What Do $40 Trillion of Portfolio Holdings Say about Monetary Policy Transmission? *

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Abstract

We use granular portfolio holdings data on major U.S. bond investors to examine the transmission of monetary policy. When the Federal Reserve conducts expansionary monetary policy, mutual funds increase their bond purchases due to capital inflows; insurance companies lengthen portfolio durations to hedge liabilities; and banks engage in both activities to accommodate deposit inflows and counteract the shortening duration of mortgages. This elevated demand acts as a "helping hand," amplifying the Fed's impact on long-term yields. Most of this excess demand is absorbed through new bond issuances, while dealers play a limited role. Using an asset demand system framework, we show that elevated asset demand explains a large share of the excess sensitivity of long-term yields. Meanwhile, bond issuance has become increasingly elastic in recent years, which explains the decline in sensitivity at low frequency. Overall, the "helping hand" effect of monetary policy is three times as important as changes in risk-free rates in driving corporate bond issuance.

Keywords: monetary policy, market clearing, demand system, state dependency

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1 Introduction

The Federal Reserve exerts a surprisingly large influence on long-term interest rates. In response to a 100 bps decrease in 1-year yields, textbook macro models predict roughly a 21 bps reduction in 10-year yields; however, the actual response averages around 44 bps at a quarterly frequency, twice the theoretical prediction.[1] Similarly, unconventional monetary policies such as quantitative easing (QE) have a much greater impact on long-term interest rates than predicted by textbook macroeconomic theories.[2] In other words, monetary policy appears "too powerful". Jeremy Stein, then a Fed governor, highlighted this puzzle in a 2013 speech, asking, "*How, in a world of eventually flexible goods prices, is monetary policy able to exert such a powerful influence on long-term real rates?*"

Adding complexity to this puzzle, in recent decades, the excess sensitivity of long rates largely reverses at lower frequencies (Hanson, Lucca, and Wright, 2021). This reversal is interpreted as evidence that the phenomenon is transitory and therefore has limited significance for understanding the broader macroeconomic impact of monetary policy.[3]

Existing literature has primarily analyzed asset prices. Nevertheless, financial media frequently report that investors closely monitor monetary policy and actively adjust their portfolios in response. This observation motivates us to study how investor portfolios change in response to monetary policy. In this paper, we construct a comprehensive dataset of granular portfolio holdings from major bond investors: mutual funds, insurance companies, banks, primary dealers, and the Federal Reserve. The dataset includes quarterly snapshots of investor positions across major bond classes—Treasury notes and bonds, agency

[1] See Gürkaynak, Sack, and Swanson (2005), Hanson and Stein (2015), Gertler and Karadi (2015), and Brooks, Katz, and Lustig (2018).

[2] See Greenwood, Hanson, and Vayanos (2023); Krishnamurthy and Vissing-Jorgensen (2011); D'Amico, English, López-Salido, and Nelson (2012); Swanson (2021); Selgrad (2023); Haddad, Moreira, and Muir (2024).

[3] For instance, Hanson et al. (2021) writes "Our findings suggest that the recruitment channel may not be as strong as Stein (2013) speculates since a portion of the resulting shifts in term premia are transitory."

mortgage-backed securities (MBS), and corporate bonds—resulting in 546 million portfolio-level observations from 20,595 investors between 2003 and 2022. By the end of our sample period, these observations represent nearly $40 trillion in bond holdings.

We begin with a set of new stylized facts regarding investor portfolio adjustments following conventional and unconventional monetary policy actions. When there is a 100 bps cut in the short-term interest rate over a one-year horizon, mutual funds and banks expand their bond holdings by 0.49% and 0.40% of the total market size in the same year, acting as a "helping hand" that amplifies the Fed's intervention. This demand expansion is enormous—equivalent to 1.6% of annual GDP.[4] This effect arises because both institutions experience significant capital inflows from households, expanding their balance sheets by 8–10%.

