$) of the term structure. Each observation corresponds to one life insurer and year. All regressions include insurer fixed effects. Column 1 confirms that hunt-for-duration is stronger when the interest rate level drops. As shown in column 3, tilt toward high duration is heavier when the slope of yield curve is steeper. To further investigate whether there is asymmetry in the intensity of hunt-for-duration between the high and low interest rate regimes, I create an indicator variable *Low* that equals one when the Federal funds rate is smaller than or equal to 1%, and zero otherwise. Column 3 shows that hunt-for-duration is more sensitive to change in the level of interest rate in the low-rate regime, which is indicated by the negative and significant coefficient on the interaction term $\Delta TY1 \times Low$.

## 1.5 Detecting hunt-for-duration: The excess duration approach

### 1.5.1 Measure of excess duration

In this section, I provide a measure of hunt-for-duration. In a similar spirit as Ozdagli and Wang (2019) and Choi and Kronlund (2018), the extent to which life insurance companies engage in hunt-for-duration is measured by excess duration. Within each NAIC rating class,[20] the excess duration of the life insurance sector $i$ in quarter $t$,

[20]There are six NAIC rating class: NAIC 1 to NAIC 6. Throughout the paper, I focus on bonds in NAIC 1 (rated AAA/AA/A) and NAIC 2 (rated BBB) because around 95% of life insurers' bond holdings are investment-grade. At the end of year 2018, life insurance companies hold 65.1% of their bonds in NAIC 1 and 29.8% in NAIC 2, according to Chart 4 of https://www.naic.org/capital_markets_archive/special_report_190725.pdf.

$ED_{i,t}$, is calculated as the weighted average duration of all corporate bonds held by the life insurance sector minus the weighted average duration of all corporate bonds outstanding in the market. That is,

$$ED_{i,t} = \sum_j w^i_{j,t} D_{j,t} - \sum_j w^m_{j,t} D_{j,t}, \tag{1.4}$$

where $D_{j,t}$ is the modified duration of bond $j$, $w^i_{j,t} = \frac{A^i_{j,t}}{\sum_j A^i_{j,t}}$ with $A^i_{j,t}$ being the amount of bond $j$ held by the life insurance sector, and $w^m_{j,t} = \frac{A^m_{j,t}}{\sum_j A^m_{j,t}}$ with $A^m_{j,t}$ being the total amount of bond $j$ outstanding in the market. Given that excess duration is computed in relative terms, it represents how much life insurers tilt their portfolios away from the market benchmark. In line with Choi and Kronlund (2018), netting out the market benchmark controls for the time-series variation in the aggregate supply of the corporate bonds. Suppose more firms issue bonds with longer maturities in some years, then the increase in hunt-for-duration would only be mechanical if market duration were not taken into account.

For later analysis at the individual bond level, I also define the excess duration for bond $j$ as the following:

$$ED_{j,t} = D_{j,t} - \sum_k w^m_{k,t} D_{k,t}, \tag{1.5}$$

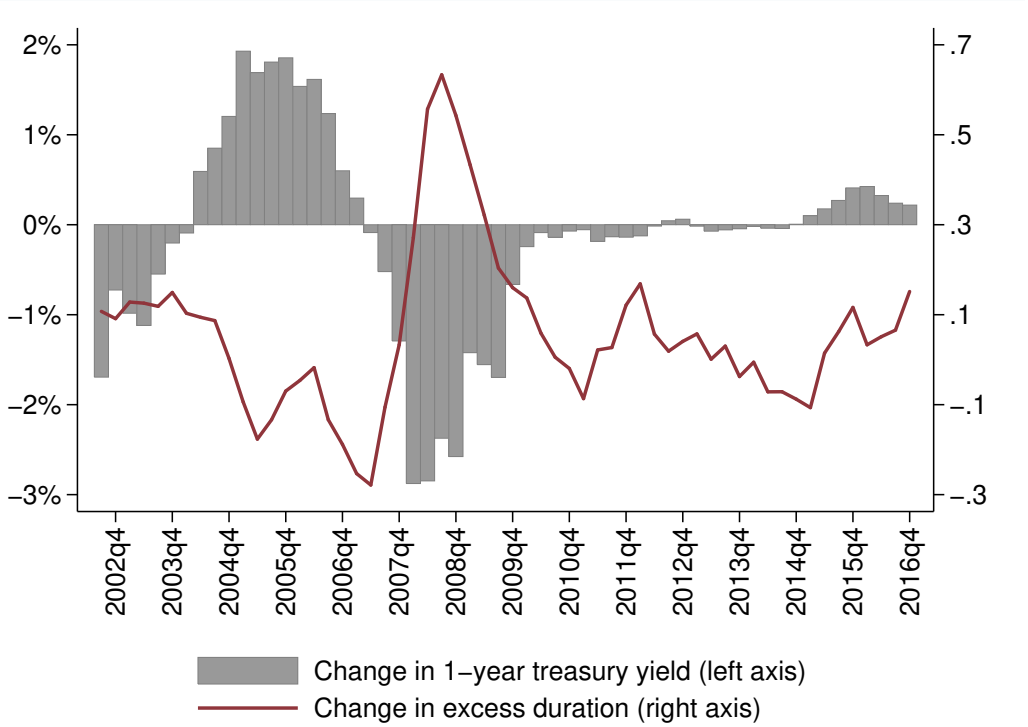
where $D_{j,t}$ is the duration of bond $j$ and $\sum_k w^m_{k,t} D_{k,t}$ is the weighted average duration of all outstanding corporate bonds in the same NAIC rating class as bond $j$.

### 1.5.2 Hunt-for-duration over time

As discussed in Section 1.2.2, the primary implication of duration-matching is that life insurers hunt for duration to hedge against interest rate risk when the interest rates decline. Figure 1.5 presents a first look at this implication. In Figure 1.5, I plot the

time series of change in the excess duration of life insurance sector's bond portfolio against the change in 1-year Treasury yield, which serves as the policy indicator in Gertler and Karadi (2015). The bar represents the cumulative change in 1-year Treasury yield from quarter $t-4$ to $t$. The line traces the cumulative change in excess duration of the life insurance sector from quarter $t$ to $t+4$. Figure 1.5 indicates a negative correlation between change in interest rate and duration adjustment of life insurers.

Figure 1.5: Excess duration of life insurers' bond portfolio and the interest rates




Notes: This figure presents the time series of change in the excess duration of life insurance sector's corporate bond holdings of NAIC1 rating group (rating AAA to A-) (right axis) and the change in 1-year Treasury yield from quarter $t-4$ to quarter $t$ (left axis). The excess duration of life insurance sector's portfolio of bonds within a given rating group is computed as the weighted average duration of all corporate bonds held by the whole life insurance sector less the benchmark duration, which is the weighted average duration of all corporate bonds outstanding in the market within the same rating group. The excess duration measure is defined formally in equation (1.4).

Formally, I examine the dynamics of excess duration following a change in the interest rate using the differenced regressions:

$$ED_{i,t+k} - ED_{i,t} = \alpha_k + \beta_k(r_t - r_{t-1}) + \Delta\epsilon_{t+k}, \tag{1.6}$$

where $r_t - r_{t-1}$ is the change in 1-year Treasury yield from quarter $t-1$ to $t$, and $ED_{i,t+k} - ED_{i,t}$ represents the cumulative change in the excess duration of the life insurers' bond portfolio over the period from quarter $t$ to $t+k$ with $k = 1, \ldots, 16$. Hence, the regressions specified in equation (1.6) explore how life insurers adjust the duration of their corporate bond portfolios in response not to the level of interest rate, but instead to a recent change in the interest rate. As it is not likely that an innovation in interest rate is met with full response immediately, I allow the horizon on the left-hand side to be up to 16 quarters.

Results in Columns [1] and [2] of Table 1.5 shows that the portfolio duration of life insurers responds gradually to interest rate changes. When the differencing horizon on the left-hand side is less than 4 quarters, the estimates of $\beta_k$ are small and statistically weak. As the horizon is widened to 4 quarters and beyond, the results become progressively stronger. When the window expands to 11 quarters, $\beta_{11}$ is estimated to be -0.59 with significance level at 1%. This suggests that a 1% decrease in the interest rate leads to a cumulative increase of 0.59 in the excess duration of life insurers' bond portfolio over the next 11 quarters.

To further identify the impact of monetary policy surprises on the duration adjustment of life insurers' bond portfolio, I re-estimate equation (1.6) using surprises in the three month ahead federal funds futures (denoted as FF4 in Gertler and Karadi (2015)) as an instrument for the change in 1-year Treasury yield. This instrument choice is based on the strong performance of the variable FF4 as an external instrument in the analysis of Gertler and Karadi (2015). Similar to papers that employ

Table 1.5: Life insurers: Dynamics of portfolio duration following a change in interest rate

| Dep. Var: Cumulative change in excess duration of bond portfolio | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Quarter-level data | | | | Insurer-quarter level data | | | |
| | Rate change | | Monetary surprise | | Rate change | | Monetary surprise | |
| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] |
| | $\beta_k$ | Std. error | $\beta_k$ | Std. error | $\beta_k$ | Std. error | $\beta_k$ | Std. error |
| k = 1 | -0.00 | [0.04] | -0.05 | [0.10] | -0.02 | [0.02] | -0.08*** | [0.01] |
| k = 2 | -0.05 | [0.08] | -0.12 | [0.16] | -0.06* | [0.03] | -0.20*** | [0.02] |
| k = 3 | -0.12 | [0.08] | -0.21 | [0.15] | -0.09* | [0.05] | -0.29*** | [0.03] |
| k = 4 | -0.18*** | [0.06] | -0.31** | [0.15] | -0.13** | [0.06] | -0.40*** | [0.03] |
| k = 5 | -0.28*** | [0.04] | -0.46*** | [0.16] | -0.18*** | [0.07] | -0.53*** | [0.03] |
| k = 6 | -0.39*** | [0.03] | -0.58*** | [0.16] | -0.23*** | [0.07] | -0.64*** | [0.04] |
| k = 7 | -0.45*** | [0.03] | -0.65*** | [0.13] | -0.26*** | [0.08] | -0.75*** | [0.04] |
| k = 8 | -0.49*** | [0.04] | -0.72*** | [0.12] | -0.30*** | [0.08] | -0.81*** | [0.04] |
| k = 9 | -0.54*** | [0.04] | -0.79*** | [0.11] | -0.33*** | [0.08] | -0.85*** | [0.04] |
| k = 10 | -0.58*** | [0.05] | -0.86*** | [0.11] | -0.33*** | [0.09] | -0.83*** | [0.04] |
| k = 11 | -0.59*** | [0.05] | -0.87*** | [0.11] | -0.34*** | [0.09] | -0.82*** | [0.05] |
| k = 12 | -0.56*** | [0.06] | -0.80*** | [0.10] | -0.32*** | [0.09] | -0.75*** | [0.05] |
| k = 13 | -0.54*** | [0.06] | -0.79*** | [0.13] | -0.31*** | [0.09] | -0.71*** | [0.05] |
| k = 14 | -0.52*** | [0.04] | -0.74*** | [0.15] | -0.27*** | [0.09] | -0.63*** | [0.05] |
| k = 15 | -0.47*** | [0.04] | -0.72*** | [0.16] | -0.25*** | [0.08] | -0.55*** | [0.05] |
| k = 16 | -0.40*** | [0.05] | -0.65*** | [0.17] | -0.21*** | [0.08] | -0.47*** | [0.05] |
| Insurer FE | - | - | - | - | Yes | - | Yes | - |

Notes: This table reports regression results from equation (1.6): $ED_{i,t+k} - ED_{i,t} = \alpha_k + \beta_k(r_t - r_{t-1}) + \Delta\epsilon_{t+k}$, where the dependent variable is the cumulative change in excess duration of life insurers' NAIC1 (rating AAA to A-) bond portfolio for horizons $k = 1, \cdots, 16$ quarters. The independent variable in Column [1] and [5] is the quarterly change in 1-year Treasury yield. The independent variable in Column [3] and [7] is the quarterly change in 1-year Treasury yield instrumented by quarterly average surprises in the three month ahead federal funds futures (denoted as FF4 in Gertler and Karadi (2015)). Newey-West standard errors allowing for $1.5 \times k$ quarters of lags are reported in brackets in Column [2], [4], [6], and [8]. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

intraday measures of monetary policy surprises (e.g., Kuttner (2001), Bernanke and Kuttner (2005) and Gurkaynak et al. (2005)), surprises in FF4 are measured within a tight window of 30 minutes of the FOMC announcement to ensure that the surprises in futures rates solely reflect news about the FOMC decision.

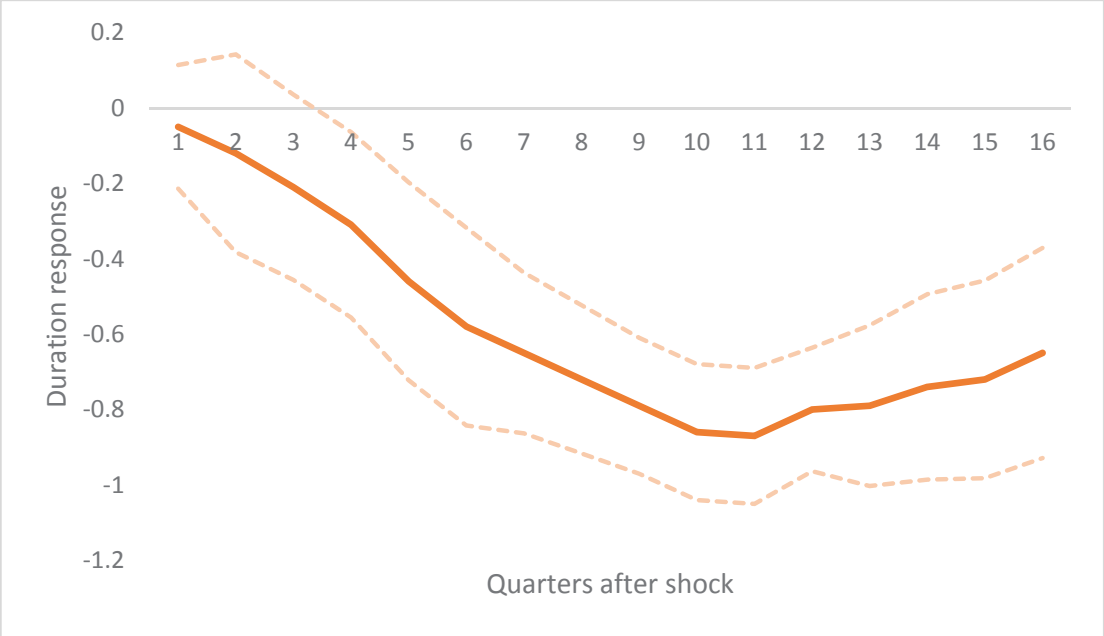
One issue is that the frequency of the quarterly snapshots of the duration of life insurers' bond portfolio does not align with the uneven number of days between the FOMC meetings. To address this issue, I turn monetary surprises on FOMC days into quarterly average surprises by following the procedure described in footnote 11 of Gertler and Karadi (2015). The calculation is done in three steps. First, I create a cumulative daily surprise series by accumulating all FOMC day surprises. Second, I take quarterly averages of the series. Finally, quarterly average surprises are obtained by taking the first difference of this series.

The dynamics of life insurers' bond portfolio duration following a monetary policy shock are reported in Columns[3] and [4] of Table 1.5 and also visualized in Figure 1.6. The F-statistic of the first stage regression of quarterly change in 1-year Treasury yield on quarterly average of FF4 surprise is 10.46, which is above the threshold of 10 proposed in Stock et al. (2002). This implies that the problem of weak instrument is absent. Over the 11 quarters following a 1% expansionary monetary policy surprise, the excess duration of life insurers' bond portfolio increase by 0.89.

### 1.5.3 Comparison with mutual funds

To illustrate that hunt-for-duration is unique to life insurance companies due to their liability-driven portfolio management, I use other major bond investors as a comparison group as in Domanski et al. (2017) and Ozdagli and Zhang (2017). In particular, I compare and contrast the evolution of bond portfolio duration of life insurers with that of mutual funds, who are the second largest participants in the corporate bond market. Different from life insurers, the investment strategies of mu-

Figure 1.6: Life insurers: Response of excess duration to monetary policy surprises




Notes: This figure plots the coefficient $\beta_k$ from estimating equation (1.6):

$$ED_{i,t+k} - ED_{i,t} = \alpha_k + \beta_k(r_t - r_{t-1}) + \Delta\epsilon_{t+k},$$

where the dependent variable is the cumulative change in excess duration of life insurance sector's NAIC1 bond portfolio for horizons $k = 1, \cdots, 16$ quarters. The independent variable is the quarterly change in 1-year Treasury yield instrumented by quarterly average surprises in the three month ahead federal funds futures (denoted as FF4 in Gertler and Karadi (2015). Confidence intervals based on Newey-West standard errors allowing for $1.5 \times k$ quarters of lags are shown as dashed lines.

tual funds are asset-driven. Mutual fund managers have strong incentive to achieve high performance to beat their peers, since investor flows into and out of mutual funds are strongly linked to their past performance (Coval and Stafford, 2007; Goldstein, Jiang, and Ng 2017). Hence, mutual funds, who are subject to short-term performance monitoring, are more likely to be averse to holding long-term bonds whose prices are volatile as the interest rates fluctuate.

I re-examine equation (1.6) in Section 1.5.2 by replacing the dependent variable with the excess duration of the mutual fund sector. Table 1.6 and Figure 1.7 present the results. In a quarter after a 1% surprise decline in the monetary policy rate, mutual funds cut the excess duration by 0.22. Over the following 8 quarters, I find a cumulative decrease of 1.1 in mutual funds' excess duration.

The results above indicate that mutual funds, in contrast with life insurers, are shifting their corporate bond portfolios toward lower duration as the interest rates decrease. Therefore, this comparison confirms that hunt-for-duration is not a general feature in the corporate bond market when the interest rates are low, but a specific one accounted for by the duration-matching portfolio management strategy of life insurance companies.

### 1.5.4 Interaction between life insurance companies and mutual funds

In the previous sections, I have shown that while the excess duration of life insurers' bond portfolio rises in the low interest rate environment, the excess duration mutual funds' bond portfolio declines. In this section, I further look into the potential trading interactions between life insurance companies and mutual funds. In particular, when mutual funds sell (buy) bonds with duration higher (lower) than the market benchmark, are life insurance companies on the other side of the trade? To answer

Table 1.6: Mutual funds: Dynamics of portfolio duration following a change in interest rate

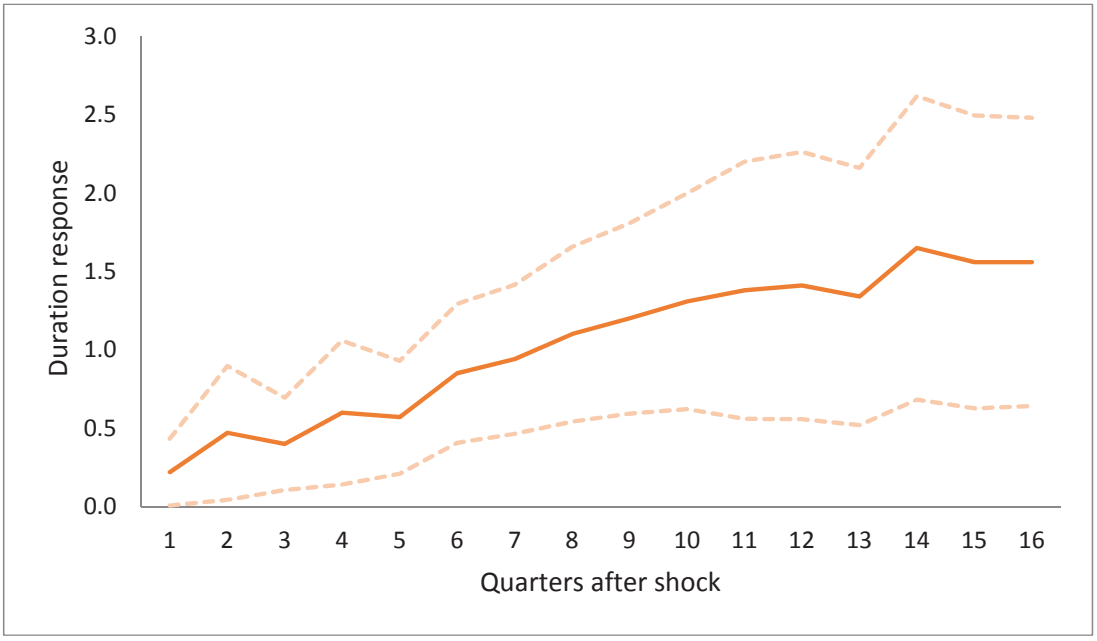
| Dep. Var: Cumulative change in excess duration of bond portfolio | | | | |
|---|---|---|---|---|
| | Rate change | | Monetary surprise | |
| | [1] | [2] | [3] | [4] |
| | $\beta_k$ | Std. error | $\beta_k$ | Std. error |
| k = 1 | 0.13*** | [0.04] | 0.22* | [0.13] |
| k = 2 | 0.23** | [0.09] | 0.47* | [0.26] |
| k = 3 | 0.26*** | [0.07] | 0.40** | [0.18] |
| k = 4 | 0.34*** | [0.09] | 0.60** | [0.28] |
| k = 5 | 0.38*** | [0.09] | 0.57** | [0.22] |
| k = 6 | 0.41*** | [0.06] | 0.85*** | [0.27] |
| k = 7 | 0.50*** | [0.06] | 0.94*** | [0.29] |
| k = 8 | 0.55*** | [0.05] | 1.10*** | [0.34] |
| k = 9 | 0.58*** | [0.07] | 1.20*** | [0.37] |
| k = 10 | 0.65*** | [0.12] | 1.31*** | [0.42] |
| k = 11 | 0.68*** | [0.14] | 1.38*** | [0.50] |
| k = 12 | 0.63*** | [0.15] | 1.41*** | [0.52] |
| k = 13 | 0.59*** | [0.17] | 1.34** | [0.50] |
| k = 14 | 0.65*** | [0.19] | 1.65*** | [0.59] |
| k = 15 | 0.67** | [0.25] | 1.56*** | [0.57] |
| k = 16 | 0.59** | [0.24] | 1.56*** | [0.56] |

Notes: This table reports regression results from equation (1.6):

$$ED_{i,t+k} - ED_{i,t} = \alpha_k + \beta_k(r_t - r_{t-1}) + \Delta\epsilon_{t+k},$$

where the dependent variable is the cumulative change in excess duration of mutual fund sector's NAIC1 bond portfolio for horizons $k = 1, \cdots, 16$ quarters. The independent variable in Column [1] is the quarterly change in 1-year Treasury yield. The independent variable in Column [3] is the quarterly change in 1-year Treasury yield instrumented by quarterly average surprises in the three month ahead federal funds futures (denoted as FF4 in Gertler and Karadi (2015). Newey-West standard errors allowing for $1.5 \times k$ quarters of lags are reported in brackets in Columns [2] and [4]. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

Figure 1.7: Mutual funds: Response of portfolio duration to monetary policy surprises




Notes: This figure plots the coefficient $\beta_k$ from estimating equation (1.6):

$$ED_{i,t+k} - ED_{i,t} = \alpha_k + \beta_k(r_t - r_{t-1}) + \Delta\epsilon_{t+k},$$

where the dependent variable is the cumulative change in excess duration of mutual fund sector's NAIC1 bond portfolio for horizons $k = 1, \cdots, 16$ quarters. The independent variable is the quarterly change in 1-year Treasury yield instrumented by quarterly average surprises in the three month ahead federal funds futures (denoted as FF4 in Gertler and Karadi (2015). Confidence intervals based on Newey-West standard errors allowing for $1.5 \times k$ quarters of lags are shown as dashed lines.

this question, I estimate the following regression similar to Cai et al. (2019):

$$NT^I_{j,t} = \beta_0 + \beta_1 \cdot NT^M_{j,t} + \beta_2 \cdot Above_{j,t} + \beta_3 \cdot NT^M_{j,t} \times Above_{j,t} + \epsilon_{j,t}, \tag{1.7}$$

where in quarter $t$, $NT^I_{j,t}$ and $NT^M_{j,t}$ are the net amount of bond $j$ traded by all life insurance companies and mutual funds, respectively. For example, $NT^M_{j,t} = -100$ ($NT^M_{j,t} = 100$) means that mutual funds, on net, sell (buy) \$100 worth of bond $j$ in quarter $t$. $Above_{j,t}$ is a dummy variable equal to 1 when the duration of bond $j$ is above the market benchmark. $\delta_t$ is the quarter fixed effect. The standard errors are clustered at the bond issuer level.

The regression specified in equation (1.7) is estimated separately for two cases where (1) mutual funds are the net seller of a bond with $NT^M_{j,t} < 0$, and (2) mutual funds are the net buyer of a bond with $NT^M_{j,t} > 0$. The sample is divided into the high (before 2009Q1) and the low (after 2009Q1) interest rate period. As in Maggio and Kacperczyk (2017), the split of the high and low interest rate period is based on the 1% of the interest rate level.

Columns [1] and [2] of Table 1.7 report the regression results for bonds that are on net sold by mutual funds. During the high interest rate period, the estimated coefficient on $NT^M_{j,t}$ in Column [1] is -0.12. The interpretation is that \$100 more sales of a bond with negative excess duration by mutual funds is associated with \$12 more purchases by life insurers. However, as indicated by the insignificant estimate of the interaction term $NT^M_{j,t} \times Above_{j,t}$, the correlation between mutual funds' sales and life insurers' purchases is not notably stronger for bonds with positive excess duration.