When mutual funds and banks purchase more bonds following a rate cut, how does the market clear? The existing literature emphasizes dealers' role as liquidity providers.[5] However, when mutual funds and banks collectively purchase 0.89% of bonds outstanding during monetary easing, primary dealers actually expand their bond holdings as well. Instead, most of the demand is met through new issuances by the Treasury Department, mortgage borrowers, and corporations: they issue more or repurchase fewer bonds totaling 1.36% of market outstanding, matching the magnitude of purchases from mutual funds, banks and other investors with similar demand. Insurance companies, facing stable capital flows that are orthogonal to monetary policy, act as liquidity providers and decrease Treasury and corporate holdings following a rate cut.

Investors adjust not only the size of their portfolio holdings but also their composition. Following a rate cut, banks increase the duration of their Treasury bond holdings, as heightened prepayment probabilities shorten the duration of MBS. Insurance companies additionally extend their portfolio duration to hedge against increased liability duration driven by convexity

[4] As of 2022, the total fixed income market is $46.2 trillion. The U.S. annual GDP was $26.0 trillion in 2022.

[5] See for instance, the class of preferred habitat models following Vayanos and Vila (2021).

effects. Regarding credit risk, mutual funds shift toward holding more lower-rated bonds, while the opposite is true for insurers. These portfolio patterns have important implications for the pricing of duration and credit risks in the cross-section of bonds.

We find similar patterns for unconventional monetary policy, where the Fed directly purchases Treasury bonds and MBS. Mutual funds and banks, once again experiencing capital inflows, purchases more bonds that amplify the declines in long-term yields. These purchases by the Fed, mutual funds, and banks are primarily met by new issuances rather than by investors selling existing assets. When the Fed conducts QE, Treasury issuance rises by 0.72% of total market size, nearly matching the combined Treasury purchases by the Fed, mutual funds and banks, which total 0.68% of total market size. Corporate bonds and MBS follow a similar pattern, with issuances playing a dominant role in absorbing investor demand, and primary dealers having only a limited impact, particularly at annual frequencies. Finally, the effects of unconventional monetary policy on portfolio characteristics also parallel those observed under conventional monetary policy.

Informed by these stylized facts, we develop an asset demand framework to quantify the impact of investor demand shifts as well as net issuances on equilibrium bond yields. In the model, investors exhibit heterogeneous preferences for bond characteristics such as credit rating and duration, reflecting their investment mandates and regulatory constraints. Policymakers set short-term rates through conventional monetary policy and affect the supply of long-term bonds via quantitative easing or tightening. The various transmission channels are evaluated by counterfactually altering the relevant demand and supply parameters.

In order to capture the complex portfolio substitution behaviors induced by monetary policy, we depart from the existing logit or nested logit demand structures that face important limitations. More specifically, the logit demand model assumes that, in response to changes in asset prices or characteristics, such as monetary policy-induced MBS duration shortening, investors substitute proportionally across all other assets within their portfolios. We borrow

insights from the industrial organization literature and introduce random coefficients into the asset demand framework. This modeling technique relaxes the proportionality assumption and enables us to capture heterogeneous cross-elasticities. As a result, investors in our framework exhibit stronger substitutability between bonds with more similar credit ratings and duration, which is essential for transmission channels such as MBS convexity (Hanson, 2014).

The estimated demand system shows that elevated asset demand following expansionary monetary policy explains a large portion of the excess yield sensitivity puzzle. Specifically, mutual fund flows, bank deposit flows, and insurers' duration demand serve as the primary amplifiers of yield sensitivity. The model further shows that the supply side is notably elastic, particularly over longer horizons. Net bond issuance by the Treasury Department, mortgage borrowers, and corporations significantly absorbs investor demand, helping to explain why long-term yields appear excessively sensitive to monetary policy at high frequencies but less so at lower frequencies. Overall, the "helping hand" effect of monetary policy is approximately three times more influential than changes in risk-free rates in driving bond issuance. This finding underscores the critical role played by financial channels in monetary policy transmission.