Over the low interest rate period, as reported in Column [2], the coefficient on $NT^M_{j,t}$ is -0.06, so that each additional \$100 of sales by mutual funds of a bond with duration lower than the market benchmark is associated with \$6 of more purchases by life insurance companies. The negative and significant coefficient of -0.29 on the

interaction term $NT^M_{j,t} \times Above_{j,t}$ indicates that when a bond with positive excess duration is on net sold by mutual funds, it is more likely to be bought by life insurers. Specifically, for bonds with duration higher than the market benchmark, each additional \$100 of sales by mutual funds is associated with \$35 (= -(-0.06-0.29)×100) more purchases by life insurance companies. The result suggests that compared to bonds with negative excess duration, the correlation between mutual funds' sales and life insurers' purchases is around six times stronger for bonds with positive excess duration.

The results for bonds which mutual funds on net buy are presented in columns [3] and [4] of Table 1.7. The bonds are restricted to those purchased from the secondary market. Primary market trading will be studied in detail in a later section. For a bond with duration above the market benchmark, \$100 more purchases of that bond by mutual funds is associated with \$6 (= -(-0.20 + 0.14)×100) more sales by life insurers in the high interest rate environment. However, in the low interest rate environment, the trading dynamics of bonds with positive excess duration between mutual funds and life insurers reverses: \$100 more purchases of a bond with duration above the market benchmark by mutual funds is associated with \$15 (= (-0.05 + 0.20)×100) more purchases by life insurers.

In summary, the results in Table 1.7 confirm that life insurers and mutual funds are trading on the opposite side. This is particularly true during times of low interest rates when life insurers acquire a substantial fraction of the bonds with duration above the market benchmark sold by mutual funds.

### 1.5.5 Hunt-for-duration in the cross-section

Up to this point, all analyses are conducted at the aggregate level of the entire life insurance sector. In this section, I explore the cross-sectional differences across individual life insurance companies. In particular, I investigate how hunt-for-duration

Table 1.7: Interactive trading between life insurance companies and mutual funds

| Dep. Var.: Life insurer net trade | | | | |
|---|---|---|---|---|
| | Mutual fund net trade $< 0$ | | Mutual fund net trade $> 0$ | |
| | [1] | [2] | [3] | [4] |
| | High rate | Low rate | High rate | Low rate |
| Mutual fund net trade | -0.12* | -0.06*** | -0.20*** | -0.05*** |
| | [0.06] | [0.02] | [0.05] | [0.02] |
| Mutual fund net trade × Above | -0.18 | -0.29*** | 0.14* | 0.20** |
| | [0.12] | [0.04] | [0.08] | [0.09] |
| Quarter FE | Yes | Yes | Yes | Yes |
| N | 21066 | 52012 | 23409 | 31735 |
| $R^2$ | 0.04 | 0.08 | 0.04 | 0.03 |

Notes: This table reports regression results on the interactive trading between mutual funds and life insurance companies in the high- (before 2009Q1) and low-interest rate(after 2009Q1) regime. The regime split is based on 1-year Treasury yield level of 1%. The dependent variable is life insurance sector's net trading amount of bond $j$ in quarter $t$. The regressions are separated into cases where the mutual fund sector on net sell (Columns [1] and [2]) or buy (Columns [3] and [4]) a particular bond in a quarter. The independent variables include mutual fund sector's net trading amount of bond $j$ in quarter $t$, a dummy variable *Above* which equals one when bond $j$ in quarter $t$ has duration above the market benchmark (i.e., positive excess duration), and the interaction term between net trade and the dummy *Above*. Retiring bonds (with amount outstanding reduced by more than 50% due to calls, maturity, conversion, etc.) are excluded. Standard errors reported in brackets are clustered at the bond issuer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

behavior is connected with certain company characteristics of life insurers. The characteristics of interest are regulatory constraints, leverage ratio, company size, and organization type.

The extent to which each life insurance company engages in hunt-for-duration is captured by the excess duration of its bond portfolio. Regulatory constraint is measured by A.M. Best's capital adequacy ratio (BCAR). BCAR is the ratio of total adjusted capital to required risk-based capital. The required risk-based capital specifies the amount of capital needed for a life insurance company to survive the risks inherent in its operations. The required risk-based capital is computed based on A.M. Best's formula which takes into account four broad risk categories that life insurers face.[21] The capital requirement component that is the most relevant to hunt-for-duration is on the interest risk. Charges on the interest risk penalize a mismatch between a life insurer's liability and asset cash flows, thereby restricting the risk of losses due to interest rate fluctuations. A higher BCAR means that the life insurer is better capitalized.

The hypothesis is that more regulatory-constrained life insurers tend to hunt for duration more; and during times of low interest rates, the connection between regulatory constraint and hunt-for-duration is even stronger. To test this hypothesis, I estimate the following regression model:

$$ED_{i,t} = \beta_0 + \beta_1 \cdot BCAR_{i,t-1} + \beta_2 \cdot Low_t + \beta_3 \cdot BCAR_{i,t-1} \times Low_t + \gamma' X_{i,t-1} + \epsilon_{i,t}, \quad (1.8)$$

where the dependent variable $ED_{i,t}$ is the excess duration of life insurer $i$'s bond portfolio at quarter $t$. $Low_t$ is a dummy variable that is equal to one for the period after 2009Q1 when the 1-year Treasury yield is below 1%, and zero otherwise. $BCAR_{i,t-1}$

[21] According to A.M. Best (2016), the four categories of risk are asset risk, insurance risk, interest-rate risk, and business risk. The total required risk-based capital is obtained by adding up the capital requirement for each risk category with a "square root rule" covariance calculation, thereby rewarding diversification across categories of risks.

is lagged A.M. Best's capital adequacy ratio of the year-end before the current quarter $t$. The vector $X_{i,t-1}$ denotes lagged company characteristics of the year-end before the current quarter $t$, as well as their interaction terms with the dummy variable $Low_t$. Additional company characteristics include leverage, company size, and stock dummy, which is equal to one if outside shareholders are co-owners of the company and zero if policyholders are co-owners of the company.[22] The leverage ratio is calculated as one minus the ratio of equity to total assets. Company size is the log of total assets. To account for time-invariant insurer characteristics, I include insurer fixed effects. Year fixed effects are also included to control for general macro trends. Standard errors are clustered at the quarter level. I drop firms with asset value smaller than $1 million or with less than ten bonds on their portfolios in a given quarter.

Column [1] of Table 1.8 reports a baseline regression of the excess duration of bond portfolio on the BCAR ratio. The negative and significant coefficient on the variable $BCAR$ indicates that a decrease of one in capital adequacy ratio corresponds to a 0.12 increase in the excess duration of bond portfolio over the period of high interest rates. This is consistent with the hypothesis that life insurers that are more regulatory constrained (i.e., with low values of BCAR) hunt for duration more (i.e., have bond portfolios with higher excess duration). Moreover, the coefficient on the interaction term $BCAR \times Low$ equals -0.10 with high significance level, implying that the negative association of hunt-for-duration with BCAR almost doubled during times of low interest rates.

In columns [2] to [4] of Table 1.8, I include additional controls: leverage, asset size, and stock company indicator. Hunt-for-duration is more pronounced among life insurers with higher leverage over the period of low interest rates, as the coefficient on the interaction term $Leverage \times Low$ is positive and significant. Also, the positive and significant coefficients on the variable $Asset$ and the interaction term

[22]For detailed definition of stock and mutual insurance companies, see https://www.investopedia.com/articles/personal-finance/011916/mutual-vs-publically-traded-insurance-companies.asp.

Table 1.8: Regulatory constraint and hunt-for-duration

| Dep. Var: Excess duration of bond portfolio | | | | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| BCAR | -0.12*** | -0.12*** | -0.11*** | -0.13*** |
| | [0.03] | [0.02] | [0.02] | [0.02] |
| BCAR × Low | -0.10*** | -0.07*** | -0.08*** | -0.04** |
| | [0.02] | [0.02] | [0.02] | [0.01] |
| Leverage | - | - | 0.83 | -0.01 |
| | - | - | [0.51] | [0.49] |
| Leverage × Low | - | - | 1.31*** | 1.18*** |
| | - | - | [0.22] | [0.22] |
| Asset | - | 0.32*** | - | 0.32*** |
| | - | [0.04] | - | [0.04] |
| Asset × Low | - | 0.15*** | - | 0.13*** |
| | - | [0.02] | - | [0.02] |
| Stock | - | -0.51*** | -0.53*** | -0.48*** |
| | - | [0.12] | [0.12] | [0.13] |
| Stock × Low | - | -0.73*** | -0.80*** | -0.79*** |
| | - | [0.08] | [0.09] | [0.09] |
| Insurer FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| $N$ | 11208 | 11208 | 11208 | 11208 |
| $R^2$ | 0.76 | 0.77 | 0.77 | 0.77 |

Notes: This table reports results from the panel regression of hunt-for-duration on characteristics of life insurance companies. The observations are at the insurer-quarter level. The dependent variable is the excess duration of a life insurer's portfolio of bonds in NAIC class 1. The independent variables include company characteristics and their interaction terms with the dummy variable Low, which equals one for the periods after 2009Q1, when the 1-year Treasury yield is below 1%. The company characteristics include BCAR, (log) total assets, leverage ratio, and an indicator for whether a life insurer is a stock company. All company characteristics are lagged values of the year-end prior to the current quarter and are winsorized at the top and bottom 5%. Life insurers with less than ten bonds in their portfolios or with total assets less than $1 million are dropped. All regressions include insurer fixed effects and year fixed effects. Standard errors reported in brackets are clustered at the quarter level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

$Asset \times Low$ suggest that larger firms hunt for duration; and appear more so in times of low interest rates. As indicated by the negative and significant coefficient on the variable $Stock$, compared to life insurance companies with mutual ownership, stock life insurers engage less in hunt-for-duration. The dispersion between these two types of life insurers further widens when interest rates are low, as the coefficient on the interaction term $Stock \times Low$ is negative and significant. Above all, the findings regarding regulatory constraint and hunt-for-duration behavior are robust to controlling for a set of company characteristics. The hypothesis is confirmed that life insurance companies under higher regulatory pressure hunt for duration more, and especially in times of low interest rates.

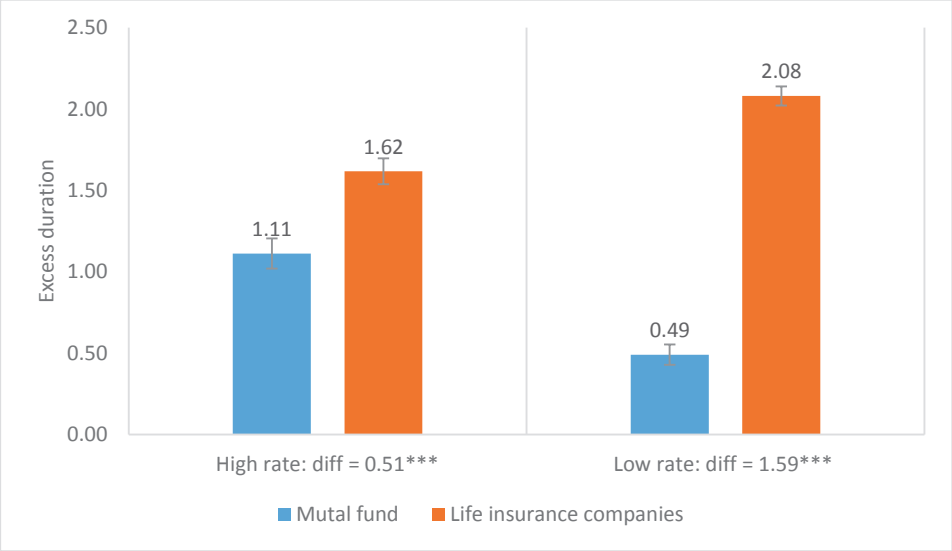
## 1.6 Hunt-for-duration: Evidence from transactions

### 1.6.1 Primary market trading

So far, we have focused on the quarter-end snapshots of the excess duration of the bond holdings of the life insurance sector. It is worth noting that according to NAIC Schedule D transaction data, around 40% of life insurers' buy trades take place in the primary market for newly issued bonds. Hence, looking at the investment choices at the time of bond issuance is essential for investigating the hunt-for-duration behavior among life insurers. Life insurers' holdings of new bonds issued in the primary market are based on acquisitions that occur within a quarter since the offering date.

Figure 1.8 presents some preliminary evidence for more pronounced hunt-for-duration on the part of life insurance companies in the primary market during times of low interest rate. Figure 1.8 contrasts, separately during periods of high and low interest rate, the weighted average of excess duration of new bond issues purchased

Figure 1.8: Excess duration of newly-issued bonds acquired by life insurers v.s. mutual funds




Notes: This figure compares the value-weighted average excess duration on NAIC2 (rating BBB) corporate bonds acquired by insurance companies and mutual funds. Bars indicate 95% confidence intervals for the average. The differences are reported as compared to life insurers. *** indicate statistical significance at the 1% level.

by life insurance companies and mutual funds. In times of high interest rate, life insurers buy bonds with excess duration, on average, 0.51 higher than mutual funds. The gap increases to 1.59 during times of low interest.

Comparison of the simple mean in Figure 1.8 doesn't take into account other bond characteristics. One concern is that life insurers are buying bonds with longer duration because those bonds happen to have higher yield spread. To address such concern, I conduct a closer investigation of life insurers' hunt-for-duration behavior in the primary market by estimating the following regression with controls of bond

characteristics:

$$PctInsurer_{j,t} = \beta_0 + \beta_1 \cdot ED_{j,t} + \beta_2 \cdot YS_{j,t} + \beta_3 \cdot Low_t + \beta_4 \cdot ED_{j,t} \times Low_t + \beta_5 \cdot YS_{j,t} \times Low_t + \gamma' X_{j,t} + \epsilon_{j,t}. \quad (1.9)$$

The regression is at the bond level: Each observation corresponds to an individual new bond $j$ issued in quarter $t$. During the quarter $t$ when bond $j$ is issued, the dependent variable $PctInsurer_{j,t}$ is the percentage of the newly-issued bond $j$ that is acquired by life insurance companies. Similar to Becker and Ivashina (2015), the percentage is calculated using the total amount of bond $j$ acquired by life insurance companies and mutual funds as the denominator. By constructing the dependent variable $PctInsurer_{j,t}$ in this way, life insurers' purchases of newly-issued bonds are measured against mutual funds. As defined in equation (1.5), $ED_{j,t}$ is the duration of bond $j$ (estimated using offering price and cash flow information from FISD) relative to all outstanding bonds within the same NAIC rating group. $YS_{j,t}$ is bond $j$'s yield (reported in FISD at the time of issuance) over the closest benchmark Treasury bond. $Low_t$ is a dummy variable equal to one for the period of low interest rate after 2009Q1. In addition, issue size is used as a proxy for bond liquidity, following Campbell and Taskler (2003). To control for the possibility that life insurers might prefer one bond credit rating to another, I include bond rating as another control variable. For brevity, the additional control variables (log of issue size and bond credit rating) as well as their interaction terms with the dummy variable $Low_t$ are denoted by vector $X_{j,t}$. Since NAIC class 1 bonds and NAIC class 2 bonds are subject to different risk-based capital requirements. I estimate equation (1.9) separately for these two NAIC classes. I cluster the standard errors at the bond issuer dimension to account for the fact that some bond issuers issue several different bonds. Above all, notice that through controlling for bond yield spread, the regression specification

(1.9) can distinguish hunt-for-duration for the purpose of hedging against interest rate risk from reach-for-yield for the purpose of generating higher expected returns.

The results for the regression specification (1.9) are documented in Table 1.9. In Columns [1] through [3], the sample includes bonds that belong to NAIC class 1. In Column [1], the positive and significant coefficient on the variable $ED$ indicates that compared with mutual funds, life insurance companies are more prone to purchase new bonds with higher excess duration. Moreover, such propensity is even stronger over the period of low interest rates because the coefficient on the interaction term $ED \times Low$ is positive and significant at the 1% confidence interval. In terms of economic magnitudes, over the period of high interest rates, a one standard deviation of increase in bond excess duration (4.15) corresponds to a 4.98% (=1.20×4.15) increase in life insurers' fraction of holdings of newly-issued bonds. This is 22.47% of the standard deviation of the dependent variable. Moreover, in times of low interest rates, a one standard deviation of increase in the excess duration (4.15) is associated with a 8.63% (= (1.20+0.88)×4.15) increase in the share of life insurance holdings. This is 38.94% of the standard deviation of the dependent variable. As we move from the high interest rate period to the low interest rate period, the effect of bond excess duration on life insurers' acquisitions of bonds at issue becomes almost 75% larger.

As shown in Column [3] of Table 1.9, the coefficients on the variable $ED$ and the interaction term $ED \times Low$ stay robust with controls of bond yield spread, liquidity, and credit rating. One important observation through comparing results in Column [2] with Column [3] is that with inclusion of excess duration, the coefficient on the interaction term $YS \times Low$ drops from significant 3.51 to 0.62, insignificantly different from zero. This implies that life insurers' inclination for buying bonds with higher yield in times of low interest rates is mainly prompted by increasing the duration of their bond portfolio for duration-matching purposes, i.e., hunt-for-duration.

Table 1.9: Life insurers: primary market acquisition of newly-issued bonds

| Dep. Var: Percentage acquired by life insurers | | | | | | |
|---|---|---|---|---|---|---|
| | NAIC class 1 | | | NAIC class 2 | | |
| | [1] | [2] | [3] | [4] | [5] | [6] |
| Excess duration (ED) | 1.20*** | - | 1.20*** | 0.61*** | - | 0.60*** |
| | [0.17] | - | [0.17] | [0.13] | - | [0.13] |
| ED× Low | 0.88*** | - | 0.89*** | 1.86*** | - | 1.84*** |
| | [0.18] | - | [0.18] | [0.17] | - | [0.17] |
| Yield spread (YS) | - | -0.69 | -0.64 | - | -1.57*** | -1.55*** |
| | - | [0.68] | [0.60] | - | [0.52] | [0.52] |
| YS× Low | - | 3.51*** | 0.62 | - | 3.48*** | 2.43*** |
| | - | [1.12] | [0.96] | - | [0.82] | [0.71] |
| Rating | 1.09*** | 1.41*** | 1.14*** | -0.69 | -0.58 | -0.42 |
| | [0.27] | [0.31] | [0.28] | [0.45] | [0.45] | [0.45] |
| Rating× Low | -0.62 | -0.62 | -0.68 | -0.38 | -1.87** | -0.94 |
| | [0.46] | [0.56] | [0.48] | [0.69] | [0.77] | [0.69] |
| Issue size | -1.91*** | -2.33*** | -1.84*** | -4.49*** | -4.18*** | -4.10*** |
| | [0.63] | [0.61] | [0.62] | [0.45] | [0.39] | [0.39] |
| Issue size× Low | -3.34*** | -5.94*** | -3.41*** | -3.59*** | -3.77*** | -3.92*** |
| | [0.84] | [0.91] | [0.84] | [0.84] | [0.88] | [0.81] |
| $N$ | 5202 | 5202 | 5202 | 4476 | 4476 | 4476 |
| $R^2$ | 0.24 | 0.13 | 0.24 | 0.29 | 0.14 | 0.29 |

Notes: This table reports results from regression of life insurers' primary market acquisition of newly-issued investment-grade corporate bonds. The dependent variable is life insurers' acquisition of a newly-issued bond as a percentage of the bond's total amount acquired by life insurers and mutual funds. The independent variables are bond characteristics as well as their interaction terms with dummy variable *Low*, which equals one for the periods after 2009Q1 when the 1-year Treasury yield is below 1%. Excess duration of a bond is its duration minus market benchmark defined in equation (1.5). Yield spread is yield to maturity at issuance over the closest benchmark Treasury bond. Issue size is log of offering amount at issuance. Rating is the numerical rating with correspondence with letter rating defined in Section 1.3. All bond characteristics (except rating) are winsorized at the top and bottom 2.5%. Standard errors reported in brackets are clustered at the bond issuer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

In Columns [4] to [6], I repeat the analysis with the sample of bonds in NAIC rating class 2. The coefficients on the variable $ED$ and the interaction term $ED \times Low$ remain similar without (Column [4]) or with (Column [6]) controlling for the bond yield. According to Column [6], in the low interest rate environment, for a one standard deviation (3.46) increase in the excess duration, life insurers' acquisition of newly-issued bonds is predicted to be 8.44% (=(0.60+1.84)×3.46) higher. This is 43.82% of the standard deviation of the dependent variable. Column [6] further shows that even when controlling for bond excess duration, there are still signs of a positive association between bond yield spread and life insurers' acquisition within NAIC rating class 2 when interest rates are low. However, the economic magnitude is relatively small: A one standard deviation increase in the yield spread (0.86%) corresponds to a 0.76% (=(-1.55+2.43)×0.86) higher share of life insurers' purchases of new bonds from the primary market over the period of low interest rates, This is equivalent to only 3.94% of the dependent variable.

Overall, the results in Table 1.9 suggest that confirm the hypothesis that life insurers tend to load more aggressively on new bonds with higher excess duration during times of low interest rates. Moreover, life insurers' shift, at first glance, towards bonds with higher yields in the low interest rate environment is for the most part brought about by life insurers' hunt-for-duration behavior. This finding is consistent with that in Ozdagli and Zhang (2019), where they use a matching-procedure to carve out the duration-risk component from the yield of life insurers' bond portfolios.

### 1.6.2 Secondary market trading

Purchasing newly-issued bonds from the primary market is not the only way through which life insurance companies can adjust the duration of their corporate bond portfolios. Duration adjustments can also be made through acquiring or disposing seasoned bonds in the secondary market. In this paper, transactions which take place after one

or more quarters following the date of bond issuance are defined as trading activities in the secondary market. According to NAIC Schedule D data, life insurers also trade a large amount in the secondary market: Over the sample period from year 2002 to 2017, an average life insurance company buys around 15% and sell 14% of its corporate bond holdings during a year in the secondary market. To investigate whether life insurers engage in hunt-for-duration in the secondary market when interest rates are low, I track the quarterly bond trades of life insurers. Specifically, I estimate the specification of the following form:

$$PctChg_{j,t} = \beta_0 + \beta_1 \cdot ED_{j,t} + \beta_2 \cdot YS_{j,t} + \beta_3 \cdot Low_t + \beta_4 \cdot ED_{j,t} \times Low_t + \beta_5 \cdot YS_{j,t} \times Low_t + \gamma' X_{j,t} + \epsilon_{j,t}. \quad (1.10)$$

where $PctChg_{j,t}$ denotes the percentage change since quarter $t-1$ in life insurance sector's total holdings of bond $j$ traded by life insurers in quarter $t$. For secondary market trades, bond duration and yield are estimated using end-of-quarter transaction prices from TRACE and cash flow information from FISD. As defined in equation (1.5), excess duration $ED_{i,j}$ is the duration of bond $j$ relative to all outstanding bonds within the same NAIC rating group. Yield spread $YS_{j,t}$ is bond $j$'s yield over the closest benchmark Treasury bond. $Low_t$ is a dummy variable equal to one for the periods after 2009Q1, over which the 1-year Treasury yield is below 1%. As defined in Nielson et al. (2012), turnover is used as a measure of bond liquidity. Specifically, bond turnover is computed as log value of total trading volume reported in TRACE in the current quarter divided by the amount outstanding in the previous quarter. NAIC1 is equal to one for bonds that belongs to NAIC1 rating class. The additional control variables as well as their interaction terms with the dummy variable $Low_t$ are denoted by vector $X_{j,t}$. To control for time-varying bond issuer characteristics, I include bond issuer-quarter fixed effects. Since there are bond issuers having more

than one bond outstanding at the same time, standard errors are clustered at the bond issuers level in order to allow for potential correlation among the different issues within bond issuers. Retiring bonds (with amount outstanding reduced by more than 50% due to calls, maturity, conversion, etc.) are excluded.

Table 1.10 presents the findings for life insurers' trading activities in the secondary market. In Column [1], the coefficient on the variable $ED$ is positive and significantly different from zero. This suggests that the quarterly change in the holdings of a bond by life insurers is an increasing function of its excess duration. That is, life insurers acquire more of the bonds with longer duration and sell more of the bonds with shorter duration. On top of that, hunt-for-duration on the part by life insurers manifests itself more during times of low interest rates. This is indicated by the positive and statistically significant coefficient on the interaction term $ED \times Low$. With regard to the magnitude of the results, during times of high interest rates, a one standard deviation of increase in a bond's excess duration (4.04) predicts a 1.94% ($= 0.48 \times 4.04$) increase in life insurers' net purchases through the secondary market. This is equivalent to 13.85% of the standard deviation of the dependent variable. In addition, in times of low interest rates, a one standard deviation increase in the excess duration (4.04) is associated with a 2.34% ($= (0.48+0.10) \times 4.04$) increase in life insurers' holdings acquired from secondary market. This equals 16.70% of the standard deviation of the dependent variable.

After controlling for yield spread in Column [3] of Table 1.10, the results with regard to bond excess duration in high and low-interest-rate periods remain similar to Column [1]. Comparing the coefficients on the variable $YS$ and the interaction term $YS \times Low$ in Columns [2] with [3], we notice that with inclusion of excess duration, the effect of yield spread in times of high interest rates is significantly weakened; and the additional positive impact of yield spread in times of low interest rates disappears. This could serve as a piece of evidence that the propensity of life insurers to buy (sell)

Table 1.10: Life insurers: Secondary market transactions

| Dep. Var: Quarterly change in holdings by life insurers | | | |
|---|---|---|---|
| | [1] | [2] | [3] |
| Excess duration (ED) | 0.48*** | - | 0.44*** |
| | [0.03] | - | [0.02] |
| ED × Low | 0.10*** | - | 0.06** |
| | [0.03] | - | [0.03] |
| Yield spread (YS) | - | 2.59*** | 0.94*** |
| | - | [0.26] | [0.24] |
| YS × Low | - | 1.47*** | 0.21 |
| | - | [0.29] | [0.27] |
| NAIC1 | 0.47 | 0.88 | 0.55 |
| | [0.88] | [1.00] | [0.91] |
| NAIC1 × Low | -0.42 | 0.35 | -0.08 |
| | [1.06] | [1.16] | [1.09] |
| Turnover | 1.16*** | 1.27*** | 1.19*** |
| | [0.08] | [0.08] | [0.08] |
| Turnover × Low | 0.75*** | 0.99*** | 0.80*** |
| | [0.10] | [0.10] | [0.10] |
| Issuer-Quarter FE | Yes | Yes | Yes |
| $N$ | 155504 | 155504 | 155504 |
| $R^2$ | 0.33 | 0.32 | 0.33 |

Notes: This table reports results from regression of life insurers' secondary market transactions of investment-grade corporate bonds. The dependent variable is the percentage change since the previous quarter in life insurance sector's total holdings of a bond transacted by life insurers in the current quarter. The independent variables are bond characteristics and their interaction terms with dummy variable *Low*, which equals one for the periods after 2009Q1 when the 1-year Treasury yield is below 1%. Excess duration of a bond is its duration minus market benchmark defined in equation (1.5). Yield spread is end-of-quarter yield to maturity over the closest benchmark Treasury bond. Turnover is log of total trading volume in the current quarter divided by amount outstanding. NAIC1 is an indicator variable equal to one for bonds in NAIC1 rating group. All bond characteristics (except NAIC1 dummy) are winsorized at the top and bottom 5%. Observations with dependent variable above 100% are dropped. Retiring bonds are excluded. Bonds with total holdings never above $10 million are dropped. All regressions include bond issuer-quarter fixed effects. Standard errors reported in brackets are clustered at the bond issuer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

more bonds with higher (lower) yield is primarily driven by life insurers loading on longer duration.

To further investigate how life insurers make their secondary market investment decisions in accordance with fluctuations in interest rates, I adjust the specification in equation (1.10) by replacing the dummy variable $Low_t$ with $\Delta r_{t-1}$, which is the quarterly change in 1-year Treasury yield lagged by one quarter. In particular, I estimate the following regression:

$$PctChg_{j,t} = \beta_0 + \beta_1 \cdot ED_{j,t} + \beta_2 \cdot YS_{j,t} + \beta_3 \cdot \Delta r_{t-1} + \beta_4 \cdot ED_{j,t} \times \Delta r_{t-1} + \beta_5 \cdot YS_{j,t} \times \Delta r_{t-1} + \gamma' X_{j,t} + \epsilon_{j,t}, \quad (1.11)$$

where the variables $PctChg_{j,t}$, $ED_{j,t}$, and $YS_{j,t}$ are defined in the same way as in the regression specification (1.10). The vector $X_{j,t}$ includes control variables turnover, NAIC1 dummy, and their interaction terms with the interest rate change $\Delta r_{t-1}$. Bond issuer-quarter fixed effects are included. The standard errors are clustered at the bond issuer level. Again, retiring bonds (with amount outstanding reduced by more than 50% due to calls, maturity, conversion, etc.) are excluded.

The specification in equation (1.11) allows us to test the effect of bond excess duration on life insurers' trades conditional on interest rate changes. Table 1.11 presents two separate sets of results for the high and low interest rate regimes. The coefficient of interest, $\beta_4$, is on the interaction term $ED_{j,t} \times \Delta r_{t-1}$. If a reduction in the interest rate leads life insurers to hunt for duration, one would expect the coefficient $\beta_4$ to bear a negative sign. As shown in Column [6], the estimate for the interaction term $ED_{j,t} \times \Delta r_{t-1}$ is negative and statistically significant, indicating that in times of low interest rates, following a 1% decrease in 1-year Treasury yield, the positive association of bond excess duration on life insurers' secondary market transactions becomes almost 45% ($= 0.22/0.49 \times 100$) stronger. Notice that in times of high

Table 1.11: Life insurers: Secondary market transactions, continued

| Dep. Var: Quarterly change in holdings by life insurers | | | | | | |
|---|---|---|---|---|---|---|
| | High rate | | | Low rate | | |
| | [1] | [2] | [3] | [4] | [5] | [6] |
| Excess duration (ED) | 0.48*** | - | 0.44*** | 0.58*** | - | 0.49*** |
| | [0.03] | - | [0.03] | [0.02] | - | [0.02] |
| ED $\times\Delta r$ | 0.01 | - | -0.02 | -0.18*** | - | -0.22*** |
| | [0.04] | - | [0.04] | [0.07] | - | [0.07] |
| Yield spread (YS) | - | 2.59*** | 0.94*** | - | 4.06*** | 1.22*** |
| | - | [0.26] | [0.24] | - | [0.15] | [0.14] |
| YS $\times\Delta r$ | - | 1.52*** | -0.19 | - | 1.20** | -1.28** |
| | - | [0.51] | [0.53] | - | [0.60] | [0.60] |
| NAIC1 | 0.53 | 0.91 | 0.61 | 0.09 | 1.26** | 0.5 |
| | [0.88] | [1.01] | [0.90] | [0.57] | [0.59] | [0.58] |
| NAIC1 $\times\Delta r$ | -3.82** | -3.95** | -3.89** | -1.56 | -0.19 | -1.32 |
| | [1.82] | [1.90] | [1.84] | [2.69] | [3.17] | [2.71] |
| Turnover | 1.16*** | 1.28*** | 1.19*** | 1.92*** | 2.28*** | 2.01*** |
| | [0.08] | [0.08] | [0.08] | [0.06] | [0.07] | [0.07] |
| Turnover $\times\Delta r$ | 0.29** | 0.31** | 0.28* | 1.07*** | 1.52*** | 1.08*** |
| | [0.14] | [0.15] | [0.15] | [0.23] | [0.24] | [0.23] |
| Issuer-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes |
| $N$ | 54811 | 54811 | 54811 | 100693 | 100693 | 100693 |
| $R^2$ | 0.32 | 0.32 | 0.33 | 0.33 | 0.32 | 0.33 |

Notes: This table reports results from regression of life insurers' secondary market transactions of investment-grade corporate bonds in the high- (before 2009Q1) and low- (after 2009Q1) interest rate regime. The regime split is based on 1-year Treasury yield level of 1%. The dependent variable is the percentage change since the previous quarter in life insurance sector's total holdings of a bond transacted by life insurers in the current quarter. The independent variables are bond characteristics and their interaction terms with change in 1-year Treasury yield lagged by one quarter. Excess duration of a bond is its duration minus market benchmark defined in equation (1.5). Yield spread is end-of-quarter yield to maturity over the closest benchmark Treasury bond. Turnover is log of total trading volume in the current quarter divided by amount outstanding. NAIC1 is a dummy variable equal to one for bonds in NAIC1 rating group. All bond characteristics (except NAIC1 dummy) are winsorized at the top and bottom 5%. Observations with dependent variable above 100% are dropped. Retiring bonds are excluded. Bonds with total holdings never above $10 million are dropped. All regressions include bond issuer-quarter fixed effects. Standard errors are clustered at the bond issuer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

interest rates, the slope of excess duration on secondary market transaction doesn't vary with rate changes, as the coefficient on the interaction term $ED_{j,t} \times \Delta r_{t-1}$ in Column [3] is zero.

Overall, findings in this section about life insurers' trading activities in the secondary market are consistent with those found in the primary market: life insurers acquire bonds with higher duration. Such hunt-for-duration behavior is more pronounced following negative interest rate changes over the period of low interest rates.

## 1.7 Implications of hunt-for-duration

In the previous sections, I have documented that life insurance companies hunt for duration through rebalancing their portfolios towards bonds with higher duration following drops in interest rates induced by monetary policy. In this section, I investigate whether hunt-for-duration by life insurers can have implications for bond prices. I hypothesize that a transition into a low interest rate environment spurs an increase in life insurers' demand for bonds with high duration, thereby creating an upward price pressure in the valuations of high duration bonds.

To test the hypothesis regarding the price pressure exerted by life insurers' hunt-for-duration behavior, I examine the path of bond abnormal returns around life insurers' purchases. The procedure is as follows. First, for each quarter, bonds are grouped into quintiles based on their excess duration. Second, I define net trade by life insurers of a given bond-quarter as life insurers' total trading volume in percent of total amount outstanding. For each quarter, I rank bonds with positive net trade, and sort them into quintiles. The top quintile is composed of bonds that are most heavily bought by life insurers, whereas the bottom quintile contains bonds that life insurers buy most lightly. Next, I form four separate portfolios, including (1) bonds in the top two quintiles of excess duration and in the top quintile of net purchase, denoted

as portfolio D5B5; (2) bonds in the top two quintiles of excess duration and in the bottom quintile of net purchase, denoted as portfolio D5B1; (3) bonds in the bottom two quintiles of excess duration and in the top quintile of net purchase, denoted as portfolio D1B5; and (4) bonds in the bottom two quintiles of excess duration and in the bottom quintile of net purchase, denoted as portfolio D1B1. Finally, I compute the quarterly equal-weighted average abnormal returns (AAR) of bonds in each of the four portfolios, using the characteristics-based procedure in Bessembinder et al. (2009). To adjust for risk, the quarterly abnormal return of a given bond is computed as its raw return (in equation (1.1)) minus the return on the benchmark portfolio to which it belongs.[23]

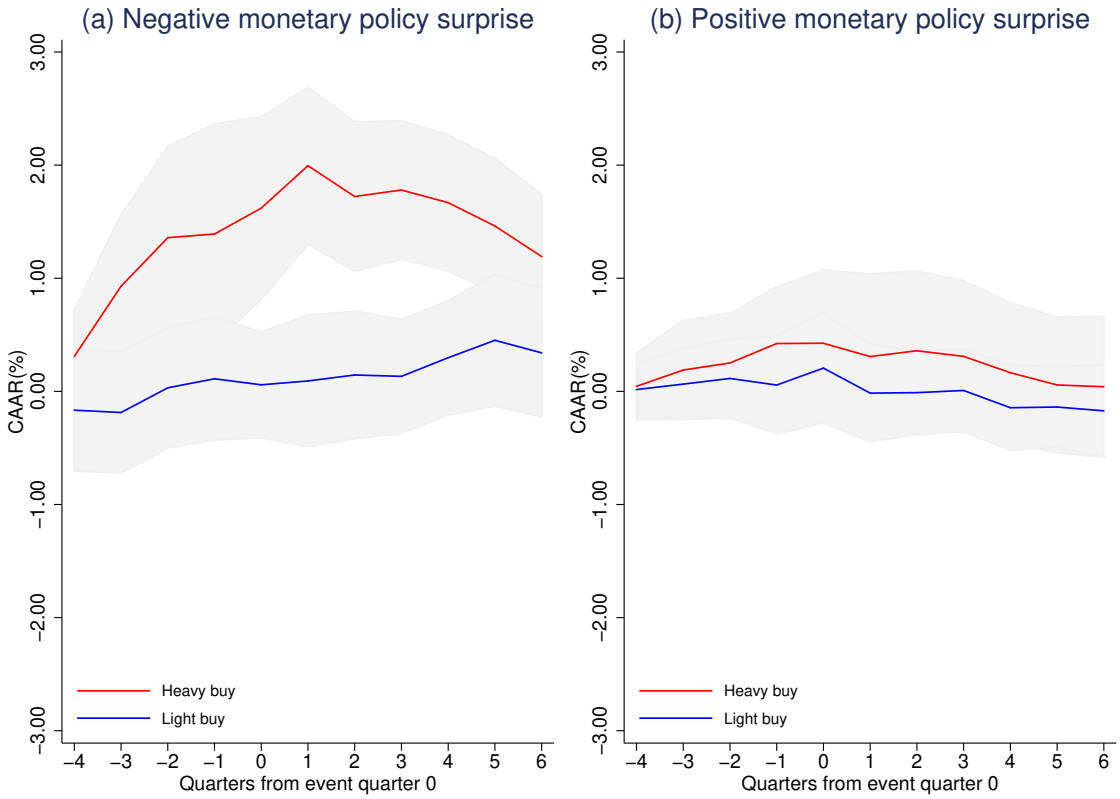
The sample period is split into quarters with negative and positive monetary policy shocks. The split is based on the quarterly monetary surprises obtained by averaging the futures surprises on FOMC days.[24] I consider bonds in the top two quintiles of excess duration most heavily bought by life insurers (i.e., bonds in portfolio D5B5) following a quarter with a negative monetary policy shock as bonds involved in hunt-for-duration-motivated trades. To see whether hunt-for-duration can bear price impacts, I compare the cumulative average abnormal returns (CAARs) of portfolio D5B5 and portfolio D5B1 (bonds in the top two quintiles of excess duration that are lightly bought by life insurers). Figure 1.9 plots the CAARs for the two portfolios by event quarters with negative and positive monetary shocks in panel (a) and (b) respectively. Table 1.12 tests whether the CAARs between the two portfolios are different (see columns [1] to [2] and [5] to [6]).

Panel A of Figure 1.9 shows that bonds in the top two excess duration quintiles purchased heavily by life insurers during quarters following a negative monetary shock

[23]The portfolio benchmarks are created based on bond credit rating and remaining time-to-maturity. At the end of every quarter, bonds are first segmented into three time-to-maturity groups (1 to 5 years, 5 to 10 years, and more than 10 years) and then three rating groups (AAA&AA, A, and BBB). This gives a total of nine groups of bonds. For each group, the equal-weighted return is computed and used as the benchmark portfolio return.

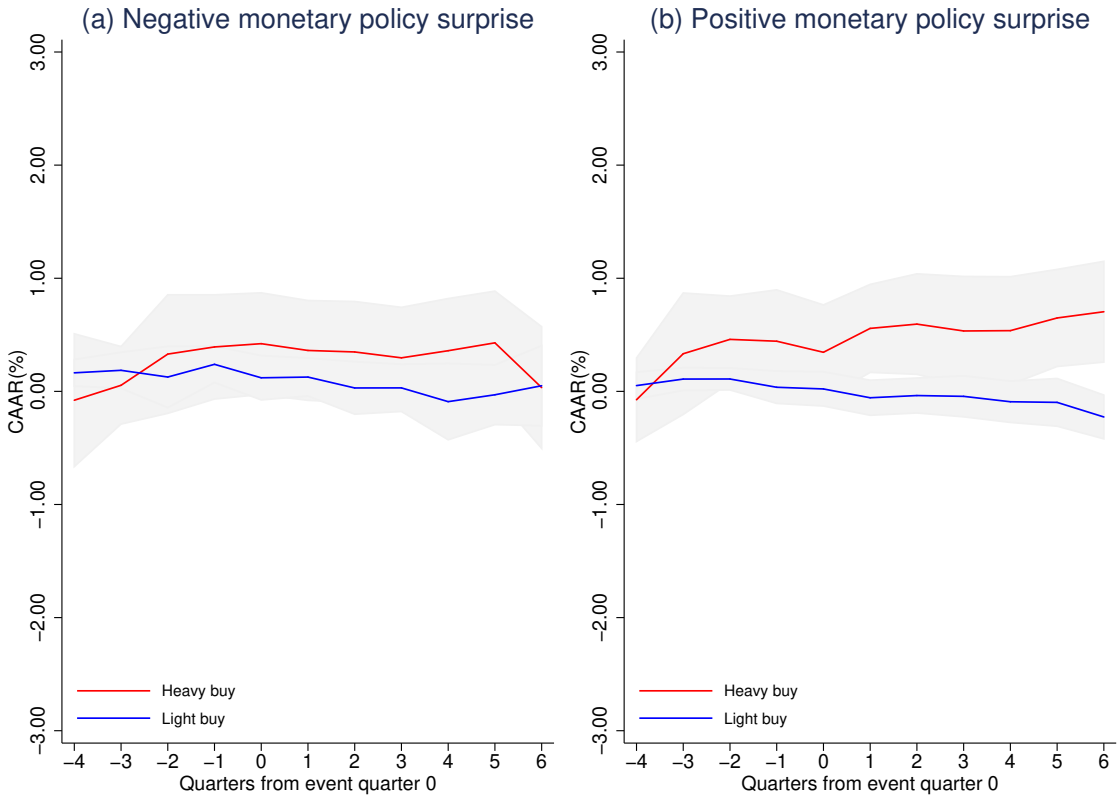
[24]Details on calculation of quarterly average surprises are discussed in Section 1.5.2.

Figure 1.9: Quarterly cumulative abnormal returns around life insurers' purchases: bonds in top two quintiles of excess duration




Notes: This figure plots the cumulative average abnormal returns (CAARs) for bonds in the top two quintiles of excess duration grouped by life insurers' net trade, four quarters before, during, and six quarters after the event quarter. The event quarters are split into those with a negative (panel A) and positive (panel B) monetary policy surprise. Net trade is defined as life insurers' total trading volume in percent of total amount outstanding. Bonds with positive net trade by life insurers are sorted into quintiles, with "heavy buy" ("light buy") denoting the top (bottom) quintile comprised of bonds most heavily (lightly) bought by life insurers following the event quarter. CAARs are measured as quarterly returns in excess of the equal-weighted average return of bonds with similar credit rating and time to maturity as in Bessembinder et al. (2009). The grey area represents the 90% confidence interval.

Figure 1.10: Quarterly cumulative abnormal returns around life insurers' purchases: bonds in bottom two quintiles of excess duration




Notes: This figure plots the cumulative average abnormal returns (CAARs) for bonds in the bottom two quintiles of excess duration grouped by life insurers' net trade, four quarters before, during, and six quarters after the event quarter. The event quarters are split into those with a negative (panel A) and positive (panel B) monetary policy surprise. Net trade is defined as life insurers' total trading volume in percent of total amount outstanding. Bonds with positive net trade by life insurers are sorted into quintiles, with "heavy buy" ("light buy") denoting the top (bottom) quintile comprised of bonds most heavily (lightly) bought by life insurers following the event quarter. CAARs are measured as quarterly returns in excess of the equal-weighted average return of bonds with similar credit rating and time to maturity as in Bessembinder et al. (2009). The grey area represents the 90% confidence interval.

Table 1.12: Abnormal returns and monetary policy shocks

| | Negative monetary shock | | | | Positive monetary shock | | | |
|---|---|---|---|---|---|---|---|---|
| | Top 2 duration quintiles | | Bottom 2 duration quintiles | | Top 2 duration quintiles | | Bottom 2 duration quintiles | |
| T | Heavy - Light CAAR (%) | t-stat | Heavy - Light CAAR (%) | t-stat | Heavy - Light CAAR (%) | t-stat | Heavy - Light CAAR (%) | t-stat |
| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] |
| -4 | 0.48 | 1.62 | -0.24 | -0.60 | 0.03 | 0.18 | -0.13 | -0.56 |
| -3 | 1.12 | 2.83 | -0.13 | -0.51 | 0.12 | 0.49 | 0.22 | 0.69 |
| -2 | 1.33 | 3.25 | 0.20 | 0.48 | 0.14 | 0.63 | 0.35 | 1.48 |
| -1 | 1.28 | 2.62 | 0.15 | 0.45 | 0.37 | 1.31 | 0.41 | 1.38 |
| 0 | 1.56 | 3.18 | 0.30 | 0.84 | 0.22 | 0.78 | 0.32 | 1.32 |
| 1 | 1.90 | 3.85 | 0.24 | 0.72 | 0.32 | 0.84 | 0.61 | 2.38 |
| 2 | 1.58 | 3.26 | 0.32 | 0.89 | 0.37 | 1.06 | 0.63 | 2.12 |
| 3 | 1.65 | 4.28 | 0.27 | 0.82 | 0.30 | 0.81 | 0.58 | 1.81 |
| 4 | 1.37 | 3.33 | 0.45 | 1.13 | 0.31 | 0.82 | 0.63 | 1.84 |
| 5 | 1.01 | 2.08 | 0.46 | 1.21 | 0.20 | 0.53 | 0.75 | 2.26 |
| 6 | 0.85 | 1.75 | -0.02 | -0.04 | 0.21 | 0.54 | 0.93 | 2.74 |

Notes: This table reports the difference in cumulative average abnormal returns (CAARs) for bonds in the top and bottom two quintiles of excess duration grouped by life insurers' net trade, four quarters before, during, and six quarters after the event quarter. The event quarters are split into those with a negative (columns [1]-[4]) and positive (columns [5]-[8]) monetary policy surprise. Net trade is defined as life insurers' total trading volume in percent of total amount outstanding. Bonds with positive net trade by life insurers are sorted into quintiles, with "heavy buy" ("light buy") denoting the top (bottom) quintile comprised of bonds most heavily (lightly) bought by life insurers following the event quarter. CAARs are measured as quarterly returns in excess of the equal-weighted average return of bonds with similar credit rating and time to maturity as in Bessembinder et al. (2009).

exhibit striking positive abnormal returns. Over the first quarter after the negative monetary policy surprise hits, the CAARs for the heavy buy group is 1.9% more positive than the light buy group with a t-statistic of 3.85 (as reported in columns [1] and [2] of Table 1.12). As in Coval and Stafford (2007) and Dessaint et al. (2019), to differentiate life insurers bringing information into prices from exerting price pressure, I look for evidence of price reversals through extending the time horizon from $t-4$ to $t+6$. The upside-down V shape price pattern in Panel A of Figure 1.9 indicates that the upward pattern in abnormal returns eventually reverses. After six quarters that follow a negative monetary policy surprise, the difference in CAARs between the heavy buy group and the light buy group shrink to 0.85 with a t-statistic of 1.75. In panel B of Figure 1.9, I find no patterns of price pressure for the event quarters with a positive monetary policy surprise. The CAARs are relatively flat, and there is no significant difference between the heavy buy group and the light buy group (see columns [5] and [6] of Table 1.12).

Figure 1.10 repeats the calculations of Figure 1.9, but with the bonds in the bottom two quintiles of excess duration. There is no sign of a CAAR pattern consistent with price pressure for event quarters with either a negative or positive monetary policy surprise (see columns [3] to [4] and [7] to [8] of Table 1.12). To put all results above into a difference-in-difference perspective: For quarters with a positive monetary policy shock, there is no upward price pressure from life insurers' buying of bonds with either high or low excess duration. For quarters with a negative monetary policy, while there is upward price pressure from life insurers buying of bonds with high excess duration, the effect is absent for bonds with low excess duration. Hence, the results demonstrate that the price pressure is generated by life insurers' purchases associated with hunt-for-duration as the interest rate declines.

As an alternative approach to evaluate the price impact exerted by life insurers, I calculate the calendar-time portfolio returns to an investment strategy that involves

bonds recognized as those purchased by life insurers' for the purpose of hunt-for-duration. Bonds involved in hunt-for-duration-motivated transactions are identified as those in the top two quintiles of excess duration bought by life insurers following a quarter with negative monetary policy shock. I use the overlapping portfolio formation method similar to Jostova et al. (2013). In particular, for each month $t$, I check if the quarter prior to the month $t$ follows a negative monetary policy shock. If yes, I form a long-short strategy with a portfolio which is long in bonds purchased by life insurers and short in bonds with no purchase by any life insurers during the quarter. Portfolio returns are equally weighted across their constituent bonds. The overall month- $t$ return of the strategy is the equally weighted average month $t$ return of the strategy implemented in the prior month and strategies formed up to twelve months earlier.

To adjust the portfolio returns for risk exposures, I estimate the intercepts (i.e., alphas) from the five-factor model developed in Fama and French (1993). In particular, the following equation is estimated:

$$r_{p,t} = \alpha + \beta^{'} F_t + \epsilon_{p,t}, \tag{1.12}$$

where $r_{p,t}$ is the month-$t$ return of the long-short strategy described above. $F_t$ includes equity ($MKT, SMB, HML$) and bond ($TERM, DEF$) factors, where $MKT, SMB$, and $HML$ are returns on the market, size, and book-to-market factors of Fama and French (1993), $TERM$ is the difference in returns between five-year Treasury bond and 3-month Treasury bill. $DEF$ is the difference in returns between investment-grade and high-yield corporate bonds (BofA Merrill Lynch index).

Table 1.13 reports the calendar-time portfolio regressions of the long-short investment strategy described above. The average monthly abnormal returns are represented by the intercepts (alphas) from the regression model in equation (1.12). The

Table 1.13: Calendar-time portfolio regressions

| | Bottom quintile | Top quintile |
|---|---|---|
| | [1] | [2] |
| Alpha | -0.045** | -0.191*** |
| | [0.018] | [0.038] |
| TERM | 0.045* | 0.285*** |
| | [0.025] | [0.064] |
| DEF | 0.026 | -0.006 |
| | [0.019] | [0.036] |
| MKT | -0.006 | 0.013 |
| | [0.008] | [0.014] |
| HML | -0.005 | -0.014 |
| | [0.010] | [0.021] |
| SMB | 0.006 | -0.003 |
| | [0.009] | [0.023] |
| $N$ | 141 | 141 |
| $R^2$ | 0.06 | 0.38 |

This table presents the result of the calendar-time portfolio regression of an investment strategy following life insurers' hunt-for-duration-motivated purchases (Column [2]). The regression specification is

$$r_{p,t} = \alpha + \beta^{'} F_t + \epsilon_{p,t},$$

where $r_{p,t}$ is the month-$t$ return of the long-short strategy which is long in bonds purchased by life insurers and short in bonds with no purchase by any life insurers in the top quintile of excess duration during the quarters following a negative shock. $F_t$ includes equity ($MKT, SMB, HML$) and bond ($TERM, DEF$) factors, where $MKT, SMB$, and $HML$ are returns on the market, size, and book-to-market factors of Fama and French (1993), $TERM$ is the difference in returns between five-year Treasury bond and 3-month Treasury bill. $DEF$ is the difference in returns between investment-grade and high-yield corporate bonds (BofA Merrill Lynch index). Column [1] reports the similar long-short strategy with bonds in the bottom quintile of excess duration. Standard errors are reported in brackets. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

exercises are repeated for both the bottom and top excess duration groups. For the top excess duration quintile, the monthly abnormal returns are economically large and statistically significant: the alpha is -0.19% with significance level at 1%. However, the pattern disappears for the bottom excess duration quintile: the alpha is -0.04%, which is small in economic terms. The results verify the findings in the earlier part of this section: Life insurers' hunt-for-duration-motivated purchases can engender price impacts.