Our structural framework further unveils important dynamics over time. There is a secular rise in the size of bond mutual funds compared to other investors (Ma, Xiao, and Zeng, 2025). Consistent with this trend, we find that the amplification effect of mutual fund flows on yield sensitivity to monetary policy has increased over time. Net issuance, particularly by corporations and mortgage borrowers, has become more elastic over time. In the most recent monetary tightening episode from 2021 to 2023, net issuance fell by almost twice as much as during the tightening episode from 2003 to 2006. Our results shed light on the decline of bond yield sensitivity to monetary policy over time (Hanson et al., 2021). Rather than being a sign of weakened monetary transmission, we show that the declining yield sensitivity

reflects the heightened responses from the real sector, which is a key part of policymakers' objective function.

Finally, we use our framework to analyze the transmission of unconventional monetary policies such as quantitative easing (QE). We find that investor demand channels amplify the direct effects from the Fed's purchases by a factor of two. Similar to conventional policies, QE is associated with significant inflows to mutual funds and banks, as well as increases in demand for duration, particularly from insurance companies, both of which further push down bond yields. Net issuance increases bond yields and almost entirely neutralizes the combined effects of the Fed and other investors. The dampening effects of net issuance help explain why the effects of QE are concentrated on announcement dates but revert quickly over time (D'Amico and King, 2013).

The transmission of monetary policy to bond markets has been widely studied, with existing literature identifying several key mechanisms. Some studies find that lower interest rates encourage institutional reaching for yield, leading investors to shift toward riskier or longer-duration bonds (Choi and Kronlund, 2018; Anadu, Bohn, Lu, Pritsker, and Zlate, 2019), while others show that regulatory constraints may limit such behavior (Li, 2024). Another major channel is duration hedging: as falling rates reduce the effective duration of mortgages, investors rebalance into long-term non-callable bonds, compressing yields (Hanson, 2014; Hanson et al., 2021). Liability-driven investors, such as insurance companies and pension funds, also adjust their portfolios to maintain asset-liability duration matching, further affecting bond yields (Domanski, Shin, and Sushko, 2017; Ozdagli and Wang, 2019; Greenwood and Vissing-Jorgensen, 2018; Jansen, 2023). Additionally, extrapolative mutual fund flows amplify bond yield sensitivity by reinforcing investor demand following rate cuts (Brooks et al., 2018; Fang, 2023; Darmouni, Siani, and Xiao, 2024).

Our paper advances this literature by compiling a comprehensive dataset of portfolio holdings across the largest bond investors, allowing us to use a quantity-based approach to

empirically quantify the relative importance of these channels. Using market clearing as the guiding principle, we assess how monetary policy reshapes portfolio allocation across different investor types, the term structure, and the credit spectrum. Our findings highlight the role of bond issuance and redemption dynamics in absorbing monetary shocks, underscoring that understanding monetary transmission requires going beyond yield changes and examining shifts in bond supply by the real sector.

This paper contributes to the growing literature that employs asset demand systems and granular portfolio holdings to study asset pricing (Koijen and Yogo, 2019, 2020; Koijen, Koulischer, Nguyen, and Yogo, 2021; Bretscher, Schmid, Sen, and Sharma, 2021; Fang, Hardy, and Lewis, 2024; Darmouni et al., 2024; Azarmsa and Davis, 2024; Jansen, Li, and Schmid, 2024; Chaudhary, Fu, and Zhou, 2024). Our primary contribution is extending existing logit and nested logit frameworks by introducing a random-coefficient demand model, drawing from the industrial organization literature (Berry, Levinsohn, and Pakes, 1995). This flexibility is essential us to capture key transmission channels, such as MBS convexity effects (Hanson, 2014), and provide a more nuanced view of how monetary policy reshapes bond market allocations.

Lastly, prior studies have typically focused on broad asset classes (Koijen and Yogo, 2020; Jiang, Richmond, and Zhang, 2022) or one specific segment of the fixed income market such as Treasury bonds (Jansen et al., 2024) or corporate bonds (Bretscher et al., 2021; Darmouni et al., 2024). In comparison, we construct a comprehensive security-level dataset that covers Treasury, corporate and MBS securities, which together virtually span the entire U.S. bond market. This approach allows us to capture transmission dynamics that involve multiple market segments, such as the substitution between Treasury bonds and MBS.