## 1.8 Conclusion

This chapter demonstrates that life insurers, who are the largest players in the corporate bond market, shift their corporate bond portfolios towards bonds with longer duration as the interest rates decline to historical lows since the 2008 financial crisis. Evidence for hunt-for-duration is found not only from snapshots of life insurers' bond holdings, but also from their bond transaction activities. Moreover, a comparison with mutual funds confirms that hunt-for-duration is not a general feature in the corporate bond market when the interest rates are low, but a specific one accounted for by life insurers' interest rate risk hedging to ensure better duration matching between their assets and liabilities. Finally, I find corroborating evidence that hunt-for-duration on the part by life insurers can drive overpricing of corporate bonds when a negative monetary policy shock hits.

## References

Becker, Bo and Ivashina Victoria, "Reaching for Yield in the Bond Market," *The Journal of Finance*, 70 (2015), 1863–1902.

Bernanke, Ben S., and Kenneth N. Kuttner, "What Explains the Stock Market's Reaction to Federal Reserve Policy?" *Journal of Finance*, 60 (2005), 1221–1257.

Bessembinder, Hendrik, Kathleen M. Kahle, William F. Maxwell, and Danielle Xu,"Measuring Abnormal Bond Performance," *The Review of Financial Studies*, 22 (2009), 4219–4258.

Cai, Fang, Song Han, Dan Li, and Yi Li, "Institutional Herding and its Price Impact: Evidence from the Corporate Bond Market," *Journal of Financial Economics*, 131 (2019), 139–167.

Campbell, John Y., and Glen B. Taksler, "Equity Volatility and Corporate Bond Yields," *The Journal of Finance*, 58 (2003), 2321–2350.

Choi, Jaewon, and Mathias Kronlund, "Reaching for Yield in Corporate Bond Mutual Funds," *The Review of Financial Studies*, 31 (2018), 1930–1965.

Coval, Joshua and Erik Stafford, "Asset Fire Sales (and Purchases) in Equity Markets," *Journal of Financial Economics*, 86 (2007), 479–512.

Dessaint, Olivier, Thierry Foucault, Laurent Frésard, and Adrien Matray, "Noisy Stock Prices and Corporate Investment", Review of Financial Studies 32 (2019): 2625–2672.

Dick-Nielsen, Jens, "Liquidity Biases in TRACE," *The Journal of Fixed Income*, 19 (2009), 43–55.

Domanski, Dietrich, Hyun Song Shin, and Vladyslav Sushko: "The Hunt for Duration: Not Waving but Drowning?" *IMF Economic Review*, 65 (2017), 113–153.

Ellul, Andrew, Chotibhak Jotikasthira, and Christian T. Lundblad, "Regulatory Pressure and Fire Sales in the Corporate Bond Market," Journal of Financial Economics, 101 (2011), 596—620.

Ellul Andrew, Chotibhak Jotikasthira, Christian T. Lundblad, and Yihui Wang, "Is Historical Cost Accounting a Panacea? Market Stress, Incentive Distortions, and Gains Trading," *The Journal of Finance*, 70 (2015), 2489–2538.

European Insurance and Occupational Pensions Authority (EIOPA): EIOPA Insurance stress test 2014, EIOPA-BOS-14/203 (2014).

Fama E. F., and French K. R., "Common Risk Factors in the Returns on Stocks and Bonds", *Journal of Financial Economics*, 33 (1993), 3–56.

Gertler, Mark, and Peter Karadi, "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7 (2015), 44–76.

Goldstein, Itay, Hao Jiang, and David T. Ng, "Investor Flows and Fragility in Corporate Bond Funds," *Journal of Financial Economics*, 126 (2017), 592—613.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson, "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, 1 (2005), 55–93.

Jostova, Gergana, Stanislava Nikolova, Alexander Philipov, and Christof W. Stahel, "Momentum in Corporate Bond Returns," *The Review of Financial Studies*, 26 (2013), 1649—1693.

Koijen, Ralph S. J., and Motohiro Yogo, "The Cost of Financial Frictions for Life Insurers," *American Economic Review*, 105 (2015), 445—475.

Koijen, Ralph S. J., and Motohiro Yogo, "A Demand System Approach to Asset Pricing," Journal of Political Economy, 127 (2019):1475–1515.

Kuttner, Kenneth N., "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market," *Journal of Monetary Economics*, 47 (2001), 523–544.

Maggio, Marco Di, and Marcin Kacperczyk, "The Unintended Consequences of the Zero Lower Bound Policy," *Journal of Financial Economics*, 123 (2017), 59–80.

Ozdagli, Ali, and Zixuan Wang "Interest Rates and Insurance Company Investment Behavior," Working paper, 2017, 2019.

Stock, James H., Jonathan H. Wright, and Motohiro Yogo. "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments." *Journal of Business and Economic Statistics*, 20 (2002): 518—529.

Stock, James H., and Motohiro Yogo, "Testing for Weak Instruments in Linear IV Regression," *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, edited by Donald W. K. Andrews and James H. Stock, Chapter 5, Cambridge University Press, Cambridge, 2005.

# Chapter 2

# The Impact of the Risk-Based Capital Reform in the Insurance Industry on Corporate Financing

## 2.1 Introduction

The U.S. insurance industry is regulated under the National Association of Insurance Commissioners (NAIC) risk-based capital (RBC) system. The RBC requires an insurance company with a riskier profile to reserve a higher amount of capital as a cushion against insolvency. The purpose of the RBC regulation is to limit the amount of risk insurance companies can take in their insurance products and asset investments. A growing body of literature has documented that the design of the RBC rules could give rise to distortions in insurers' behavior (see, for example, Koijen and Yogo (2015), Ellul, Jotikasthira, and Lundblad (2011), Ellul et al. (2015), and Becker and Ivashina (2015)).[1]

[1]Koijen and Yogo (2015) and Ellul et al. (2015) find that the RBC regulation interacted with accounting rules could bear unintended consequences. Koijen and Yogo (2015) show that life insurers may boost their regulatory capital positions in the short run through selling policies at deep discounts relative to actuarial value, making them susceptible to insolvency in the long run. Ellul et al. (2015)

In the context of corporate bonds, this paper explores how the RBC could influence life insurers' asset investment behavior at its very initiation in year 1993, and how RBC-induced distortion in insurers' investment practices could generate shifts in credit allocation. I develop empirical tests to assess how the RBC-driven shift in credit supply would affect price and quantity of credit, and furthermore, firms' real investment in the economy. The motivation to focus on the impact of the RBC regulation that governs life insurers' investment in corporate bonds is multifold. First, life insurance companies invest 40% of their financial assets in corporate and foreign bonds,[2] thereby rendering the treatment of corporate bonds the key element in the RBC calculation. Second, life insurers are the largest institutional holders of corporate and foreign bonds, with their holdings accounting for around 25% of the amounts outstanding.[3] Therefore, through its investment activities in corporate bonds, life insurance sector provides a vital source of funding to other sectors of the economy. Third, looking at the setting of the initial adoption of the RBC allows for sharper identification of how regulatory reform of insurance companies would have an impact on credit allocation, and ultimately, real investment in the economy.

To determine the capital requirements for insurers' bond holdings, the NAIC sorts bonds into six risk categories defined by bond credit ratings, with NAIC risk category 1 composed of bonds with the best ratings and category 6 the worst. There are two salient features of the RBC rule. First, the capital requirements increase sharply as one moves to a riskier category. Compared with category 1, bonds in category

record that insurers engage in "gains trading" where, to shore up their capital positions, insurers selectively dispose of otherwise unrelated assets with the largest unrealized gains, rather than the troubled assets. Ellul et al. (2011) find evidence that the RBC requirements force regulatory-constrained insurance companies to sell downgraded corporate bonds, inducing fire sales in the bond market. Becker and Ivashina (2015) find that the NAIC RBC's bond classes defined by broad categories of credit ratings lead insurance companies to "reach for yield", i.e., buying the riskier bonds within a bond class to achieve higher yields, in the corporate bond market.

[2]Refer to Table L.116 of the Federal Reserve Flow of Funds at https://www.federalreserve.gov/releases/z1/.

[3]Refer to Table L.213 of the Federal Reserve Flow of Funds at https://www.federalreserve.gov/releases/z1/.

2 are charged three times more, and category 6 a hundred times more. Second, the NAIC risk categories are loosely defined: Each category contains bonds with a wide range of credit ratings. In particular, bonds with ratings ranging from AAA to A- are all classified as category 1. While the first feature of the RBC rule limits risk-taking through deterring insurers from investing in worse-rated bonds in riskier categories, the second feature leaves insurers room to acquire riskier bonds to achieve higher yields within a given NAIC risk category, however, without being charged additional capital reserve.[4] Consequently, the impact of the RBC can manifest itself in insurers' increased relative demand for certain bonds. Using NAIC's data on insurers' corporate bond holdings that span the pre- and post-RBC period from 1991 to 1996,[5] I find that after the RBC reform, life insurers tilt their corporate bond portfolios towards A-rated bonds, which is the lowest tier of NAIC risk category 1. On top of that, the expanded holdings of A-rated bonds are more noticeable among insurers that are more constrained by the RBC regulation.

After documenting insurers' increased acquisition of A-rated corporate bonds following the RBC reform, I analyze the implication of the RBC-driven shift in insurers' bond demand on risk premiums. I treat the yield spreads of new bonds at issuance as the relevant risk premiums. There is evidence that the yield spreads on A-rated bonds experience a disproportionate drop after the RBC reform, compared with other risk tiers AAA and AA in NAIC risk category 1 as well as BBB in category 2. The result is consistent with insurers' enhanced demand for A-rated bonds due to the discontinuity of the RBC rule across risk categories and plentiful leeway for risk-taking within a given risk category. This finding suggests that the RBC could have an impact on credit pricing through insurers' distorted bond demand ascribable to RBC's flawed design of risk categories not sensitive enough to risk. A further implication is

[4]This is the "reaching for yield" behavior documented in Becker and Ivashina (2015).

[5]The NAIC's earliest available recording of insurance companies' bond holdings starts in year 1991.

that corporations who issue bonds that happen to barely meet the criterion for low capital charges would be able to raise funds at lower costs.

In the next set of tests, I examine the implication of the RBC-induced shift in insurers' bond demand on corporate debt issues of non-financial firms, employing a difference-in-difference empirical strategy. I propose to isolate the effect of the RBC reform on debt issuance by studying the differential post-RBC changes across not only firms' credit ratings but also their corresponding industries' varying degrees of dependence on life insurance company funding prior to the RBC reform. The industry-level measure of dependence on insurer financing is defined as the proportion of all outstanding bonds in each four-digit Standard Industrial Classification (SIC) code held by life insurers, averaged over the pre-reform period 1991 to 1992. The identification assumption central to this empirical approach is that A-rated firms in industries that are more reliant on insurer financing before the reform would respond more to the shift induced by the RBC reform in credit supply through increasing debt issuance. First, I find that A-rated firms in more insurer-dependent industries experience a relative increase in long-term debt compared to other investment-grade firms. Moreover, I don't observe a significant change in short-term debt. These findings confirm that RBC's impact operates through driving long-term borrowing, which is consistent with the fact that life insurers are long-term investors given their liability structure. Lastly, I repeat the above analysis, but separate firms into those facing stronger or weaker financial constraints on the basis of dividend payout ratio, operating cash flows, and size. I find that the post-reform increase in long-term debt is especially pronounced among the group of constrained firms. This last result suggests that the RBC relaxes financial constraints for firms that are ex-ante constrained.

In the final set of tests, I investigate the implication of the RBC reform for firms' investment and employment decisions. The results show a relative growth in investment and employment for A-rated firms in more insurer-dependent industries after the

reform. What's more, the growth in investment and employment is stronger among the group of firms facing more financial constraints. This observation is consonant with the above finding that ex-ante constrained firms benefit from the RBC reform in that they are able to raise debt issuance thanks to the shift in insurers' demand. Taken together, these findings illustrate a channel through which the regulatory reform on insurance companies can bear real consequences.

The remainder of this chapter is organized as follows. Section 2.2 discusses the details about the NAIC's RBC reform and the hypotheses regarding the reform's impacts. Section 2.3 presents the data. Section 2.4 reports changes in corporate bond holdings in insurance companies' portfolios after the reform. The effect of the reform on bond risk premium is reported in Section 2.5, whereas Section 2.6 examines the reform's impact on debt issuance. Section 2.7 evaluates the reform's real implication on firms' investment behavior. Section 2.8 concludes.

## 2.2 The NAIC's RBC reform and the hypotheses

Before the NAIC's RBC reform, the financial condition of an insurance company is evaluated by insurance regulators under the fixed capital standards. Without consideration of the risks embedded in an insurer's insurance products and investment portfolios, the fixed capital standards require an insurance company to maintain the same minimum amount of capital for retaining a business license. As insolvencies of insurance companies became more frequent and severe in the late 1980s and early 1990s, the fixed capital standards were no longer considered as effective in equipping the insurance industry with a safety net against insolvency. As a consequence, the NAIC responded by adopting a RBC system that includes two major components: (1) a RBC formula that generates the regulatory minimum capital requirement; and (2) a RBC model that gives regulators the authority to intervene in accordance with

the capital deficiency indicated by the RBC result. Approved by the NAIC in December 1992, the RBC rules came into effect in the 1993 annual statement filed in March 1994 (Webb and Lilly III, 1994).

In contrast with the fixed capital standards, the RBC formula determines the minimum capital requirement based on the risk profile of an insurance company. Companies with a higher level of risk are charged a greater amount of capital. The RBC formula takes into account four broad risk categories that insurance companies face: C-1 Asset risk, C-2 Insurance risk, C-3 Interest rate risk, and C-4 Business risk.[6] The total required RBC is then obtained by adding up the capital requirements for each risk category with a "square root rule" covariance calculation, thereby rewarding diversification across categories of risks.[7] Regulators use the RBC ratio, which is the minimum capital level established by the RBC formula divided by a company's actual capital level, to decide whether any regulatory action is in need.[8]

An insurance company's holdings of corporate bonds, which is the primary focus of this paper, fall under C-1 Asset risk. Since bonds are a major investment vehicle for insurers, insurance companies are required to hold enough capital to deal with the risk that bond issuers default on interest or principal payments. The capital requirements for bonds vary by the NAIC risk categories, which are determined by bond credit ratings. There are six NAIC risk categories (1 through 6). Bonds rated AAA/AA/A belong to category 1. Bonds rated BBB are in category 2. Junk bonds rated BB or below are subsequently put into categories 3 to 6. The capital requirements for each

[6]C-1 Asset risk arises from default (on bonds or mortgages) or market declines (of stocks). C-2 Insurance risk is associated with product mispricing. C-3 stems from mismatch between assets and liabilities. C-4 Business risk encompasses all other risks not captured in C-1, 2, or 3.

[7]Specifically, the formula for covariance adjustment is $C4 + \sqrt{(C1 + C3)^2 + C2^2}$.

[8]The higher the RBC ratio, the better capitalized an insurance company is. As the RBC ratio falls below 2, four levels of supervisory interventions can be triggered: company action, regulatory action, authorized control, and mandatory control. For details on what actions need to be taken by the insurer and the regulator in the event of a RBC intervention, please refer to https://www.naic.org/store/free/MDL-312.pdf.

risk category in year 1993, the first year in which the NAIC RBC system took effect, are listed in the Table 3.8.

Table 2.1: The NAIC RBC requirements for bonds

| NAIC risk category | Credit rating | Capital factor |
|---|---|---|
| U.S. Government Bonds | | 0.00% |
| NAIC 1: Highest Quality | AAA<br>AA+/AA/AA-<br>A+/A/A- | 0.30% |
| NAIC 2: High Quality | BBB+<br>BBB<br>BBB- | 1.00% |
| NAIC 3: Medium Quality | BB+<br>BB<br>BB- | 4.00% |
| NAIC 4: Low Quality | B+<br>B<br>B- | 9.00% |
| NAIC 5: Lower Quality | CCC+<br>CCC<br>CCC- | 20.00% |
| NAIC 6: In or Near Default | CC<br>Or Below | 30.00% |

Notes: This table lists the capital factors for each NAIC risk category. These factors are first used in the NAIC life risk-based capital report for year 1993. See Appendix H of Webb and Lily III (1994).

Two features can be observed from Table 3.8. First, as one moves to a riskier category, the capital requirements increase drastically. For each $100 invested, the capital charge for category 1 bonds is $0.3, whereas the capital charge for category 2 bonds triples to $1. The insurer that invests in bonds of category 6 would be charged $30, which is 100 times the capital requirement for category 1 bonds. Second, each NAIC risk category contains a wide credit rating range. Especially for category 1, bonds with credit rating ranging from AAA through A- are treated in the same way.

While the first feature of the RBC rule serves the purpose of restricting insurance companies from investing in bonds with worse credit ratings, the second feature could

allow insurers room for "reaching for yield", i.e., acquiring the riskiest bonds within a given category without being charged a higher capital reserve (Becker and Ivashina, 2015). With data on insurance companies' corporate bond holdings before and after the RBC reform, I am able to directly investigate whether the RBC reform induces insurers to take on additional risk, causing the relative demand for certain bonds to rise after the RBC reform. Exploiting the discontinuity of the RBC rule at the boundary between NAIC risk category 1 and 2 as well as the plentiful leeway for risk-taking within category 1, I examine, in particular, whether insurance companies hold more of the A-rated bonds after the RBC reform. As the lowest tier within category 1, bonds rated A could deliver higher yields than those rated AAA or AA, while subject to the same capital requirement. Increased purchase on the part of insurance companies may bear the following two empirical implications:

*Hypothesis 1*: As insurers' demand for A-rated bond would rise after the RBC reform, the risk premiums for A-rated bonds would decrease.

*Hypothesis 2*: Insurers' greater demand for A-rated bonds after the RBC reform would create a shift in supply of credit to individual firms. A-rated firms that are more dependent on life insurance company funding prior to the reform would respond more to the credit supply shock by increasing debt issuance.

## 2.3 Data

Data for the empirical tests in this paper are collected from several sources. First, insurance companies' transactions and holdings of corporate bonds are obtained from the NAIC Schedule D files. Part 1 of the Schedule D data provide information on insurers' year-end bond holdings, including bond identification, holding size, and other accounting items. Parts 3 to 5 include insurers' transaction records with transaction date, bond identification, trade size, price, direction, and counter-parties.

Second, data on bond characteristics are from Mergent Fixed Income Security Database (FISD). This data set contains bond-specific information such as bond identification, issue and maturity dates, issue size, yield to maturity at issue, and coupon rate and payment frequency. In addition, Mergent FISD records historical bond-level credit ratings issued by S&P, Moody's, or Fitch. I determine a bond's credit rating according to the following rule used by the NAIC.[9] When all three rating agencies rate a bond, I use the middle rating. If two agencies rate a bond, I use the lower rating. If only one agency rates a bond, that single rate is used.

Third, I rely on Lehman Brothers Fixed Income Database (LSFID) to construct the market portfolio composed of investment-grade corporate bonds that are in the Lehman Brothers Bond Index.[10]

The fourth source of data is the Compustat North America database. I use the Fundamentals Annual data to construct the measure for a firm's dependence on long-term debt and a set of firm-level control variables. I resort to S&P Ratings data for firm-level credit ratings.

Merging the NAIC Schedule D and Mergent FISD is straightforward: The merge can be done through bond CUSIP available in both data sets. However, combining Mergent FISD and Compustat can be tricky. Although both data sets have CUSIP as the firm identifier, linking through CUSIP would not be accurate. The problem is that while Mergent FISD keeps the historical firm CUSIP as is when the firm issues a bond, Compustat only keeps the most recent firm CUSIP if a firm changes its CUSIP due to corporate actions such as acquisitions. The permanent firm identifier in Compustat is GVKEY. One approach suggested by Wharton Research Data Services (WRDS) Knowledge Base is to use the historical link between CUSIP and GVKEY provided

[9]See p.21 of https://www.naic.org/documents/committees_e_rea_wg_related_showing_all_fe_text.pdf.

[10]The index in renamed as Barclays Capital Bond Index after Lehman Brothers filed for bankruptcy in September 2008.

in the S&P Ratings Xpress database.[11] The first step is to match the Mergent FISD issuer ID with the entity ID in S&P Ratings Xpress using CUSIP. Next, using the mapping between entity ID and GVKEY available in S&P Ratings Xpress, Mergent FISD can be combined with Compustat via GVKEY.

## 2.4 Changes in insurers' bond holdings after the RBC reform

As discussed in Section 2.2, because of the specific features embedded in the RBC rules, the impact of the RBC reform could manifest itself through prompting changes in insurance companies' investment behavior. In particular, the RBC system leaves insurers space to reach for yield, thereby boosting insurers' demand for A-rated bonds. A-rated bonds are in the lowest tier of NAIC risk category 1 and could render higher yields for the same amount of capital requirement. This section examines whether insurance companies indeed tilt their portfolios towards A-rated bonds following the RBC reform.

As aggregate evidence, I first compare the share of A-rated bonds in insurers' portfolios with that in the market portfolio. The graphs in Figure 2.1 trace the evolution of the difference in the share of A-rated bonds between insurers' portfolios and the market portfolio over the period from 1991 to 1996. These two time series of insurers' deviation from the market benchmark represent the extent to which insurance companies tilt towards A-rated bonds in their acquisitions of newly-issued bonds (the top graph) and in their bond holdings (the bottom graph). In the top graph of bond acquisitions by insurance companies when bonds are first issued in the primary market, the deviation measure stayed constant in 1991 and 1992 before the

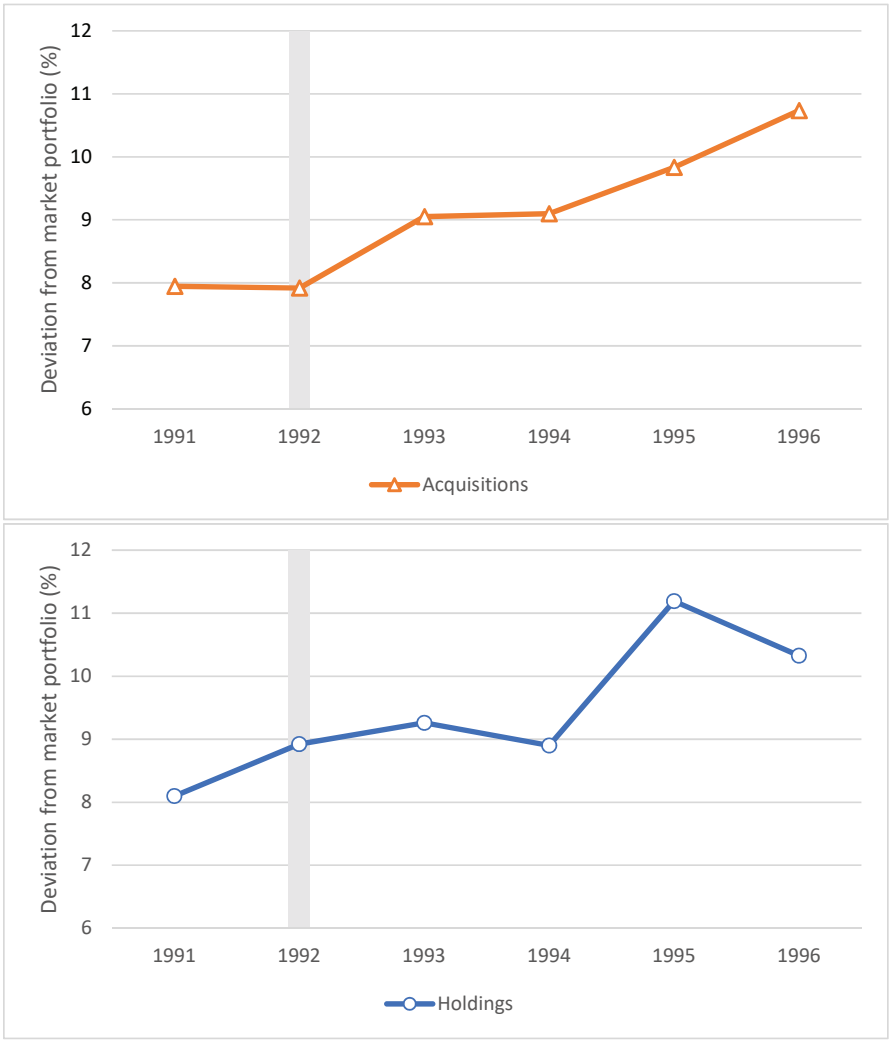
[11] Refer to the instructions from https://wrds-www.wharton.upenn.edu/pages/support/support-articles/mergent-fisd/linking-mergent-compustat-or-crsp/. WRDS log-on is needed.