2 Data

2.1 Portfolio holdings

The core of our analysis relies on a comprehensive dataset of portfolio holdings. We focus on five types of bond investors for which we have granular holdings data: mutual funds, insurance companies, banks, primary dealers, and the Federal Reserve.[6] Data on mutual fund holdings come from Morningstar Direct. We include both U.S.-domiciled funds and foreign funds that focus on U.S. assets (indicated by base currency). We restrict to funds whose broad investment category is fixed income or allocation and therefore make meaningful investment in bonds.

Data on insurance company general account holdings come from NAIC statutory filings, Schedule D. Quarterly holdings are calculated using annual holdings (Part 1) and daily transactions (Part 3 and 4). We focus on those that sell life insurance or P&C insurance and exclude health insurers, which have small bond holdings.

Data on bank holdings come from call reports. Each bank reports holdings across bond classes – Treasury, agency obligations, municipal, MBS, ABS, and others – and by maturity buckets – less than 1Y, 1-3Y, 3-5Y, 5-15Y, 15Y or above. We map bank holdings to the more granular security level according to amount outstanding.

Data on primary dealer holdings come from New York Fed's Primary Dealer Statistics. The data are aggregated across all primary dealers. Similar to banks, holdings are reported by bond classes and by maturity buckets – less than 2Y, 2-3Y, 3-6Y, 6-7Y, 7-11Y, 11-21Y, 21Y or above.

[6] Our definition of mutual funds include exchange-traded funds (ETFs) and variable annuity funds, which are also open-end funds that have similar investor flow dynamics. We include both domestic funds and offshore ones that are domiciled in Ireland and Luxembourg.

Data on the Fed holdings come from System Open Market Account (SOMA) and Secondary Market Corporate Credit Facility (SMCCF). SOMA contains weekly holdings of Treasury and agency securities at the CUSIP level, from 2003 to present. SMCCF contains corporate bond holdings and transactions since 2020. Primary Market Corporate Credit Facility (PMCCF) was never actually used.

2.2 Bond securities

We collect data on three classes of bonds, which together span virtually the entire U.S. taxable bond market: Treasury bonds, corporate bonds, and mortgage-backed securities (MBS).[7] As they share similar characteristics and similar investor base, the yields of these three bond classes are tightly linked, and they should be jointly determined in equilibrium. At the same time, having a diverse set of bonds is essential for us to capture some of the transmission channels that would have been silent otherwise (e.g. MBS convexity). One key consideration is the availability of data on amount outstanding, which is required to derive equilibrium through market clearing — this why we exclude, for example, foreign bonds and private (non-144A) bonds.

Data on Treasury bonds come from CRSP. We focus on Treasury notes and Treasury bonds and treat Treasury bills as cash. We exclude flower bonds. Data on corporate bonds (including agency direct obligations) come from Mergent FISD (for characteristics) and TRACE (for pricing). We include private placement bonds under Rule 144A. We exclude convertible bonds, equity-linked bonds, preferred securities and puttable bonds. Data on agency MBS come from Refinitiv. We focus on agency pools and TBAs and exclude CMOs. We exclude foreign bonds and private (non-144A) bonds because they lack data on amount outstanding, trading, or other characteristics that are essential for our demand system analysis.

[7] We treat agency direct obligations as corporate bonds with high credit ratings. Our main results are similar if we treat agency direct obligations as a stand-alone bond class.

We take the median credit rating from S&P, Moody's, and Fitch. All Treasury bonds are AAA-rated, all agency securities are rated AA or higher, and most of corporate bonds are rated. We convert letter rating to a numeric scale from 0 (AAA) to 6 (CCC or lower). Bonds without credit rating are dropped. Our main results are robust to treating unrated bonds as having the lowest rating.

We measure duration by weighted-average life, that is, the weighted average of years to each coupon or principal payment. The calculation is straightforward for non-callable bonds. For callable bonds such as MBS, we estimate duration by simulation. Specifically, for given values of macroeconomic variables such as the short-term rate, we simulate a large set of future scenarios. For each scenario, we predict prepayments based on their historical conditional means. We take the average of realized duration across scenarios.