RBC is implemented. As indicated by the climb in the deviation measure over the post-RBC period (1993 to 1996), insurers showed a tendency to put more weights on A-rated bonds in their investment choices at the time of bond issuance. A similar pattern is observed in the bottom graph of insurance companies' holdings of A-rated bonds in their portfolios. Altogether, Figure 2.1 provides suggestive evidence that the RBC reform induced a higher relative demand for A-rated bonds among insurance companies.

Table 2.2 offers a formal examination of the post-reform changes in insurance companies' bond portfolios. At the core of the empirical test in Table 2.2 is the assumption that insurers facing varying degrees of the RBC regulatory constraint have different amount of incentives to reach for yield following the RBC reform. I employ the A.M. Best's capital adequacy ratio (BCAR) as the measure of regulatory constraint. In the same spirit as the NAIC's RBC ratio, BCAR is the ratio of total adjusted capital to required risk-based capital, where both the available capital and the required capital are computed using A.M. Best's formula.[12] Insurance companies with higher BCAR are considered to be better capitalized. Due to the data limitation that BCAR becomes available only starting from year 1993, I can't have a precise measure of an insurer's pre-reform regulatory constraint. Instead, I use an insurer's average BCAR over the years 1993 to 1996 as a proxy for its level of regulatory constraint. Insurance companies are sorted into quintiles (Q1 to Q5) based on their average BCAR. Group Q1 consists of insurers that are the most constrained (i.e., with the lowest BCAR), whereas group Q5 consists of insurers that are the least constrained (i.e., with the highest BCAR). The dependent variable of column 1 in Table 2.2 is the proportion of A-rated bonds in an insurer's portfolio. The regression includes insurer and year fixed effects, a set of controls including insurer size (log of total bond value reported in Schedule D Part 1), portfolio duration (average bond

[12]See http://www.ambest.com/ratings/bcar_lh.pdf for details on how BCAR is calculated.

Figure 2.1: Deviation of share of A-rated bonds in insurers' portfolios from market portfolio




Notes: The top graph plots the difference in share of A-rated bonds between insurers' acquisitions and market portfolio. Insurers' share is calculated as follows. First, for each insurer, I calculate the proportion of A-rated bonds in its purchase of new investment-grade bonds issued in the current year. Next, I take the median proportion among all insurers as the insurers' share. The market share is the proportion of all new investment-grade bonds issued in the current year that have a credit rating of A. The bottom graph plots the difference in share of A-rated bonds between insurers' holdings and market portfolio. Insurers' share is computed as the fraction of total holdings of A-rated bonds divided by total holdings of investment-grade bonds summed over all insurers. The market portfolio consists of all investment-grade bonds outstanding in the Lehman Brothers Fixed Income Database (LBFID). Given that the earliest Schedule D data becomes available in 1991, both series span the pre-RBC period (1991 to 1992) and post-RBC period (1993 to 1996).

Table 2.2: Change in insurer' bond holdings following the RBC reform

| Dependent variable: | Share of A-rated bonds in holdings | | Share of A-rated newly-issued bonds in acquisitions | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| Post × BCAR Q1 | 2.10** | - | -0.47 | - |
| | [0.93] | - | [2.60] | - |
| Post × BCAR Q2 | 1.75** | - | 0.3 | - |
| | [0.83] | - | [2.47] | - |
| Post × BCAR Q3 | 0.42 | - | -3.16 | - |
| | [0.85] | - | [2.37] | - |
| Post × BCAR Q4 | 0.16 | - | -1.47 | - |
| | [0.95] | - | [2.86] | - |
| Post × A | - | -3.37** | - | -7.62* |
| | - | [1.49] | - | [4.24] |
| Post × B | - | -2.34 | - | -6.06 |
| | - | [1.47] | - | [4.24] |
| Insurer controls | Yes | Yes | Yes | Yes |
| Insurer FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| $N$ | 3161 | 2795 | 1772 | 1621 |
| $R^2$ | 0.94 | 0.94 | 0.83 | 0.83 |

Notes: This table reports results regarding post-RBC changes in insurers' bond portfolios. The sample period is from 1991 to 1996. The dependent variable in columns 1 and 2 is the share of A-rated bonds in an insurer's portfolio. The dependent variable in columns 3 and 4 is the share of A-rated bond as a percentage of an insurer's total purchases of new bonds issued within a given year. The independent variables include interaction terms of proxies for an insurer's regulatory constraints with the dummy variable *Post* that equals one starting from year 1993 and zero otherwise. In columns 1 and 2, the regulatory constraint is measured by an insurer's average BCAR over 1993 to 1996. Insurers are sorted into BCAR quintiles Q1 to Q5, where Q5 is the base group and include the least constrained insurers. In columns 3 and 4, the regulatory constraint is proxied by an insurer's FSR in 1992. Insurers are grouped into those with FSR above A, between A and B, and below B. The base group is the below B group which is financially weak. Additional controls include insurer size (log of total bond value reported in Schedule D Part 1), portfolio duration (average bond duration), portfolio rating (average bond rating). All regressions include insurer and year fixed effects. Standard errors reported in brackets are clustered at the insurer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

duration weighted by amount held), portfolio rating (average bond rating weighted by amount held),[13] as well as their interaction terms with the post-reform dummy (which equals one starting from year 1993, and zero otherwise). Standard errors are clustered at the insurer level.

The variables of interest are the interaction terms on the post-reform indicator and the BCAR quintiles. The result in column 1 of Table 2.2 indicates that the insurers that are more constrained by the RBC regulatory requirement have more incentive to reach for yield through shifting their portfolio towards A-rated bonds following the RBC reform. Compared to an insurer with BCAR in the top quintile (Q5), the share of A-rated bonds increases on average by an additional 2.10 percentage points for an insurer with BCAR in the lowest quintile (Q1), and 1.75 percentage points for an insurer with BCAR in the second lowest quintile (Q2).

Column 2 of Table 2.2 redoes the exercise in column 1 with an alternative measure for sorting insurance companies. The measure is A.M. Best's financial strength rating (FSR). First available in year 1992, A.M. Best's rating system provides an opinion of an insurer's financial strength and ability to meet its ongoing obligations to policyholders. The scale of FSR ranges from A++ to D, which corresponds to superior to poor financial strength.[14] Based on their pre-reform FSR in year 1992, insurance companies are grouped into those with FSR above A, between A and B, and below B. In column 2, I interact the post reform indicator with the FSR dummies. The result shows that the proportion of A-rated bonds decreases monotonically as the FSR increases. For an insurer with FSR above A, the share of A-rated bonds shrinks on average by another 3.37 percentage points compared to an insurer with FSR below B.

[13]Each letter rating is assigned to a number. Specifically, AAA corresponds to 1, AA+ corresponds to 2, ..., BBB corresponds to 9, and BBB- corresponds to 10.

[14]See http://www.ambest.com/ratings/guide.pdf for FSR category definitions.

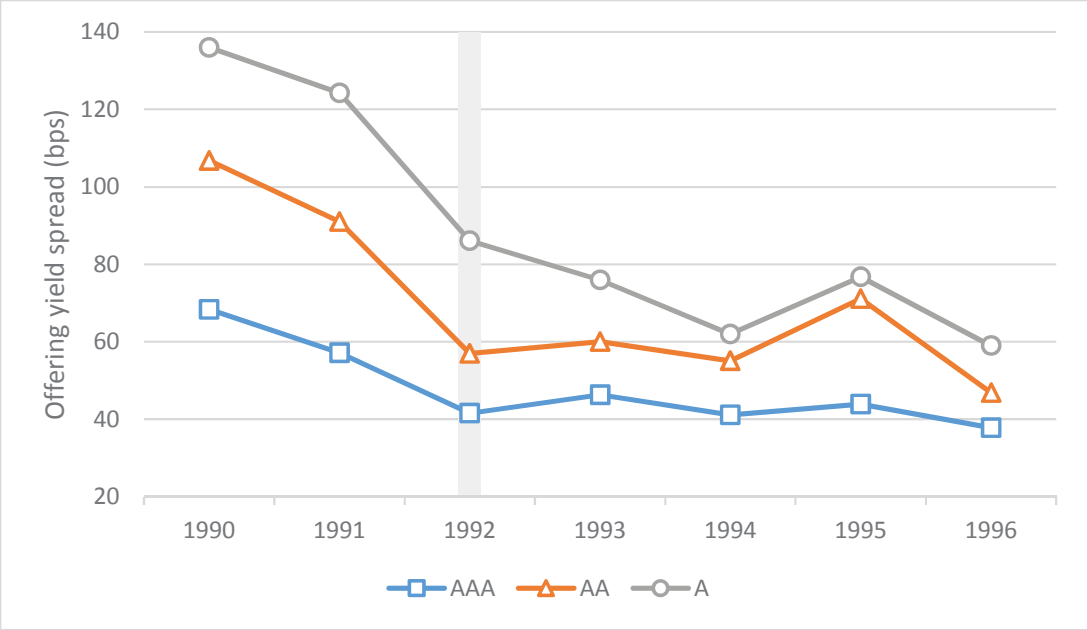
To focus on insurers' investment behavior in the primary market, in columns 3 and 4 of Table 2.2, I replace the dependent variable with the proportion of the newly-issued bonds acquired by an insurer that have a credit rating of A. I obtain significant results using FSR to sort insurers. Relative to an insurer with FSR below B, the share of A-rated bonds acquired by an insurer with FSR above A goes down on average by another 7.62 percentage point. Overall, the patterns in Table 2.2 confirm that the RBC reform is associated with insurers' reaching for yield behavior, which is manifested by insurers' increased demand for the riskiest bonds within a given NAIC risk category.

## 2.5 The impact of the RBC reform on bond yield

This section examines the impact of the RBC reform on risk premiums. Specifically, I test the hypothesis that RBC-driven shift in insurers' demand towards A-rated bonds documented in Section 2.4 would lower the risk premiums for A-rated bonds. I treat as the relevant risk premium the spread between a bond's offering yield to maturity (reported in FISD at the time of issuance) over the closest benchmark Treasury.

In Figure 2.2, I plot, respectively, the average offering yield spreads for newly issued bonds rated AAA, AA, and A in NAIC risk category 1 over the period from 1990 to 1996. Figure 2.2 provides visual evidence of the treatment effect of the RBC reform, which is consistent with insurers' increased demand for A-rated bonds. During the pre-RBC period (1990 to 1992), the yield spreads of the treatment group (bonds rated A) and control group (bonds rated AAA or AA) followed a parallel trend. However, over two years into the RBC regime (1993 to 1994), the yield spreads of A-rated bonds fell by 24 bps (from 86 to 62 bps), whereas the yield spreads of AAA and AA-rated bonds remained relatively flat.

Figure 2.2: Average offering yield spreads




Notes: This figure plots the average offering yield spreads for newly issued bonds rated AAA, AA, and A, respectively, in NAIC risk category 1. The spread is calculated as the difference between a bond's offering yield to maturity (reported in FISD at the time of issuance) over the closest benchmark Treasury. The series spans the pre-RBC period (1990 to 1992) and post-RBC period (1993 to 1996).

Table 2.3 formally tests RBC's impact on bond yields with difference-in-difference regressions. Each observation corresponds to an individual newly issued bond over the sample period from 1990 to 1996. The dependent variable is the log of a bond's yield spread at the time of issuance over the closest benchmark Treasury. The dummy variable *Post* is defined to be equal to one in years (1993 to 1996) after the RBC reform is initiated, and zero otherwise. In addition to bond credit rating dummies and their interaction terms with the reform dummy *Post*, I include a set of bond, issuer, and macroeconomic controls as in Campbell and Taksler (2003). The bond-level controls are log of issue size, years to maturity, and coupon rate. Time-varying issuer characteristics include financial health measures (pre-tax interest coverage and

operating income to sales) and leverage measures (long-term debt to assets and total debt to capitalization). These measures are constructed using Compustat data. Pre-tax interest coverage is calculated as [operating income after depreciation (Compustat item oiadp) + interest expense (item xint)] divided by interest expense (item xint). As in Blume et al. (1998), four dummies are created to control for skewness in the distribution of pre-tax interest coverage. The four dummies are set to indicate whether pretax interest coverage is below 5, between 5 and 10, between 10 and 20, or above 20, respectively. Operating income to sales is the ratio of operating income before depreciation (item oibdp) to net sales (item sale). Long-term debt to asset is computed as total long-term debt (item dltt) divided by total asset (item at). The formula for total debt to capitalization is [total long-term debt (item dltt) + debt in current liabilities (item dlc)] divided by [total liabilities (item lt) + market value of equity (item csho $\times$ item prcc_f)]. All firm characteristics data are one calendar year prior to the firm's new bond issuance year. Furthermore, to capture the economic conditions, I include the level (2-year Treasury rate) and slope (10-year minus 2-year Treasury rate) of the term structure, as well as the TED spread (3-month London Interbank Offer Rate (LIBOR) minus 3-month Treasury rate). To account for any time-invariant issuer characteristics and general macro trends in the data, I include issuer and year fixed effects. Standard errors are clustered at the issuer level.

In Column 1 of Table 2.3, the sample consists of bond issues in NAIC risk category 1. The coefficient of interest is on $Post \times A$, which is the interaction term of the dummy variable for the reform and the dummy variable for A-rated bonds. This interaction term captures the difference-in-difference effect on the yield spreads of A-rated bonds during the post-RBC era. The effect is statistically and economically significant. Consistent with the patterns depicted in Figure 2.2, the coefficient estimate implies that the yield spreads of A-rated bonds fell by an additional 34% relative to other bonds in category 1 (i.e., bonds rated AAA or AA). In Column 2, I switch the sample

Table 2.3: The impact of the RBC reform on bond yield spreads

| Dependent variable: | Yield spread | | | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| | NAIC 1 | NAIC 2 | NAIC 1 & BBB+ | NAIC 1 & 2 |
| Post × A | -0.34*** | - | -0.34*** | -0.21*** |
| | [0.10] | - | [0.09] | [0.07] |
| Post × BBB+ | - | - | -0.15 | - |
| | - | - | [0.11] | - |
| Post × BBB- | - | -0.17* | - | - |
| | - | [0.09] | - | - |
| Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| $N$ | 1802 | 737 | 2094 | 2566 |
| $R^2$ | 0.52 | 0.70 | 0.55 | 0.58 |

Notes: This table reports results regarding the RBC's impact on bond yield spreads of newly-issued investment-grade corporate bonds. The sample period is 1991 to 1996. The dependent variable is log yield spread between a bond's yield to maturity at the time of issuance over the closest benchmark Treasury. The independent variables are bond credit rating dummies and their interaction terms with the reform dummy *Post*, which equals one for years 1993 to 1996. The controls include bond-level, issuer-level, and macroeconomic variables. The bond-level controls are log of issue size, years to maturity, and coupon rate. Time-varying issuer characteristics (one calendar year prior to the issuer's new bond issuance year) include pre-tax interest coverage, operating income to sales, long-term debt to assets, and total debt to capitalization. Macroeconomic controls are the level (2-year Treasury rate) and slope (10-year minus 2-year Treasury rate) of the term structure, as well as the TED spread (3-month London Interbank Offer Rate (LIBOR) minus 3-month Treasury rate). All regressions include issuer and year fixed effects. Standard errors are clustered at the issuer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

to category 2 bonds and obtain qualitatively similar results as Column 1. Within category 2, bonds with the lowest rating (i.e., BBB-) experience an extra drop of 17%, compared with BBB+ or BBB bonds, as indicated by the significant coefficient estimate of $Post \times BBB-$, which is the interaction term of the dummy variable for the reform and the dummy variable for bonds rated BBB-. Column 3 looks at the sample consisting of bonds in category 1 as well as bonds rated BBB+. The specification in Column 3 exploits the discontinuity of the RBC rule at the boundary between two NAIC risk categories. Notice from Table 3.8 that the capital requirement on category 2 is over three times the category 1 requirement. Of particular interest is the difference in the coefficients on the interaction terms $Post \times A$ and $Post \times BBB+$. A Wald-test gives an F-statistics of 5.09, rejecting the null that the coefficients on $Post \times A$ and $Post \times BBB+$ are equal. Column 4 extends the sample to both category 1 and 2 bonds. The result shows that the yield spreads of A-rated bonds shrink by a greater amount (21% more) than all other investment-grade bonds.

Overall, the drop in yield spreads of A-rated bonds are consistent with insurers' boosted demand for A-rated bonds due to the sharp discontinuous increase in capital charges across NAIC risk categories and the loosely defined risk category covering a wide range of bond ratings. The results in Table 2.3 provide supporting evidence that the RBC could have an impact on credit pricing through insurers' distorted bond demand ascribable to the RBC's flawed design of risk categories not sensitive enough to risk. A further implication is that corporations who issue bonds that barely fit the criterion for low capital charges would be able to raise funds at lower costs.

## 2.6 The impact of the RBC reform on debt issuance

This section focuses on the impact of the RBC reform on debt issuance. To isolate RBC's effect, I apply a difference-in-difference estimation approach that studies differential post-RBC changes in debt issuance across not only firms' credit ratings but also their corresponding industries' varying degrees of dependence on insurance company funding prior to the RBC reform. Using the pre-reform dependence on insurer funding as an additional dimension of treatment intensity is inspired by Bertrand, Schoar, and Thesmar (2007), who study the impacts of the French banking reforms in the 1980. They construct an industry-level measure of banking dependence in the pre-reform period as a proxy for relative exposure to the banking reform.[15]

As the RBC reform induces a higher relative demand for A-rated debt among insurance companies, the identification assumption for the empirical approach is that A-rated firms which are more reliant on insurance company funding prior to the RBC reform would respond more to the shift in credit supply through increasing debt issuance. The major goal of this section is to provide direct evidence for this identification assumption that relies on firms' differing exposure to the RBC reform.

The measure of pre-reform dependence on insurance company funding is constructed at the industry level. Using data from the NAIC Schedule D and LBFID, the extent to which an industry relies on insurance company funding is defined as the fraction of total outstanding bonds that are held by all life insurance companies in each four-digit SIC averaged over the pre-reform years 1991 to 1992. Firm-level credit rating, debt issue, and accounting variables are extracted from Compustat. I use S&P's domestic long-term issuer credit rating (Compustat item splticrm) to categorize firms. This rating reflects a forward-looking opinion of an obligor's overall

[15] Another paper that constructs the treatment intensity variable with a similar taste is Hombert et al. (2020), who study the impact of the reform of French unemployment benefits.

creditworthiness.[16] As in Chaney et al. (2012), a firm's net change in long-term debt is computed as the yearly difference in long-term debt (item dltt) normalized by past year's property, plant, and equipment (PPE, item ppent). Net change in short-term debt is calculated as the yearly difference in debt in current liabilities (item dlc) scaled by lagged PPE (item ppent). I include additional firm-level accounting variables commonly used in the empirical studies on debt issuance (e.g., Badoer and James 2016, Chaney et al. 2012, and Leary and Roberts 2005). Specifically, these controls cover firm size, profitability, financial health, leverage, asset tangibility, and investment opportunity. Firm size is log of total assets (item at). Profitability is captured by return on assets, calculated as the ratio of operating income before depreciation (item oibdp) to assets (item at). Financial health is measured by pretax interest coverage dummies (defined in Section 2.5) and the ratio of cash flows (item dp + item ib) to assets (item at). Same as in Section 2.5, I use long-term debt to assets and total debt to capitalization as measures of leverage. Asset tangibility is computed as the ratio of PPE (item ppent) to assets (item at). Investment opportunity is measured by the ratio of book equity (common equity (item ceq) + deferred taxes and investment tax credit (item txditc)) to market equity (item prc_f×item csho). Similar to Chaney et al. (2012), some of the above accounting ratios, including the ratio of fixed assets, the ratio of cash flows to assets, and the book-to-market ratio, are included as time-varying state variables in the debt issuance regression. The rest of the accounting variables are added to the regression as initial firm controls interacted with the post-reform dummy, where the initial firm characteristics are the average values over years 1970 to 1990.

[16]For details on S&P's issuer credit ratings, refer to https://www.standardandpoors.com/en_US/web/guest/article/-/view/sourceId/504352.

### 2.6.1 Main results

Table 2.4 reports the results on the post-RBC changes in debt issuance for investment-grade firms across credit rating and differing degrees of reliance on insurance company funding. Each observation in sample corresponds to one firm and year over the period from 1991 to 1996. Following prior literature on capital structure, I exclude financial firms (with SIC codes 6000-6999). While columns 3 and 5 focus on investment-grade firms rated A or higher, columns 1, 2 and 4 extend the sample to all investment-grade firms with credit ratings spanning from AAA to BBB. All regressions include initial and time-varying firm-level characteristics as controls, as well as firm and year fixed effects. Standard errors are clustered at the firm level.

Column 1 of Table 2.4 starts with a simple estimation of the change in long-term debt with $Post \times A$, which is the double interaction term between the post-RBC dummy (which equals one for years 1993 to 1996, and zero otherwise) and the dummy for A-rated firm (which equals one for firms with credit rating of A, and zero otherwise). The result in column 1 reveals no significant difference in post-reform change in long-term debt between firms with a credit rating of A and firms in other credit rating tiers within the investment-grade category. However, this simple specification could mask a relative increase in long-term debt of A-rated firms that are the most exposed to the RBC reform, i.e., A-rated firms in industries that are more reliant on insurance company funding; and the relative decrease in long-term debt of A-rated firms that are least exposed to the reform. Therefore, to allow for differential effects, I add to column 2 the triple interaction term of the post-RBC dummy, the dummy for A-rated firm, and the firm's pre-RBC level of dependence on insurance company funding ($Post \times A \times InsurerDep$). The coefficient on the variable of interest in column 2, $Post \times A \times InsurerDep$, is positive and significant. This indicates a relative post-reform increase in long-term debt among A-rated firms in industries that are more reliant on insurance company funding. In economic terms, long-term

Table 2.4: The impact of the RBC reform on debt growth

| Dependent variable: | Change in long-term debt | | | Change in short-term debt | |
|---|---|---|---|---|---|
| | AAA/AA/A & BBB | | AAA/AA/A | AAA/AA/A & BBB | AAA/AA/A |
| | [1] | [2] | [3] | [4] | [5] |
| Post × A | -0.02 | -0.12** | -0.19** | 0.06 | 0.06 |
| | [0.02] | [0.06] | [0.09] | [0.06] | [0.07] |
| Post × A × InsurerDep | - | 0.28* | 0.38* | -0.17 | -0.16 |
| | - | [0.15] | [0.21] | [0.13] | [0.19] |
| Post × InsurerDep | - | -0.07 | -0.13 | 0.19 | 0.17 |
| | - | [0.10] | [0.19] | [0.12] | [0.20] |
| Initial controls × Post | Yes | Yes | Yes | Yes | Yes |
| Time-varying controls | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| $N$ | 2521 | 2521 | 1654 | 2521 | 1654 |
| $R^2$ | 0.29 | 0.29 | 0.19 | 0.09 | 0.13 |

Notes: This table reports results regarding the RBC's impact on bond issuance of investment-grade corporate firms. The sample period is 1991 to 1996. The dependent variable of columns 1 to 3 is the net change in long-term debt. The dependent variable of columns 4 and 5 is the net change in short-term term. *Post* is a dummy equal to one for years 1993 to 1996, and zero otherwise. *A* is a dummy equal to one for firms with credit rating of A, and zero otherwise. *InsurerDep* is the fraction of total outstanding bonds that are held by all life insurance companies by industry averaged over the pre-reform years 1991 to 1992. All regressions control for firm initial characteristics (firm size, return on assets, pre-tax interest coverage, long-term debt to assets, total debt to capitalization) interacted with the *Post* dummy, as well as time-varying firm characteristics (ratio of fixed assets, ratio of cash flow to assets, and book-to-market ratio). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

debt goes up by a relative 5% for a firm in an industry that is at the 75th percentile of the pre-reform dependence on insurance company funding compared to a firm in an industry that is at the 25th percentile.[17] Column 4 uses the same independent variables as column 2, but replaces the dependent variable with the change in short-term debt. As indicated by the statistically insignificant coefficients on the double interaction term $Post \times A$ and the triple interaction term $Post \times A \times InsurerDep$ in column 4, I don't find any significant change in short-term debt for A-rated firms after the reform. Furthermore, there is no significant indication of differential post-reform changes in short-term debt among A-rated firms in the more insurer-dependent industries. The findings in column 2 and 4 suggest that the impact of the RBC reform operates through driving long-term borrowing, which is consistent with the fact that life insurance companies invest in long-term assets to meet their long-term liabilities. I obtain qualitatively similar results when focusing on the subsample of firms rated A or higher: There exists differential growth in long-term debt among A-rated firms based on their industries' pre-reform dependence on insurance company funding (column 3); and there is no significant impact on short-term debt (column 5).

### 2.6.2 Heterogeneous effects: Ex-ante financial constraints

In this subsection, I further examine whether the post-reform change in long-term debt would be different for firms facing various extent of financial constraint. To investigate the role of financial constraint in shaping a firm's debt issuance response to the RBC reform, I first sort firms into two groups: one with more constrained firms, and the other with less constrained firms. Then, I re-estimate the specification in column 2 of Table 2.4 separately for the more constrained group and less constrained group.

[17] Pre-reform insurance company funding dependence is 0.43 at the 75th percentile, and 0.26 at the 25th percentile. The relative increase of 5% is obtained from $(0.43 - 0.26) \times 0.28$.

Table 2.5: The impact of the RBC reform on debt growth: by ex-ante financial constraints

| Dependent variable: | Change in long-term debt | | | | | |
|---|---|---|---|---|---|---|
| | Payout policy | | Cash flow | | Firm size | |
| | constrained | unconstrained | constrained | unconstrained | constrained | unconstrained |
| | [1] | [2] | [3] | [4] | [5] | [6] |
| Post × A | -0.21*** | 0.02 | -0.17** | 0.01 | -0.06 | -0.19* |
| | [0.07] | [0.08] | [0.07] | [0.10] | [0.07] | [0.11] |
| Post × A × InsurerDep | 0.49** | -0.09 | 0.39** | -0.04 | 0.17 | 0.43 |
| | [0.20] | [0.19] | [0.19] | [0.23] | [0.16] | [0.28] |
| Post × InsurerDep | -0.11 | -0.04 | -0.07 | -0.1 | -0.15 | 0.02 |
| | [0.13] | [0.09] | [0.12] | [0.14] | [0.11] | [0.18] |
| Initial controls × Post | Yes | Yes | Yes | Yes | Yes | Yes |
| Time varying controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| $N$ | 1377 | 1144 | 1393 | 1122 | 1316 | 1205 |
| $R^2$ | 0.32 | 0.16 | 0.31 | 0.2 | 0.34 | 0.19 |

Notes: This table reports results regarding the RBC's impact on bond issuance of investment-grade corporate firms for constrained and unconstrained firms. Three measures of financial constraints are used: dividend payout ratio (columns 1 and 2), ratio of cash flow to sales (columns 3 and 4), and firm size (columns 5 and 6). Firms with the constraint measure below (above) the median are classified as facing more (less) constraints. The sample period is 1991 to 1996. The dependent variable is the net change in long-term debt. *Post* is a dummy equal to one for years 1993 to 1996, and zero otherwise. *A* is a dummy equal to one for firms with credit rating of A, and zero otherwise. *InsurerDep* is the fraction of total outstanding bonds that are held by all life insurance companies by industry averaged over the pre-reform years 1991 to 1992. All regressions include firm initial characteristics (firm size, return on assets, pre-tax interest coverage, long-term debt to assets, total debt to capitalization) interacted with the *Post* dummy, and time-varying firm characteristics (ratio of fixed assets, ratio of cash flow to assets, and book-to-market ratio). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

Firms are grouped on the basis of three different measures of financial constraint used in Agrawal and Matsa (2013). I begin with dividing the sample of firms using their dividend payout ratio, which is computed as dividends (Compustat item dvc) divided by income before extraordinary items (item ibadj). Firms that keep more earnings (i.e., whose payout ratio is low) are considered to encounter greater financial constraint (Fazzari, Hubbard, and Petersen, 1988; Kaplan and Zingales, 1997). I also classify the firms based on their ratio of cash flow (item dp + item ib) to sales (item sale). A lower cash flow margin implies a higher level of financial constraint (Kaplan and Zingales, 1997). The third measure of credit constraint is firm size, which is proxied by sales (item sale). Smaller firms are thought to be more financially constrained (Hadlock and Pierce, 2010). I take the historical average of each measure over the period 1970 to 1990 as the ex-ante level of financial constraint. Firms with the constraint measure below (above) the median are classified as facing more (less) constraints.

As shown in Table 2.5, for two out of the three measures of financial constraint (i.e., dividend payout ratio and cash to sales ratio), there exists heterogeneity in the post-reform change in long-term debt between the two groups of more constrained firms and less constrained firms. The estimated coefficient on the triple interaction term $Post \times A \times InsurerDep$ remains positive and significant only for the group of constrained firms. For instance, in column 1, within the group of firms whose dividend payout ratio is below the median, an A-rated firm in an industry that is at the 75th percentile of the pre-reform insurance company dependence distribution observe a relative increase of 8% in long-term debt compared with an A-rated firm in an industry that is at the 25th percentile.[18] Hence, the findings in Table 2.5 indicate that the RBC reform induces a more pronounced change in long-term debt among firms with greater financial constraint, but has an insignificant impact on less

[18]Pre-reform insurance company funding dependence is 0.43 at the 75th percentile, and 0.26 at the 25th percentile. The relative increase of 8% is obtained from $(0.43 - 0.26) \times 0.49$.

constrained firms. In other words, there is evidence that the RBC reform relaxes financial constraints for firms that are ex-ante constrained.

### 2.6.3 Alternative treatment intensity variable

So far, I have used the pre-reform dependence on insurance company funding aggregated at the industry level as the baseline treatment intensity variable. Due to the data limitation that the NAIC Schedule D becomes available only from year 1991 onward, one might be worried that this variable could be somewhat loose or endogenous to the reform, as it is constructed using only two years of data immediately preceding the reform. To address this concern, I conduct the analysis employing an alternative variable to measure the strength of exposure to the RBC reform, which can be constructed based on data over a longer pre-reform period. This alternative definition of treatment intensity is the degree to which a firm relies on long-term debt prior to the reform.

The rationale for using long-term debt dependence to assess the intensity of exposure to the RBC reform is that life insurance companies, the largest participants in the corporate bond market, tend to invest heavily in long-term fixed income securities.[19] This is due to life insurers' need to align assets with their long-term insurance products (e.g., life insurance and annuities), which customers will make claims on or withdrawals from in the future. With this alternative variable for treatment intensity, the underlying identification assumption is that A-rated firms that are more reliant on long-term debt prior to the reform should be "more treated" by the shift in the supply of credit brought about by insurers' changed investment behavior after the RBC reform.

Similar to Foley-Fisher et al. (2016), the extent to which a firm relies on long-term debt is computed as the ratio of long-term debt (Compustat item dltt) to total

[19] According to Berends et al. (2013), life insurance industry's aggregate bond portfolio has an average maturity of 10.2 years.

debt, which is the sum of long-term debt and debt in current liabilities (item dltt + item dlc). To account for any endogenous movement due to the RBC reform, the long-term debt dependence ratio, denoted as $LtDep$, is averaged over the pre-RBC years 1970 to 1990.

In columns 1 and 2 of Table 2.6, I replicate the analysis of post-reform change in long-term debt in columns 1 and 2 of Table 2.4, respectively, using the firm-level dependence on long-term debt as the treatment intensity variable. I find qualitatively similar results as in Table 2.4. The double interaction $Post \times A$ alone in column 1 of Table 2.6 is quantitatively small and statistically insignificant, indicating that there is no significant more change in long-term debt, on average, for A-rated firms after the reform. Column 2 of Table 2.6 allows for differential effects based on a firm's pre-reform dependence on long-term debt. The positive and significant estimated coefficient on the triple interaction term $Post \times A \times LtDep$ confirms a relative post-reform increase in long-term debt among A-rated firms that are more dependent on long-term debt.

Using the pre-reform long-term debt dependence to measure the treatment intensity may raise one concern which has to do with the fact that during post-RBC period, the government issued less long-term debt. This could lead to an alternative interpretation that the more pronounced relative increase in long-term debt among A-rated firms that are more reliant on long-term debt may signal the gap-filling behavior in corporate borrowing. That is, when the government issues less long-term debt, firms respond by tilting their debt issuance toward long-term debt (Greenwood et al. 2010; Badoer and James 2016). To address this source of concern, I control for the supply of long-term government debt, which is measured by the fraction of U.S. Treasury debt with a maturity of more than one year. I obtain the annual time series of long-term government share from the Internet Appendix of Greenwood et

Table 2.6: The impact of the RBC reform on debt growth: alternative treatment intensity variable

| Dependent variable: | Change in long-term debt | | |
|---|---|---|---|
| | [1] | [2] | [3] |
| Post × A | -0.04 | -0.42* | -0.67*** |
| | [0.03] | [0.22] | [0.25] |
| Post × A × LtDep | - | 0.45* | 0.70** |
| | - | [0.24] | [0.28] |
| Post × LtDep | - | -0.32* | -0.59*** |
| | - | [0.17] | [0.22] |
| GovShare × A | - | - | -0.07 |
| | - | - | [0.05] |
| GovShare × A × LtDep | - | - | 0.08 |
| | - | - | [0.05] |
| GovShare × LtDep | - | - | -0.08** |
| | - | - | [0.04] |
| Initial firm controls × Post | Yes | Yes | Yes |
| Time-varying firm controls | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| $N$ | 2777 | 2777 | 2777 |
| $R^2$ | 0.3 | 0.3 | 0.3 |

Notes: This table reports results regarding the RBC's impact on bond issuance of investment-grade corporate firms, using an alternative treatment variable. The sample period is 1991 to 1996. The dependent variable is the net change in long-term debt. *Post* is a dummy equal to one for years 1993 to 1996, and zero otherwise. *A* is a dummy equal to one for firms with credit rating of A, and zero otherwise. *LtDep* is a firm's ratio of long-term debt to total debt, averaged over the pre-RBC years 1970 to 1990. *GovShare* is the fraction of U.S. Treasury debt with a maturity of more than one year. All regressions control for firm initial characteristics (firm size, return on assets, pre-tax interest coverage, long-term debt to assets, total debt to capitalization) interacted with the *Post* dummy, as well as time-varying firm characteristics (ratio of fixed assets, ratio of cash flow to assets, and book-to-market ratio). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

al. (2010).[20] Column 3 of Table 2.6 shows that the results are robust to inclusion of additional interaction terms involving the government share, since the estimated coefficient on the triple interaction term $Post \times A \times LtDep$ remains positive and significant.

## 2.7 The real effects of the RBC reform

The analysis in the previous sections has established that through shifting insurers' demand, the RBC reform have affected the cost and allocation of credit. In this section, I further investigate whether the RBC reform could carry real effects in the economy. In particular, I study whether the relaxation in outside financing after the RBC reform has allowed the reform's most "treated" group, i.e., A-rated firms in industries that rely more heavily on insurance company funding before the reform, to engage in more investment activities.

Table 2.7 examines firm-level decisions. The variables I choose for firm decisions are capital expenditure, employment, cash holdings, and dividends and stock repurchases. Choice of these variables follows Foley-Fisher et al. (2016), who consider these four dimensions of firm decisions to study firms' response to the lower borrowing costs and increased credit availability brought about by the unconventional monetary policy after the 2008 financial crisis. On one hand, more capital expenditures and employees would support the hypothesis that firms take advantage of the increased availability of outside financing to expand investment and employment. On the other hand, more cash holdings or dividends and share buybacks would suggest firms' precautionary motives when good investment opportunities are absent. Con-

[20] To construct this time series, Greenwood et al. (2010) decompose the stream of each outstanding Treasury issue's cash flows into a series of principal and coupon payments, using detailed bond information provided in CRSP U.S. Treasury Database. Every month, after adjusting for changes in the face value outstanding owing to repurchases or reopenings of an existing issue, payments due in upcoming $n$ periods, are are aggregated across all outstanding issues. The long-term government share is computed as payments due in more than one year, divided by payments due in all future periods.

forming with the analysis in the previous section, the identification strategy relies on studying differential post-reform changes across firm credit ratings and industries with various pre-reform levels of dependence on insurance company funding. I use the same set of controls as employed in Section 2.6. These controls include time-varying state variables, as well as the initial firm characteristics interacted with the post-reform indicator. All regressions in this table include firm and year fixed effects. Standard errors are clustered at the firm level.

Columns 1 and 2 of Table 2.7 report results for capital expenditure and employment, where capital expenditure and employment are measured in log growth rates of PPE (Compustat item ppent) and employees (item emp), respectively. I find that the expansion in employment is faster after the reform among A-rated firms that are more insurer-dependent. As indicated by the coefficient on the triple interaction term $Post \times A \times InsurerDep$ in column 2, employment growth is up by about 3% on average among A-rated firms in industries at the 75th percentile of the pre-reform insurer funding dependence distribution compared to industries at the 25th percentile.[21] There seems no significant change in PPE growth in column 1. I will show in the next table that there is heterogeneity in the response of employment between the two groups of firms that are ex-ante constrained and unconstrained. The dependent variables in columns 3 and 4 are the log growth rates of cash holdings (item che) and dividends and stock repurchases (item dvt + item prstkc - item pstkrv), respectively. There is no indication that A-rated firms that are more insurer-dependent raise their cash holdings or increase their dividends or stock repurchases.

The specifications in Table 2.8 are the same as those in Table 2.7, but applied separately to two groups of firms: one with firms that face greater financial constraint (below median dividend payout), and the other with firms that face weaker financial

[21] Pre-reform insurance company funding dependence is 0.43 at the 75th percentile, and 0.26 at the 25th percentile. The relative increase of 3% is obtained from $(0.43 - 0.26) \times 0.19$.

Table 2.7: The real effects of the RBC reform

| Dependent variable: | PPE | Employees | Cash holdings | Dividends |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| Post × A | -0.04 | -0.07** | 0.08 | -0.24 |
| | [0.03] | [0.03] | [0.20] | [0.16] |
| Post × A × InsurerDep | 0.04 | 0.19** | -0.14 | 0.52 |
| | [0.08] | [0.08] | [0.50] | [0.44] |
| Post × InsurerDep | 0.02 | -0.05 | -0.42 | -0.44 |
| | [0.07] | [0.05] | [0.30] | [0.36] |
| Initial controls × Post | Yes | Yes | Yes | Yes |
| Time-varying controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| N | 2606 | 2558 | 2590 | 1734 |
| $R$ | 0.44 | 0.42 | 0.1 | 0.18 |

Notes: This table reports results regarding the RBC's real effects on investment-grade firms' decisions. The sample period is 1991 to 1996. The dependent variables are log growth rates of PPE (column1), employees (column2), cash holdings (column3), and dividends and stock repurchases (column4). *Post* is a dummy equal to one for years 1993 to 1996, and zero otherwise. $A$ is a dummy equal to one for firms with credit rating of A, and zero otherwise. $InsurerDep$ is the fraction of total outstanding bonds that are held by all life insurance companies by industry averaged over the pre-reform years 1991 to 1992. All regressions control for firm initial characteristics (firm size, return on assets, pre-tax interest coverage, long-term debt to assets, total debt to capitalization) interacted with the *Post* dummy, as well as time-varying firm characteristics (ratio of fixed assets, ratio of cash flow to assets, and book-to-market ratio). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

Table 2.8: The real effects of the RBC reform: by ex-ante financial constraints

| Panel A: Constrained firms | | | | |
|---|---|---|---|---|
| Dependent variable | PPE | Employee | Cash holdings | Dividends |
| | [1] | [3] | [5] | [7] |
| Post × A | -0.10** | -0.07** | 0.28 | -0.02 |
| | [0.04] | [0.03] | [0.27] | [0.23] |
| Post × A × InsurerDep | 0.22** | 0.23** | -0.98 | 0.13 |
| | [0.10] | [0.11] | [0.63] | [0.69] |
| Post × InsurerDep | -0.10 | -0.08 | 0.03 | -0.49 |
| | [0.08] | [0.07] | [0.40] | [0.52] |
| $N$ | 1178 | 1241 | 1254 | 889 |
| $R^2$ | 0.52 | 0.5 | 0.18 | 0.25 |
| Panel B: Unconstrained firms | | | | |
| Dependent variable | PPE | Employee | Cash holdings | Dividends |
| | [2] | [4] | [6] | [8] |
| Post × A | -0.04 | -0.04 | 0.03 | -0.21 |
| | [0.04] | [0.07] | [0.48] | [0.19] |
| Post × A × InsurerDep | 0.00 | 0.08 | 0.05 | 0.53 |
| | [0.09] | [0.17] | [1.14] | [0.50] |
| Post × InsurerDep | 0.08 | -0.01 | -0.93 | 0.23 |
| | [0.07] | [0.10] | [0.75] | [0.33] |
| $N$ | 1404 | 990 | 1002 | 622 |
| $R^2$ | 0.46 | 0.43 | 0.17 | 0.25 |
| Initial controls × Post | Yes | Yes | Yes | Yes |
| Time-varying controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

Notes: This table reports results of the RBC's real effects on investment-grade firms' decisions for constrained and unconstrained firms. The measure of financial constraint is dividend payout ratio. Firms with constraint measure below (above) the median are classified as facing more (less) constraints. The sample period is 1991 to 1996. The dependent variables are log growth rates of PPE (column1), employees (column2), cash holdings (column3), and dividends and stock repurchases (column4). Dummy variable *Post* equals one for years 1993 to 1996. Dummy variable $A$ equals one for firms rated A. $InsurerDep$ is the fraction of total outstanding bonds that are held by all life insurers by industry averaged over the pre-reform years 1991 to 1992. All regressions include firm initial characteristics (firm size, return on assets, pre-tax interest coverage, long-term debt to assets, total debt to capitalization) interacted with the *Post* dummy, and time-varying firm characteristics (ratio of fixed assets, ratio of cash flow to assets, and book-to-market ratio). All regressions include firm and year fixed effects. Standard errors are clustered at the firm level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

constraint (above median dividend payout.[22] Panel A focuses on more constrained firms, while panel B focuses on less constrained firms. The results in columns 1 to 4 suggest that there is heterogeneity in the response of investment and employment to the RBC reform across the two groups of constrained and unconstrained firms. As indicated by the positive and significant coefficient on the triple interaction term $Post \times A \times InsurerDep$ in columns 1 and 3, within the group of constrained firms, those with credit rating A and heavier pre-reform dependence on insurance funding experience relatively faster growth in PPE and employees. On average, PPE and employees growths both go up by about 4 percentage points for A-rated firms in industries at the 75th percentile of the pre-reform insurer funding dependence distribution compared to industries at the 25th percentile.[23] These are the same set of firms, documented in Section 2.6.2 that experience a relative increase in long-term debt. Collectively, the findings indicate that the relaxed access to outside financing after the RBC reform has allowed the most "treated" group of firms to raise debt issues and finance additional investment and employment.

## 2.8 Conclusion

In this chapter, I study the economic consequences of the NAIC RBC reform in the insurance industry after 1993. The focus is on the RBC regulation that imposes capital requirements on life insurers' investment in corporate bonds, where the amount of capital charges is tied to NAIC risk categories defined by bond credit ratings. There are two salient features associated with the RBC rule: (1) the sharp increase in capital requirements across risk categories, and (2) the broad range of bond ratings within a risk category. Using the NAIC data on insurers' corporate bond holdings, I first

[22] I also repeat the tests using other group assignment criteria used in Section 2.6.2 that are based on firm cash flows or size. The results are qualitatively similar.

[23] Pre-reform insurance company funding dependence is 0.43 at the 75th percentile, and 0.26 at the 25th percentile. The relative increase of 4% in PPE (employment) growth is obtained from $(0.43 - 0.26) \times 0.22$ ($(0.43 - 0.26) \times 0.23$).

document changes in insurers' bond investment practices attributable to the above two features of the RBC rule. In particular, I find that, after the RBC reform, life insurers tilt their corporate bond portfolios towards A-rated bonds, which is the lowest tier of NAIC risk category 1. Next, I observe that the yield spreads on A-rated bonds experience a disproportionate drop after the RBC reform. Employing a difference-in-difference design where the treatment intensity is measured by firm rating and firms' pre-reform dependence on insurers' funding, I also observe a relative increase in long-term debt issuance among A-rated firms in more insurer-dependent industries. These findings suggest that through inducing a shift in insurers' bond demand, the RBC reform affects the supply of credit to individual firms in the economy. Last, I show that the increase in availability of outside financing driven by the RBC reform has benefited the group of A-rated firms in insurer-dependent industries, in that these firms are able to take advantage of the credit supply conditions through increasing investment and employment. In sum, this chapter demonstrates a mechanism through which regulatory reform on insurance companies can affect credit allocation and ultimately, real investment in the economy.

# References

Agrawal, K. Anshiwini and David A. Matsa. 2013. "Labor Unemployment Risk and Corporate Financing Decisions." *Journal of Financial Economics*, 108: 449–470.

Badoer, Dominique C. and Christopher M. James. 2016."The Determinants of Long-Term Corporate Debt Issuances" *Journal of Finance*, 71(1): 457–492.

Becker, Bo and Victoria Ivashina. 2015. "Reaching for Yield in the Bond Market." *Journal of Finance*, 70(5): 1863–1902.

Berends, Kyal, Robert McMenamin, Thanases Plestis, and Richard J. Rosen. 2013. "The Sensitivity of Life Insurance Firms to Interest Rate Changes." *Economic Perspectives*, 37(2): 47–78.

Bertrand, Marianne, Antoinette Schoar, and David Thesmar. 2007. "Banking Deregulation and Industry Structure: Evidence from the French Banking Reforms of 1985." *Journal of Finance*, 62(2): 597–628.

Blume, Marshall E., Felix Lim, and A.Craig MacKinlay. 1998. " The Declining Credit Quality of U.S. Corporate Debt: Myth or Reality?" *Journal of Finance*, 53(4): 1389–1413.

Campbell, John Y. and Glen B. Taskler. 2003. "Equity Volatility and Corporate Bond Yields." *Journal of Finance*, 58(6): 2321–2349.

Chaney, Thomas, David Sraer, and David Thesmar. 2012. "The Collateral Channel: How Real Estate Shocks Affect Corporate Investment." *American Economic Review*, 102(6): 2381–2409.

Ellul, Andrew, Chotibhak Jotikasthira, and Christian T. Lundblad. 2011. "Regulatory Pressure and Fire Sales in the Corporate Bond Market." *Journal of Financial Economics*, 101: 596–620.

Ellul, Andrew, Chotibhak Jotikasthira, Christian T. Lundblad, and Yihui Wang. 2015. "Is Historical Cost Accounting a Panacea? Market Stress, Incentive Distortions, and Gains Trading." *Journal of Finance*, 70(6): 2489–2538.

Fazzari, Steven M., R. Glenn Hubbard, Bruce C. Petersen. 1988. "Financing Constraints and Corporate Investment." *Brookings Papers on Economic Activity*, 1: 141–195.

Foley-Fisher, Nathan, Rodney Ramcharan, and Edison Yu. 2016. "The Impact of Unconventional Monetary Policy on Firm Financing Constraints: Evidence from the Maturity Extension Program." *Journal of Financial Economics*, 122: 409–429.

Greenwood, Robin, Samuel Hanson, Jeremy C. Stein. 2010. "A Gap-Filling Theory of Corporate Debt Maturity Choice." *Journal of Finance*, 65: 993–1028.

Hadlock, Charles J. and Joshua R. Pierce. 2010. "New Evidence on Measuring Financial Constraints: Moving Beyond the KZ Index." *Review of Financial Studies*, 23: 1909–1940.

Hombert, Johan, Antoinette Schoar, David Sraer, and David Thesmar. 2020. "Can Unemployment Insurance Spur Entrepreneurial Activity? Evidence from France." *Journal of Finance*, 75(3): 1247–1285.

Kaplan, Steven N. and Luigi Zingales. 1997. "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics*, 112: 169–215.

Koijen, Ralph S. J. and Motohiro Yogo. 2015. "The Cost of Financial Frictions for Life Insurers." *American Economic Review*, 105(1): 445–475.

Leary, Mark T., and Michael R. Roberts. 2005. "Do Firms Rebalance Their Capital Structure?" *Journal of Finance* 60(6): 2575—2619.

Webb, Bernard L. and Claude C. Lilly III. 1994. "Raising the Safety. Risk-Based Capital for Life Insurance Companies." Retrieved from http://www.naic.org/documents/prod_serv_statistical_rsn_lb.pdf.

# Chapter 3

# The Portfolio Rebalancing Channel of Quantitative Easing: Inspecting the Life Insurance Companies

## 3.1 Introduction

In the aftermath of 2007-2008 financial crisis, the Federal Reserve (Fed) has resorted to various unconventional monetary policies. One of the unconventional policy tools is quantitative easing (QE), which involves three rounds of large-scale asset purchases (LSAPs, known as QE1, QE2, and QE3) and a maturity extension program (MEP). During these programs between 2008 and 2014, the Fed has purchased longer-term securities, including U.S. Treasury securities, agency mortgage-backed securities (MBS), and agency debt.[1] The QE programs have led to an almost nine-fold expansion in the Fed's Open Market Account (SOMA) portfolio, from 0.49 trillion (at the initiation of QE1 in November 2008) to 4.22 trillion (at the end of the QE3 in October 2014).[2]

[1]The agency MBS's are mortgage-backed securities backed by Fannie Mae, Freddie Mac, and Ginnie Mae. The agency debts are direct obligations of housing-related government sponsored enterprises Fannie Mae, Freddie Mac, and the Federal Home Loan Banks.

[2]See https://fred.stlouisfed.org/series/WSHOSHO#0.

As summarized in Koijen et al. (2021) and Kuttner (2018), there are several potential channels through which QE could affect asset prices and provide accommodative financial conditions to stimulate economic activity. One important channel is through portfolio rebalancing.[3] With imperfect substitutability of financial assets in investors' portfolios, through buying longer-term securities, the Fed reduces the relative supply of these securities available to investors, thereby lowering their yields. On top of that, the Fed pushes investors to reallocate their portfolios to other assets with similar characteristics (e.g., duration and credit risk) to assets that are bought by the Fed as part of the QE programs. Therefore, QE-induced portfolio rebalancing further depresses the yields of the assets substituted by the investors (Bernanke 2010).

This paper uses the life insurance industry as a laboratory to investigate whether the portfolio rebalancing channel is at work. The motivation to focus on life insurers is the following. Due to the long-term nature of their liabilities, life insurers invest largely in longer-term bonds, accounting for around 70% of their financial assets. Within the bond asset class, U.S. government bond and agency MBS rank the third and fourth in terms of portfolio weight in bond holdings of the life insurance sector.[4] This makes life insurers potential institutional investors that can accommodate the Fed's QE purchases. On top of that, corporate bonds make up the largest share of life insurers' bond portfolio. With around 40% of assets invested in corporate bonds, life insurers are the largest institutional holders of this asset class. If life insurers indeed rebalance their portfolios towards corporate bonds when the Fed conducts QE purchases, the portfolio rebalancing could operate through the life insurance sector,

[3]QE could operate through two other transmission mechanisms. One is the signaling channel: The Fed's large-scale purchases of long-term bonds send the signal of its intention of keeping interest rates low for an extended period of time. The other channel is through stimulating banks' lending: The Fed's QE purchases raise the value of assets on banks' balance sheets and hence their capital ratio, thereby making banks more willing to lend.

[4]See Table 1 and 2 of https://www.naic.org/cipr_newsletter_archive/vol16_insurers_reaching_for_yield_low_interest_environment.pdf.

thereby affecting corporate bond yields and supply of financing to other sectors of the economy.

To empirically examine whether life insurers sell to the Fed over the QE periods, I use data on the Fed's operation results of Treasury securities, which identifies the eligible securities and those are actually purchased by the Fed. I then combine the Fed's operation results data with insurance companies' security-level transactions and holdings of bonds obtained from the National Association of Insurance Commissioners (NAIC) Schedule D files. The analysis suggests that life insurers sell purchase-eligible securities over certain QE periods including QE2, MEP, and QE3. Over these three periods, life insurers cumulatively reduce 10.4%, 11.5%, and 13.9% of their holdings of the Treasury securities that are purchased into the Fed's SOMA account. Studying the security-level data has the advantage over the aggregate Flow of Funds data. The aggregate data doesn't distinguish between the maturity sectors of securities, which is the major criterion for the Fed's purchases. Hence, the aggregate data doesn't make a distinction between eligible and ineligible securities.

After documenting that life insurers sell the securities that the Fed buys during certain QE programs, I examine the question of toward what securities do life insurers rebalance their bond portfolios. To answer this question, I propose to analyze the QE-induced portfolio rebalancing by studying the differential response of life insurers based on their exposure to the Fed's SOMA purchases, which is measured by the percentage of a life insurer's portfolio invested, at the prior year-end, in Treasury securities and MBS that are purchased by the Fed into its SOMA account over the current year. I find supporting evidence that life insurers exhibit portfolio rebalancing behavior during the QE periods. Specifically, portfolio rebalancing is more pronounced among life insurers with higher exposure to the Fed's SOMA purchases, and they reallocate mostly to corporate bonds. In addition, life insurers rebalanced toward corporate bonds rated A or A-, the lowest tier within a risk category defined

by the risk-based capital (RBC) rule under which insurers are regulated. Overall, the results suggest that the portfolio rebalancing channel can work through the life insurance sector.

The remainder of this chapter is organized as follows. Section 3.2 provides an overview of QE implemented between 2008 and 2014. In Section 3.3, I discuss the related literature on the impact of QE programs. Section 3.4 presents the data. Section 3.5 investigates whether life insurers indeed accommodate the Fed's QE purchases. I examine life insurers' portfolio rebalancing behavior in QE times in Section 3.6. Section 3.7 concludes.

## 3.2 The Fed's QE programs

I summarize in Table 3.1 the Fed's several rounds of asset purchase programs between 2008 and 2014.[5] Figure 3.1 traces the Fed's SOMA holdings of agency debt, Treasury bonds, and MBS over time. Notice that it is not until the start of QE1 does the Fed begin to acquire agency debt and MBS onto its SOMA account. Figure 3.2 plots the monthly purchases of QE securities by the Fed during the QE programs.

The Fed implemented the first round of large-scale asset purchases (QE1) from November 2008 through March 2010. QE1 entailed acquisitions of $175 billion of agency debt, $1.25 trillion of agency MBS, and $300 billion U.S. Treasury securities with longer maturity. The second round of large-scale asset purchases (QE2) concentrated on Treasury securities. Over QE2 between November 2010 and June 2011, the Fed bought $600 billion of longer-term Treasury securities. From September 2011 through December 2012, the Fed added MEP to lengthen the average maturity of the securities in its portfolio. During MEP, the Fed sold or redeemed a total of $667 billion in shorter-term (with remaining maturities of 3 years or less) Treasury securities,

[5] https://www.newyorkfed.org/markets/programs-archive/large-scale-asset-purchases for a detailed timeline.

Table 3.1: Summary of QE programs

| Program | Date | Asset bought by the Fed | Size ($ billion) |
|---|---|---|---|
| QE1 | Nov 2008 to Mar 2010 | Agency debt | 175 |
| | | Agency MBS | 1250 |
| | | longer-term Treasury | 300 |
| QE2 | Nov 2010 to Jun 2011 | longer-term Treasury | 600 |
| MEP | Sep 2011 to Dec 2012 | Treasury with remaining maturities of 6 to 30 years | 667 |
| QE3 | Sep 2012 to Oct 2014 | Agency MBS | 823 |
| | | longer-term Treasury | 790 |

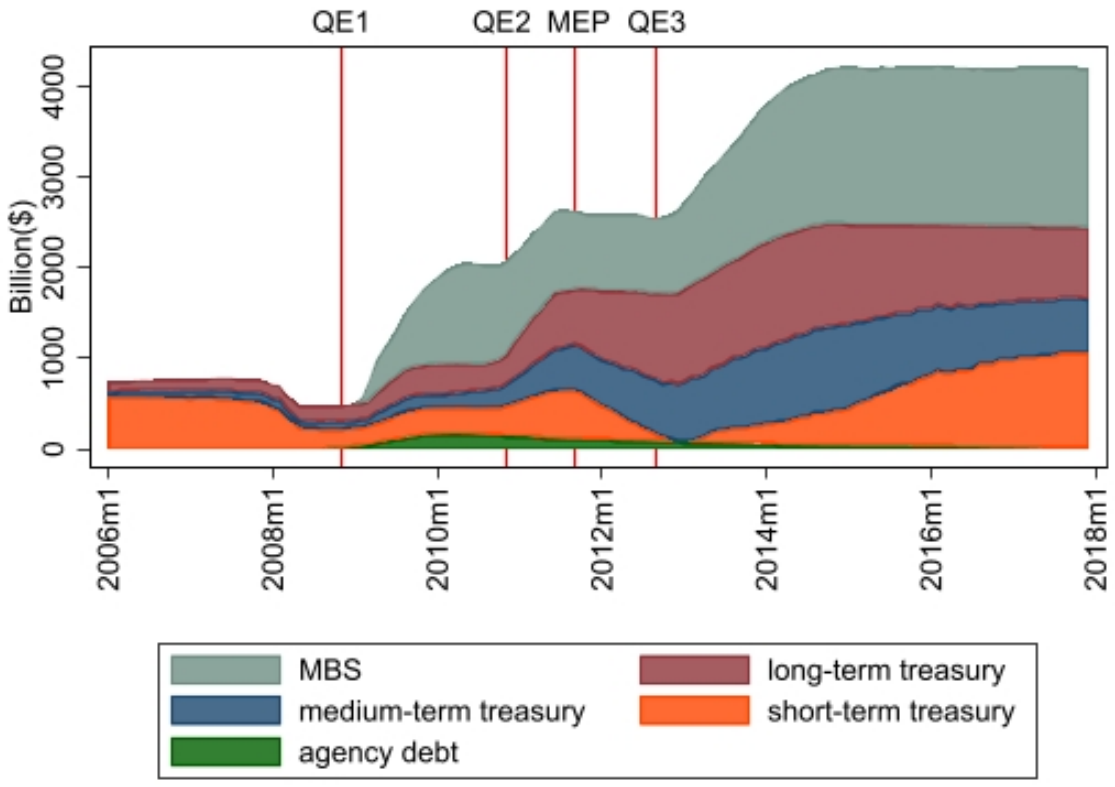
Notes: Summary of the QE programs based on information from https://www.newyorkfed.org/markets/programs-archive/large-scale-asset-purchases.

and in exchange, purchased an equal amount of longer-term Treasury securities (with remaining maturities of 6 years to 30 years). The third round of large-scale asset purchases (QE3) took place from September 2012 to December 2013, followed by a tapering period till October 2014. In total, QE3 involved purchases of $823 billion in agency MBS and $790 billion in Treasury securities.

## 3.3 Related literature

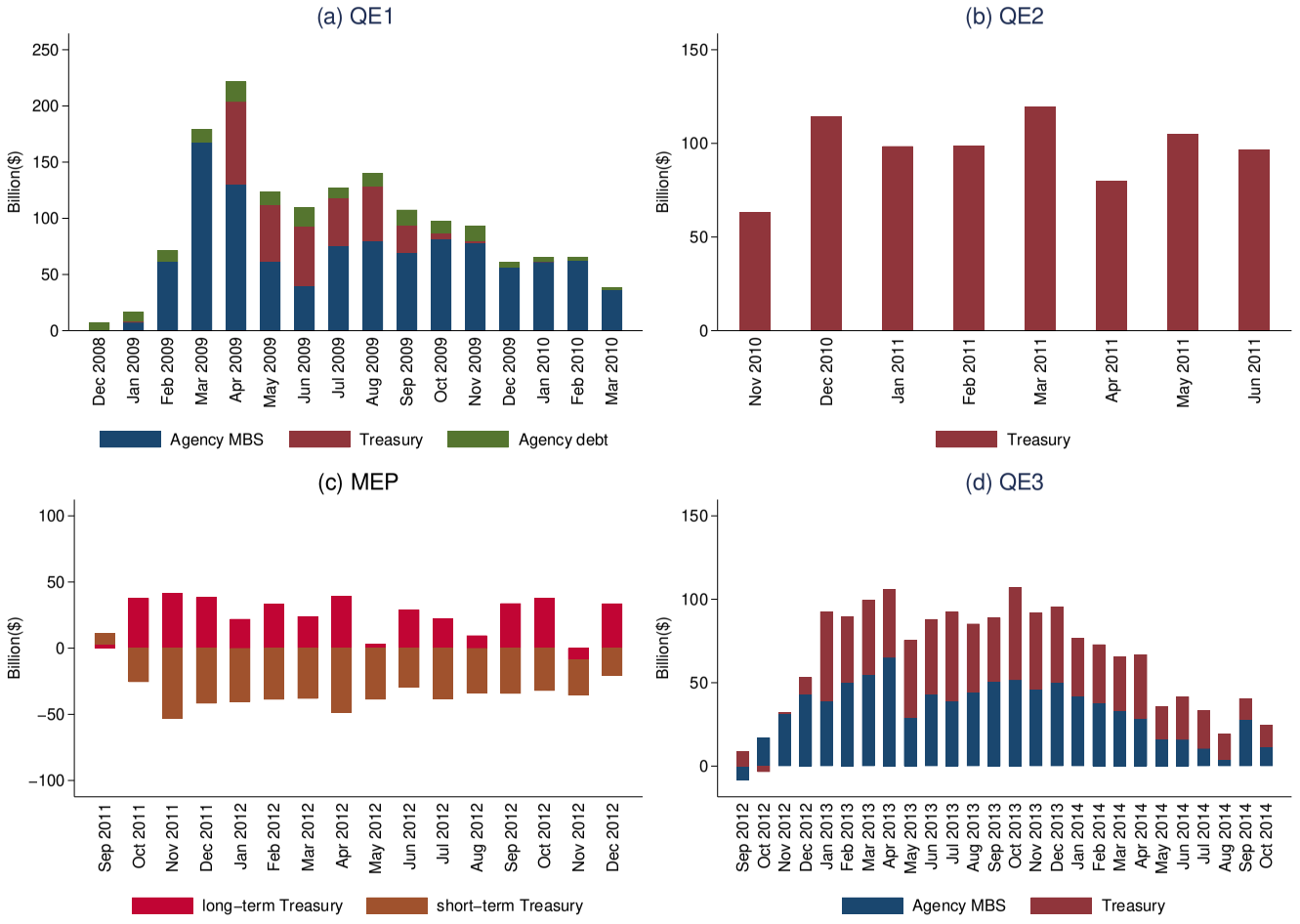
A large body of literature on central banks' QE programs has focused on assessing these programs' impact on interest rates. Event studies (e.g., Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Ehlers (2012), Bauer and Neely (2014)) investigate changes in bond yields over an event window of one or two days around announcements of QE programs. These event studies suggest that QE programs have a significant negative effect on long-term interest rates. Several papers (e.g., Gagnon et al. (2011), D'Amico et al. (2013), Ihrig et al. (2018), Hamilton and Wu (2012)) analyze time series models of term premiums. Findings in these studies indicate that QE programs bring down term premiums.

Figure 3.1: The Fed's SOMA portfolio




Notes: This figure presents the monthly holdings of the Fed's SOMA account by security type. Author's calculation based on data from https://www.newyorkfed.org/markets/soma-holdings. Short-, medium-, and long-term Treasury correspond to Treasury bonds with less than 3 years, 3 to 6 years, and more than 6 years remaining to maturity, respectively.

Figure 3.2: The Fed's QE purchases by security type




Notes: Each panel in this figure presents the monthly change in QE securities held by the Fed's SOMA account. Author's calculation based on data from https://www.newyorkfed.org/markets/soma-holdings. Short- and long-term Treasury correspond to Treasury bonds with remaining maturities of 3 years or less and 6 to 30 years, respectively.

There are differing views on what the most important channel is through which QE affects the market interest rates: Declines in interest rates can be explained by the signaling channel which lowers expectations of future short-term interest rates, or the portfolio rebalancing channel which narrows the term premium. There are several attempts to disentangle the two channels.

Through identifying forward guidance and LSAP components of FOMC announcements, Swanson (2021) finds that LSAPs are more effective than forward guidance at moving longer-term Treasury and corporate bond yields. Gagnon et al. (2011) use the 1-year-ahead forward rate as a measure of market interest rate expectations and examine this rate on the two FOMC announcements dates (December 16, 2008 and March 18, 2009) when the Fed stated the prospects of an extended period of low interest rate. They find that though the 1-year-ahead forward rate dropped on these two dates, the decline quickly reversed over the next few days. Based on this observation, Gagnon et al. (2011) conclude that these two FOMC announcements didn't have significant impact on interest rate expectations, and therefore attribute the declines in longer-term interest rates on those dates to the portfolio rebalancing channel.

Krishnamurthy and Vissing- Jorgenson (2011), on the other hand, consider that the signaling channel is at play. Examining the total effect of five QE1 announcements, they report a 40 basis point (bp) decrease in the 24th-month federal funds futures contract. They further estimate a signaling effect of 20 to 40 bp for 107 bp decline in 10-year Treasury yield, and 41 bp for 60 decline in long-term Baa corporate yield.

There is a growing body of literature that examines the portfolio rebalancing channel by directly looking into how investors adjust their portfolio holdings during different QE programs. Koijen et al. (2021) use security-level data on holdings of all asset classes for all investor sectors in the euro area to investigate whether portfolio rebalancing is at work during the European Central Bank (ECB)'s asset purchase pro-

gram.[6] They show that foreign investors outside the euro area, followed by banks and mutual funds, have accommodated the ECB's asset purchases. Insurance companies and pension funds in the euro area are not the sellers, but rather the buyers of the same bonds purchased by the ECB. Furthermore, there is no substantial indication of rebalancing across asset classes for any of the investor sectors.

In an effort to investigate whether investors' portfolios have changed in response to the Fed's asset purchases, Carpenter et al. (2015) use the quarterly Flow of Funds data on aggregate holdings of different asset classes by various investor types. They find evidence that a subset of investor types (including households, broker-dealers, insurance companies, investment funds, and pension funds) are the ultimate sellers when the Fed engages in asset purchases of Treasury securities and MBS. In particular, households and pension funds exhibit portfolio rebalancing concurrent with the Fed's asset purchases towards riskier asset classes.

Goldstein et al. (2018) focus just on mutual funds and analyze how mutual funds rebalance their portfolios during the Fed's QE programs.[7] Their results suggest that mutual funds do sell the QE securities that the Fed buys. On top of that, mutual funds replenish their portfolios with other government and agency securities with similar characteristics as the QE securities. While portfolio rebalancing towards riskier assets such as corporate bonds by mutual fund managers is comparatively small in magnitude, they observe that, in response to the Fed's QE purchases, end investors move out of government-focused funds and flow into corporate bond funds.

[6] Another study on the ECB's asset purchase program is Albertazzi et al. (2020), who detect portfolio rebalancing towards riskier corporate debts in more vulnerable countries in the euro area.

[7] Another example that zooms in on portfolio holdings of individual investors is Joyce et al. (2017), who find that insurance companies and pension funds shift their portfolios from gilt to riskier corporate bonds as a result of the Bank of England's QE program.

## 3.4 Data

I use several sources of data to analyze U.S. insurers' portfolio decisions in response to the Fed's QE programs.

First, insurance companies' transactions and holdings of bonds are obtained from the National Association of Insurance Commissioners (NAIC) Schedule D files. Part 1 of the NAIC Schedule D data provide information on insurers' year-end bond holdings, including bond identification, holding size, and other accounting items. Parts 3 to 5 include insurers' transaction records with transaction date, bond identification, trade size, price, direction, and counter-parties.

For Treasury securities, the QE purchases are implemented by the New York Fed. Before each purchase operation, the Fed announces a range of total amount and an eligible maturity date range of the Treasury securities to be purchased. Therefore, the set of eligible issues can be identified through the announcement. Furthermore, the Fed posts the outcomes of each operation that list which eligible securities are actually purchased onto the Fed's SOMA account.[8]

The Fed's System Open Market Account (SOMA) Holdings database contains historical data on the Fed's domestic securities holdings.[9] Based on the quarterly change in SOMA portfolio holdings at the security level, I can identify the MBS securities that are added to the Fed's SOMA account in a given quarter. I apply similar criteria used in Goldstein et al. (2018). I define an agency MBS as being purchased as part of a QE program in a given quarter if the Fed increases holdings of this MBS in its SOMA portfolio in the quarter. One technical issue is that the SOMA holdings of agency MBS are reported with aggregated CUSIPs, whose underlying components are agency MBS's with similar characteristics, such as original term of

[8]https://www.newyorkfed.org/markets/desk-operations/treasury-securities.

[9]The data is available for download at https://www.newyorkfed.org/markets/soma-holdings.

maturity and coupon.[10] To match the SOMA holdings with insurers' holdings, I also consolidate the agency MBS securities in NAIC Schedule D, using the listing of the individual agency MBS CUSIPs underlying each aggregated CUSIP.

## 3.5 Do life insurers accommodate the Fed's QE purchases?

In this section, I investigate whether life insurers indeed sell the securities that are eligible for the Fed's purchase under the QE programs. For Treasury securities, the major eligibility criterion is the maturity range.[11] Before each purchase operation, the Fed announces a range of total amount and an eligible maturity date range of the Treasury securities to be purchased. Therefore, the set of eligible issues can be identified through the announcement. The second column of Table 3.2 lists the maturity segments of eligible Treasury securities. The third column reports the percentage of eligible securities among all outstanding Treasury securities. The fourth column shows the proportion of eligible securities in the life insurance sector's Treasury securities portfolio. Each statistic is an average over the quarters of each QE program.

As the range of eligible maturity shrinks, the percentage of eligible securities among outstanding Treasury securities decreases: QE1 has the highest percentage of

[10]To reduce the cost and complexity of managing every single agency MBS CUSIP at large scale, the Fed has engaged in three rounds of agency MBS CUSIP aggregation in 2011, 2015, and 2019. Refer to https://www.newyorkfed.org/markets/opolicy/operating_policy_150731.html and https://www.newyorkfed.org/markets/Agency_MBS_CUSIP_Aggregation_faqs.html for more information regarding the agency MBS CUSIP aggregation.

[11]For purchases of Treasury securities over each QE program, the Fed announces the eligible maturity sectors and their approximate weights. The Fed does not purchase Treasury bills, STRIPS, or securities trading in the when-issued market. The Fed also has a per issue limit for Treasury holdings. Over QE1, the limit is 35%. Over the other QE programs, SOMA holdings of an individual Treasury issue are allowed to rise above 35%, but only in modest increments. For more details on purchases of Treasury securities for QE1, see https://www.newyorkfed.org/markets/POMO_faq_090324.html. For QE2, see https://www.newyorkfed.org/markets/lttreas_faq_101103.html. For MEP, see https://www.newyorkfed.org/markets/opolicy/operating_policy_120620.html. For QE3, see https://www.newyorkfed.org/markets/longertermtreas_faq_12122012.html.

Table 3.2: Eligible Treasury securities by QE programs

| Program | Eligible maturity | % of eligible | |
|---|---|---|---|
| | | Total outstanding amount | Total life insurers' holdings |
| QE1 | 1 to 30 years | 81.2 | 88.3 |
| QE2 | 1.5 to 30 years | 79.2 | 84.8 |
| MEP | 6 to 30 years | 31.8 | 60.4 |
| QE3 | 4 to 30 years | 46.7 | 68.6 |

Notes: This table reports the eligible Treasury securities as a percentage of total outstanding Treasury securities, and of total life insurers' holdings of Treasury securities. Each statistic is an average over the quarters of each of the QE programs.

eligible securities (81.2%) with eligible maturity spanning from 1 to 30 years, whereas MEP has the lowest eligibility ratio (31.8%) with eligible maturity of more than 6 years. The same pattern holds for the proportion of eligible securities in the life insurance sector's Treasury securities portfolio: The highest and the lowest average percent of eligible securities in the life insurance sector's Treasury securities portfolio is 88.3% over QE1 and 60.4% over MEP, respectively. Table 3.2 shows the advantage of using the security-level data over the aggregate Flow of Funds data. Since the aggregate data doesn't distinguish between maturity sectors of securities, it doesn't make a distinction between eligible and ineligible securities.

As a preliminary exercise, I present in Table 3.3 life insurers' rebalancing of Treasury securities over each QE program. As in Koijen et al. (2021), the investor $i$'s rebalancing amount of security $j$ for time $t$ is defined as

$$D_{i,j,t} = \Delta Q_{i,j,t} \cdot P_{j,t}, \tag{3.1}$$

where $\Delta Q_{i,j,t}$ is the change in the par value of security $j$ held by investor $i$ from time $t-1$ to time $t$, and $P_{j,t}$ is its price at time $t$.[12] For each quarter, I aggregate over all life insurers by eligibility of Treasury securities. In columns 4 and 5 of Table 3.3,

[12]For Treasury securities, I use the quarter-end price from CRSP U.S. Treasury database.

I report life insurance sector's cumulative rebalancing of eligible and ineligible Treasury securities in billion dollars over all quarters for each QE program. Furthermore, within the eligible securities, I am able to differentiate between the securities that are accepted for purchase by the Fed versus those that are not based on the outcomes of each operation posted by the Fed. Column 2 reports the result for eligible and accepted securities, and column 3 reports the result for eligible and unaccepted securities. The second row of each program shows the cumulative rebalancing of eligible security as a percent of the total initial holdings of the life insurance sector at the start of each QE program.

Table 3.3: Life insurance sector's adjustment of QE securities

| Program | Eligible | | | Ineligible |
|---|---|---|---|---|
| | Purchased by the Fed | Not purchased by the Fed | Total | |
| QE1 | 12.4 | 4.1 | 16.5 | 6.4 |
| | [18.6%] | [6.2%] | [24.8%] | [9.6%] |
| QE2 | -9.7 | 7.1 | -2.5 | 8.2 |
| | [-10.4%] | [7.6%] | [-2.7%] | [8.8%] |
| MEP | -13.0 | 4.7 | -8.3 | 4.5 |
| | [-11.5%] | [4.2%] | [-7.3%] | [4.0%] |
| QE3 | -17.0 | 11.9 | -5.1 | 11.8 |
| | [-13.9%] | [9.8%] | [-4.2%] | [9.7%] |

Notes: This table reports life insurance sector's the cumulative rebalancing of Treasury securities by eligibility for QE purchase. The first row of each program reports the rebalancing amount in billion dollars. The second row reports the rebalancing as a percentage of life insurers' total holdings of Treasury securities at the start of each QE program.

Over QE1, the life insurance sector does not sell but instead buy eligible Treasury securities. Life insurers buy a total amount of $16.5 billion of eligible Treasury securities, accounting for 24.8% of its initial holdings of Treasury securities. During QE2, life insurance companies collectively sell $9.7 billion of eligible Treasury securities

that are actually purchased by the Fed, which makes up 10.4% of life insurance sector's initial holdings of Treasury securities. Meanwhile, life insurers buy $7.1 billion of Treasury securities that are eligible but not purchased by the Fed. In total, life insurers sell $2.5 billion of eligible Treasuries. Similarly, during MEP and QE3, life insurers are net sellers of the eligible Treasury securities. In particular, they sell $13.0 billion and $17.0 billion of the securities purchased by the Fed over MEP and QE3, making up 11.5% and 13.9% of their initial holdings of Treasury securities. Overall, the results in Table 3.3 show that the life insurance sector has accommodated the Fed's QE purchases of Treasury securities over QE2, MEP, and QE3, but not over QE1.

Given that the purchase-eligible securities are identified, and that life insurers' bond trades are reported in their Schedule D filings, I can investigate whether life insurers in aggregate accommodate the Fed's QE purchases at the security level. Specifically, I look at how life insurers adjust holdings of a given security in a quarter. I use two different dependent variables to capture insurers' adjustments. The first dependent variable is

$$Net\,trade_{j,t} = \frac{\sum_i (\Delta Q_{i,j,t} \cdot P_{j,t})}{\sum_i MV_{i,j,t-1}}, \tag{3.2}$$

where $\Delta Q_{i,j,t}$ is the change in total par value of security $j$ held by insurer $i$ in quarter $t$; $P_{j,t}$ is its price; and $MV_{i,j,t-1}$ is the market value of security $j$ held by insurer $i$ at the end of the prior quarter. Therefore, the variable $Net\,trade$ is the percentage change in the aggregate holding of a given security held by all life insurers. The second dependent variable of interest is

$$Net\,seller_{j,t} = \frac{\sum_i Buy_{i,j,t} - \sum_i Sell_{i,j,t}}{\sum_i Own_{i,j,t-1}}, \tag{3.3}$$

where $Buy_{i,j,t}$ is equal to one if insurer $i$ increases its holding of bond $j$ during quarter $t$, and zero otherwise. Similarly, $Sell_{i,j,t}$ is equal to one if insurer $i$ decreases its

holding of bond $j$ during quarter $t$, and zero otherwise. $Own_{i,j,t-1}$ takes the value of one if insurer $i$ possesses bond $j$ at the end of the prior quarter. Hence, the variable $Net\,seller$ is the net fraction of sellers among all life insurers of a given security.[13]

Table 3.4: Do life insurers accommodate the Fed's QE purchase of Treasury securities?

| Dependent variable | Net trade | Net seller |
|---|---|---|
| | [1] | [2] |
| QE2 | -0.08*** | -0.04*** |
| | [0.03] | [0.02] |
| MEP | -0.11** | -0.08*** |
| | [0.05] | [0.02] |
| QE3 | -0.14** | -0.05* |
| | [0.05] | [0.03] |
| Constant | 0.11 | 0.01 |
| | [0.25] | [0.16] |
| Time-varying security controls | Yes | Yes |
| Security FE | Yes | Yes |
| N | 2375 | 2375 |
| $R^2$ | 0.17 | 0.17 |

Notes: This table examines life insurers' trading of purchase-eligible Treasury securities over QE periods. The sample period is 2009Q1 to 2014Q4. The dependent variable for column 1 is $Net\,trade$, which is the percentage change in the aggregate holding of a given security held by all life insurers. The dependent variable for column 2 is $Net\,seller$, which is the net fraction of sellers among all life insurers of a given security. Each of the dummy variables $QE2$, $MEP$, and $QE3$ takes the value of one if a bond-quarter observation falls within a corresponding QE program period listed in Table 3.1, and zero otherwise. All regressions include time-varying security characteristics (yield, duration, and amount outstanding), as well as security fixed effects. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

Table 3.4 formally tests whether life insurers accommodate the Fed's QE purchases of Treasury securities. The sample focuses on purchase-eligible Treasury securities.

[13]For illustrative purpose, suppose 10 insurers own bond A at current year-end. During the next quarter, 6 insurers reduce their holdings of A, and 1 insurer increases its holdings of A. Then, the value of $Net\,trade$ for this quarter is (1-6)/10 = -50%, which means that 50% of the owners of A are sellers of A.

Table 3.5: Do life insurers accommodate the Fed's QE purchase of Treasury securities? Continued

| Dependent variable | Net trade | Net seller |
|---|---|---|
| | [1] | [2] |
| Eligible | 0.05 | 0.02 |
| | [0.03] | [0.01] |
| QE2 | 0.03 | 0.02 |
| | [0.04] | [0.02] |
| MEP | -0.00 | -0.02 |
| | [0.04] | [0.02] |
| QE3 | -0.02 | -0.01 |
| | [0.05] | [0.02] |
| Eligible × QE2 | -0.11*** | -0.07*** |
| | [0.04] | [0.02] |
| Eligible × MEP | -0.09** | -0.05*** |
| | [0.04] | [0.02] |
| Eligible × QE3 | -0.08** | -0.03* |
| | [0.04] | [0.02] |
| Constant | 0.04 | 0.03 |
| | [0.09] | [0.05] |
| Time-varying security controls | Yes | Yes |
| Security FE | Yes | Yes |
| N | 5123 | 5123 |
| $R^2$ | 0.09 | 0.12 |

Notes: This table examines life insurers' trading of both purchase-eligible and ineligible Treasury securities over QE periods. The sample period is 2009Q1 to 2014Q4. The dependent variable for column 1 is $Net\,trade$, which is the percentage change in the aggregate holding of a given security held by all life insurers. The dependent variable for column 2 is $Net\,seller$, which is the net fraction of sellers among all life insurers of a given security. The dummy variable *Eligible* is defined to be equal to one if the security is a purchase-eligible security, and zero otherwise. Each of the dummy variables $QE2$, $MEP$, and $QE3$ takes the value of one if a bond-quarter observation falls within a corresponding QE program period listed in Table 3.1, and zero otherwise. All regressions include time-varying security characteristics (yield, duration, and amount outstanding), as well as security fixed effects. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

The sample period is from 2009Q1 to 2014Q4, where 2009Q1 (2014Q4) is the start (end) of the Fed's QE Treasury purchase. Each observation corresponds to a bond-quarter. The dependent variable in column 1 is $Net\,trade$, which is the percentage change in the aggregate holdings of a given security held by all life insurers. The dependent variable in column 2 is $Net\,seller$, which is the net fraction of sellers among all life insurers of a given security. The independent variables include a series of dummy variables. I compare life insurers' adjustments separately for each QE program by using dummy variables $QE2$, $MEP$, and $QE3$, where each of the dummy variables takes the value of one if a bond-quarter observation falls within a corresponding QE program period listed in Table 3.1, and zero otherwise. I control for time-varying security characteristics, including yield, duration, and amount outstanding. To account for any time-invariant security characteristics, I include security fixed effects.

The QE dummy variable captures the average adjustment of eligible Treasury securities relative to QE1. Column 1 of Table 3.4 shows results consistent with those in Table 3.3. Compared with QE1, life insurers' aggregate holdings of a purchase-eligible Treasury security reduces, on average, by 8%, 11%, and 14% during QE2, MEP, and QE3, respectively. The findings are robust when I use the net fraction of sellers as the dependent variable in column 2. Specifically, relative to QE1, there are 4%, 8%, and 5% more life insurers on the sell side of a purchase-eligible Treasury security during QE2, MEP, and QE3 respectively.

Table 3.5 expands the sample to both purchase-eligible and ineligible Treasury securities. The independent variables include a series of QE program dummy variables and interaction terms. The dummy variable *Eligible* is defined to be equal to one if the security is a purchase-eligible security, and zero otherwise. Same as in Table 3.4, I control for time-varying security characteristics, including yield, duration, and amount outstanding. To account for any time-invariant security characteristics, I include security fixed effects.

The variables of interest are the interaction terms on the eligible indicator and the QE program dummies, which capture the difference in adjustments between eligible and ineligible securities relative to QE1. The negative and significant coefficients on the interaction terms in column 1 of Table 3.5 show that life insurers sell more of the eligible securities relative to ineligible securities in comparison with QE1. In particular, life insurers, on average, reduce 11%, 9%, and 8% of their aggregate holdings of a purchase-eligible Treasury security during QE2, MEP, and QE3, respectively. Findings in column 2 shows that life insurers also experience a significant change in the net fraction of sellers of eligible securities. Relative to QE1, there are 7%, 5%, and 3% more life insurers on the sell side of a purchase-eligible Treasury security during QE2, MEP, and QE3 respectively.

## 3.6 Portfolio rebalancing in response to QE programs

The analysis in Section 3.5 suggests that life insurers sell to the Fed the Treasury securities during certain QE programs. In this section, I investigate whether QE induces portfolio rebalancing behavior among life insurers. To answer this question, I resort to the insurer-level data and examine their portfolio allocations across the following major bond classes: corporate bonds, government bonds, agency and non-agency MBS, municipal bonds, foreign bonds, agency and non-agency commercial-backed securities (CBS), asset-backed securities.[14]

I use the identification strategy that exploits variation among life insurers in their exposure to the Fed's QE purchases. Table 3.6 provides an overview of insurers' QE exposure and their QE asset allocation behavior in response to QE programs. The QE

[14]In Schedule D data, the asset class of a bond can be identified from the line number with which it is reported. In case of inconsistency in classification of a bond, I use the asset class definition reported by most insurers in most years.

Table 3.6: Rebalance of QE securities by exposure to the Fed's QE purchases

| | QE1 exposure quartile | | | | QE2 exposure quartile | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| QE Treasury | 0.13 | 1.21 | 1.72 | 8.02 | -0.03 | -0.88 | -0.61 | -3.10 |
| QE Agency MBS | 0.11 | 0.07 | -0.27 | -1.11 | - | - | - | - |
| QE Agency debt | 0.02 | 0.13 | -0.40 | 0.12 | - | - | - | - |
| | MEP exposure quartile | | | | QE3 exposure quartile | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| QE Treasury | 0.09 | -0.66 | 0.13 | -3.65 | -0.08 | 0.11 | -0.35 | -1.85 |
| QE Agency MBS | - | - | - | - | 0.01 | -0.09 | -0.16 | -0.70 |
| QE Agency debt | - | - | - | - | - | - | - | - |

Notes: This table tabulates the cumulative rebalancing of QE securities aggregated over all insurers in the same quartile of exposure to the Fed's QE purchase, scaled by the market value of total bond holdings of all insurers in the exposure quartile entering the QE program. The strength of exposure to the Fed's QE purchase is measured by the proportion of an insurer's portfolio at the year-end prior to the start of a QE program that is invested in securities identified as QE purchases.

exposure is computed as the proportion of an insurer's portfolio at the year-end prior to the start of a QE program that is invested in securities identified as QE purchases. Insurers are sorted (in ascending order) into quartiles according to their QE exposure. Each cell corresponds to the cumulative rebalancing of QE securities aggregated over all insurers in the exposure quartile, scaled by the market value of total bond holdings of all insurers in the exposure quartile entering the QE program. Several patterns can be observed from Table 3.6. First, consistent with findings in Section 3.5, life insurers accommodate the Fed's QE purchases of Treasury bonds over all, but QE1. Next, as one moves to higher QE (during QE2, MEP, QE3) exposure quartile, the amount of cumulative rebalancing becomes more negative, indicating that life insurers in higher exposure quartile accommodate more of the Fed's QE purchase.

Table 3.7 formally tests whether life insurers rebalance to other asset classes over the QE programs. The dependent variable is life insurer $i$'s cumulative rebalancing of bond class $c$ over year $t$, scaled by the market value of life insurer $i$'s total bond

holdings at the end of year $t-1$. I create two dummy variables $QE1$ and $QE\,rest$ capture the period of QE1 and the rest periods of QE2, MEP, and QE3. The reason to differentiate QE1 from the other QE programs is that findings in Section 3.5 indicate that life insurers accommodate the Fed's QE purchases over QE2, MEP, and QE3; whereas over QE1, life insurers in aggregate also buy the Treasury securities the Fed buys during that period. The dummy variable $QE1$ equals one for year 2009, and zero otherwise. The dummy variable $QE\,rest$ equals one for years 2010 to 2014, and zero otherwise. The sample period is from year 2004 to 2017. At the core of the empirical test in Table 3.7 is the assumption that insurers with more exposure to the Fed's SOMA purchases engage in more portfolio rebalancing. For regression specification, the strength of a life insurer's exposure to the Fed's SOMA purchases is constructed as the following. For each year, I identify the securities that are purchased onto the Fed's SOMA account over the year using the criteria described in Section 3.4. Then, I look at each life insurer's bond holdings at the previous year-end and calculate the market value weight of a life insurer's bond portfolio invested in the securities that are part of SOMA purchases of the current year. The independent variables in the regression include the SOMA purchase exposure measure and its interaction terms with the indicator variables $QE1$ and $QE\,rest$. The regression also includes insurer and year fixed effects, as well as time-varying insurer characteristics. The insurer controls are firm size (the log of total assets), leverage (one minus equity over assets), and the capital adequacy ratio (BCAR) as the measure of regulatory constraint.[15] Standard errors are clustered at the insurer level.

Each column in Table 3.7 corresponds to a bond class. The coefficient of interest is that on the interaction term between the QE period dummy $QE\,rest$ and the measure of SOMA purchase exposure $SOMA\,purchase\,exposure$. In column 3 for

[15]Data on insurer characteristics is from A.M. Best. BCAR is the ratio of total adjusted capital to required risk-based capital, where both the available capital and the required capital are computed using A.M. Best's formula. Insurance companies with higher BCAR are considered to be better capitalized. See http://www.ambest.com/ratings/bcar_lh.pdf for details on how BCAR is calculated.

Table 3.7: Portfolio rebalancing across bond class

| | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] |
|---|---|---|---|---|---|---|---|---|---|
| | Corporate | Municipal | Government | Agency MBS | Non-agency MBS | Foreign | Agency CBS | Non-agency CBS | ABS |
| Soma purchase exposure | 0.088*** | 0.017 | 0.079** | 0.004 | 0.002 | 0.001 | 0.000 | 0.007** | 0.001 |
| | [0.029] | [0.010] | [0.038] | [0.009] | [0.003] | [0.001] | [0.000] | [0.003] | [0.002] |
| Soma purchase exposure | -0.019 | -0.036** | 0.025 | 0.000 | 0.010* | 0.000 | 0.000 | -0.006 | -0.001 |
| ×QE1 | [0.060] | [0.014] | [0.079] | [0.014] | [0.005] | [0.001] | [0.000] | [0.006] | [0.002] |
| Soma purchase exposure | 0.091* | -0.003 | -0.103** | 0.014 | 0.008** | 0.001 | 0.000 | 0.003 | -0.001 |
| ×QE rest | [0.049] | [0.015] | [0.050] | [0.014] | [0.003] | [0.001] | [0.001] | [0.004] | [0.003] |
| Insurer controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Insurer FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 9323 | 9323 | 9323 | 9323 | 9323 | 9323 | 9323 | 9323 | 9323 |
| $R^2$ | 0.17 | 0.15 | 0.12 | 0.13 | 0.13 | 0.13 | 0.18 | 0.12 | 0.18 |

Notes: This table reports the results regarding life insurers' portfolio rebalancing behavior across asset classes. The sample period is 2004 to 2017. The dependent variable for each column corresponds to a life insurer's annual cumulative rebalancing of a bond class, scale by scaled by the market value of its total bond holdings at the end of the prior year. The dummy variable $QE1$ equals one for year 2009, and zero otherwise. The dummy variable $QE\,rest$ equals one for years 2010 to 2014, and zero otherwise. The regression also includes insurer and year fixed effects, as well as time-varying insurer characteristics. The insurer controls are firm size (the log of total assets), leverage (one minus equity over assets), and the capital adequacy ratio (BCAR) as the measure of regulatory constraint. Standard errors are clustered at the insurer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

government bond, the estimated coefficient on $SOMA\,purchase\,exposure \times QE\,rest$ is negative and significantly different from zero. This confirms the findings in Section 3.5 that, over the rest of the QE programs (excluding QE1), life insurers sell the Treasury securities the Fed purchases. The coefficient estimate implies that, a one standard deviation increase in SOMA purchase exposure is associated with 1.4% ($-0.103 \times 0.136$) reduction in allocation to the Treasury bonds. This corresponds to 9.7% of the standard deviation of the dependent variable.

How do life insurers allocate their proceeds from selling QE securities? Across all bond classes, I observe from column 1 that there is almost one-to-one increase in allocation to corporate bonds. A one standard deviation increase in SOMA purchase exposure translates into a 1.2% ($0.091 \times 0.136$) increase in allocation to corporate bonds, which is equivalent to about 7.4% of a standard deviation of the dependent variable. Overall, the findings in this table provide supporting evidence of portfolio rebalancing behavior of life insurers toward corporate bonds.

Next, I further investigate the question: What credit ratings of corporate bonds are life insurers rebalancing toward? Life insurers' bond holdings are subject to NAIC's risk-based capital (RBC) requirement.[16] To determine the capital requirements for insurers' bond holdings, the NAIC sorts bonds into six risk categories defined by bond credit ratings, with NAIC risk category 1 composed of bonds with the best ratings and category 6 the worst. There are two salient features of the RBC rule listed in Table 3.8. First, the capital requirements increase sharply as one moves to a riskier category. Compared with category 1, bonds in category 2 are charged three times more, and category 6 a hundred times more. Second, the NAIC risk categories are loosely defined: Each category contains bonds with a wide range of credit ratings. In particular, bonds with ratings ranging from AAA to A- are all classified as category 1. While the first feature of the RBC rule limits risk-taking through de-

[16]For an overview of NAIC RBC system, see https://content.naic.org/cipr_topics/topic_riskbased_capital.htm

terring insurers from investing in worse-rated bonds in riskier categories, the second feature leaves insurers room to acquire riskier bonds to achieve higher yields within a given NAIC risk category without being charged additional capital reserve.

Table 3.8: The NAIC RBC requirements for bonds

| NAIC risk category | Credit rating | Capital factor |
|---|---|---|
| U.S. Government Bonds | | 0.00% |
| NAIC 1: Highest Quality | AAA<br>AA+/AA/AA-<br>A+/A/A- | 0.30% |
| NAIC 2: High Quality | BBB+<br>BBB<br>BBB- | 1.00% |
| NAIC 3: Medium Quality | BB+<br>BB<br>BB- | 4.00% |
| NAIC 4: Low Quality | B+<br>B<br>B- | 9.00% |
| NAIC 5: Lower Quality | CCC+<br>CCC<br>CCC- | 20.00% |
| NAIC 6: In or Near Default | CC<br>Or Below | 30.00% |

Notes: This table lists the capital factors for each NAIC risk category.

Table 3.9 examines the credit ratings of life insurers' corporate bond portfolios over QE periods. The credit ratings of corporate bonds are obtained from Mergent FISD.[17] The dependent variable in columns 1 and 2 of Table 3.7 is the proportion of bonds rated A or A- in an insurer's investment-grade corporate bond portfolio.[18]

[17]Mergent FISD records historical bond-level credit ratings issued by S&P, Moody's, or Fitch. I determine a bond's credit rating according to the following rule used by the NAIC.See p.21 of https://www.naic.org/documents/committees_e_rea_wg_related_showing_all_fe_text.pdf. When all three rating agencies rate a bond, I use the middle rating. If two agencies rate a bond, I use the lower rating. If only one agency rates a bond, that single rate is used.

[18]I focus on investment-grade bond because life insurers hold 90% of their corporate bond portfolios in investment grade bonds. See https://content.naic.org/sites/default/files/capital-markets-special-report-cash-invested-assets-2015.pdf

The independent variables in the regression include the SOMA purchase exposure measure and its interaction terms with the indicator variables $QE1$ and $QE\,rest$, all of which defined in the same way as in Table 3.7. The regression also includes insurer and year fixed effects. Column 2 also includes an additional set of controls including firm size (the log of total assets), leverage (one minus equity over assets), the capital adequacy ratio (BCAR) as the measure of regulatory constraint, portfolio duration (average bond duration weighted by amount held), portfolio rating (average bond rating weighted by amount held)[19], as well as their interaction terms with the indicator variables $QE1$ and $QE\,rest$. Standard errors are clustered at the insurer level.

The coefficient of interest on the interaction term between $SOMA\,purchase\,exposure$ and $QE\,rest$ is positive and significant. The coefficient estimate in column 1 suggests that over the periods of QE2, MEP, and QE3, a one standard deviation increase in SOMA purchase exposure is associated with 1.21% ($0.173 \times 0.07$), which is equivalent to a 10% standard deviation increase in the share of bonds rated A or A-. Column 2 shows that the results are robust to including additional insurer controls.

Columns 3 and 4 of 3.9 focus on life insurers' acquisition of newly-issued bonds. The dependent variable is replaced with the proportion of the newly-issued bonds acquired by an insurer that have a credit rating of A or A-. The coefficient of interest on the interaction term between $SOMA\,purchase\,exposure$ and $QE\,rest$ in column 3 is positive and significant. Over the periods of QE2, MEP, and QE3, a one standard deviation increase in SOMA purchase exposure is associated with 1.71% ($0.244 \times 0.07$), which corresponds to a 10% standard deviation increase in the share of bonds rated A or A-. The result remains similar with additional insurer controls. Overall, the patterns in Table 3.9 confirm that life insurers that are more exposed to SOMA

[19]Each letter rating is assigned to a number. Specifically, AAA corresponds to 1, AA+ corresponds to 2, ..., BBB corresponds to 9, and BBB- corresponds to 10.

Table 3.9: Portfolio rebalancing across corporate bond credit rating

| Dependent variable: | Share of bonds in holdings rated A or A- | | Share of newly-issued bonds in acquisitions rated A or A- | |
|---|---|---|---|---|
| | [1] | [2] | [3] | [4] |
| Soma purchase exposure | -0.082 | -0.035 | -0.127 | -0.065 |
| | [0.050] | [0.057] | [0.089] | [0.077] |
| Soma purchase exposure | 0.08 | 0.089 | 0.167 | 0.338*** |
| × QE1 | [0.081] | [0.067] | [0.147] | [0.117] |
| Soma purchase exposure | 0.173** | 0.116* | 0.244** | 0.211** |
| × QE rest | [0.069] | [0.070] | [0.114] | [0.100] |
| Insurer controls | No | Yes | No | Yes |
| Insurer FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| N | 8393 | 7636 | 6493 | 6103 |
| $R^2$ | 0.56 | 0.63 | 0.3 | 0.48 |

Notes: This table reports the results regarding life insurers' portfolio rebalancing behavior across corporate bond credit ratings. The sample period is 2004 to 2017. The dependent variable in columns 1 and 2 is the share of corporate bond rated A or A- in an insurer's portfolio. The dependent variable in columns 3 and 4 is the share of corporate bond rated A or A- as a percentage of an insurer's total purchases of new bonds issued within a given year.The dummy variable $QE1$ equals one for year 2009, and zero otherwise. The dummy variable $QE\,rest$ equals one for years 2010 to 2014, and zero otherwise. The regression also includes insurer and year fixed effects, as well as time-varying insurer characteristics. The insurer controls are firm size (the log of total assets), leverage (one minus equity over assets), and the capital adequacy ratio (BCAR) as the measure of regulatory constraint, portfolio duration (average bond duration), portfolio rating (average bond rating). Standard errors are clustered at the insurer level. The symbols ***, **, and * indicate significance levels at 1%, 5%, and 10%, respectively.

purchase rebalance towards investment-grade corporate bonds with A or A- rated bonds.

## 3.7 Conclusion

In this chapter, I study portfolio rebalancing over the U.S. QE period from 2008 to 2014. The availability of security-level data of individual life insurers' bond holdings and transactions allows me to undertake an investigation of whether portfolio rebalancing can operate through the insurance industry. The first condition for the portfolio rebalancing mechanism to operate through the insurance industry is that life insurers accommodate the Fed's QE purchases. I find that life insurers sell the securities that are bought by the Fed during the QE programs. Next, I ask toward what kind of securities do life insurers rebalance their portfolios. I show that life insurers with higher exposure to the Fed's SOMA purchases engage in more portfolio rebalancing, and they reallocate mostly to corporate bonds. In addition, life insurers rebalanced toward corporate bonds rated A or A-, the lowest tier within a risk category defined by the risk-based capital (RBC) rule under which insurers are regulated. Overall, these findings show that the QE's portfolio can work through the life insurance sector. Overall, these results provide micro-level evidence suggesting that the Fed's large-scale asset purchases for QE purposes lead to rebalancing of portfolios toward riskier corporate bonds, validating the rebalancing channel at work.

# References

Albertazzi, Ugo, Bo Becker, and Miguel Boucinha. 2020. "Portfolio Rebalancing and the Transmission of Large-scale Asset Purchase Programs: Evidence from the Euro Area." *Journal of Financial Intermediation*, forthcoming.

Bauer, Michael D., and Christopher J. Neely. 2014. "International Channels of the Fed's Unconventional Monetary Policy." *Journal of International Money and Finance*, 44: 24–46.

Bernanke, Ben S. 2010. "The Economic Outlook and Monetary Policy." Remarks at the Federal Reserve Bank of Kansas City Economic Symposium Jackson Hole, Wyoming.

Carpenter, Seth, Selva Demiralp, Jane Ihrig, and Elizabeth Klee. 2015. "Analyzing Federal Reserve asset purchases: From whom does the Fed buy?" *Journal of Banking and Finance*, 52: 230–244.

D'Amico, Stefania, and Thomas B. King. 2013. "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply." *Journal of Financial Economics*, 108(2): 425–448.

Ehlers, Torsten. 2012. "The Effectiveness of the Federal Reserve's Maturity Extension Program - Operation Twist 2: The Portfolio Rebalancing Channel and Public Debt Management." BIS Papers, 65: 245–256.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack. 2011. "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases." *International Journal of Central Banking*, 7(1): 3–43.

Goldstein, Itay, Jonathan Witmer, and Jing Yang. 2018. "Following the Money: Evidence for the Portfolio Balance Channel of Quantitative Easing." Bank of Canada staff working paper.

Hamilton, James D., and Jing Cynthia Wu. 2012. "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment." Journal of Money, Credit and Banking, 44(1): 3–46.

Ihrig, Jane, Elizabeth Klee, Canlin Li, Brett Schulte, and Min Wei. 2018. "Expectations about the Federal Reserve's Balance Sheet and the Term Structure of Interest Rates." *International Journal of Central Banking*, 341–390.

Joyce, Michael A.S., Zhuoshi Liu, Ian Tonks. 2017. "Institutional Investors and the QE Portfolio Balance Channel." *Journal of Money, Credit and Banking*, 49(6): 1225–1246.

Koijen, Ralph S.J., François Koulischer, Benoît Nguyen, and Motohiro Yogo. 2021. "Inspecting the Mechanism of Quantitative Easing in the Euro Area." *Journal of Financial Economics*, 140(1): 1–20.

Krishnamurthy, Arvind, and Annette Vissing- Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." Brookings Papers on Economic Activity, 1: 215–287.

Kuttner, Kenneth N. 2018. "Outside the Box: Unconventional Monetary Policy in the Great Recession and Beyond." *Journal of Economic Perspectives*, 32(4): 121–146.

Swanson, Eric T. 2021. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." *Journal of Monetary Economics*, 118: 32–53.