Bid and ask quotes are directly available for Treasury bonds through CRSP. For agency MBS, we randomly sample 10,000 CUSIPs, hand-collect their historical bid and ask quotes from Refinitiv, and assume that they represent their respective cohorts (i.e., those with the same origination year, coupon, and term). For corporate bonds, the convention is to calculate bid-ask spreads using trades. Specifically, for each bond on each date, we calculate the bid price as the average price of dealer purchases from customers and the ask price as the average price of dealer sales to customers.

The timings of early redemption can be inaccurate for corporate bonds, so we cross-check with firm-level total bond outstanding from Capital IQ and make manual corrections. For agency MBS, we randomly sample 10,000 CUSIPs, hand collect their historical amount outstanding (factor history) from Refinitiv, and assume that they represent their respective cohorts (i.e. those with the same origination year, coupon and term). For resecuritizations, such as Treasury strips and agency re-securitized mortgage-backed security (megas), we ensure not to double count them when calculating the total amount outstanding.

Figure 1 shows aggregate holdings for each investor type. It confirms that the three bond classes we consider capture the majority of these bond investors' holdings. Figure A1 shows aggregate ownership of each bond class. It confirms that the four investors we consider capture the majority of the ownership of these bonds.

3 Stylized Facts on Portfolio Adjustments in Response to Monetary Policy

In this section, we present several stylized facts on how investors' portfolios change in response to conventional and unconventional monetary policy. This is a quantities-only approach, and we will jointly study prices as well as quantities in the next section. For simplicity, we categorize investors at the sector level: mutual funds, insurance companies, banks, primary dealers, and the Federal Reserve. The remaining investors not covered by our data are labeled as the residual sector. In addition to analyzing investor behavior, we also examine net issuances of Treasuries, MBS, and corporate bonds. By market clearing, the sum of purchases (including repurchases by bond issuers) must equal the sum of sales (including new bond issuances).

We run the following quarterly time series regression for each sector and separately for Treasuries, MBS, and corporate bonds:

$$\Delta q_t = \alpha + \beta_1 \Delta r_t^{1Y} + \beta_2 \Delta q_t^{FED} + \epsilon_t \tag{1}$$

Δq denotes the year-over-year change in par amount held by the sector, scaled by the total amount outstanding of Treasuries, MBS and corporate bonds combined. Δr^{1Y} denotes the year-over-year change in the one-year Treasury rate as a proxy for the action of conventional

monetary policy.[8] Δq denotes year-over-year purchases of Treasuries and MBS by the Fed, scaled by the total bond market. We focus on active purchases and sales of bonds and exclude natural redemptions at maturity. We also exclude redemptions through the exercising of call or prepayment options. In these cases, investors are forced to sell their bonds to the bond issuers.

3.1 Changes in holding amounts

We first describe how holding amounts change following conventional monetary policy in Panel A of Figure 2. We plot $-\beta_1$, which can be interpreted as portfolio changes facing a 100 bps decline in the one-year Treasury rate. Starting at the top of the graph, mutual funds increase holdings across all classes of bonds. Specifically, their Treasury, MBS, and corporate holdings increase by 0.12%, 0.18%, and 0.19% of total market size over the same year. This is consistent with the fact that bond mutual funds tend to experience large inflows of return-chasing capital when interest rates decline (Brooks et al., 2018; Fang, 2023). As shown in Panel A of Figure 5, bond mutual funds experience significant inflows following a 100 bps rate cut, with about 2% of their AUM in the first quarter, increasing to 7% in four quarters.

Similar to mutual funds, banks experience large inflows of checking and savings deposits (Drechsler, Savov, and Schnabl, 2017; Drechsler, Savov, Schnabl, and Supera, 2024). As shown in Panel A of Figure 5, banks experience significant inflows following a 100 bps rate cut, with about 3% of their AUM in one quarter, rising to 8% in four quarters. Figure 2 shows that banks primarily invest the deposit inflows in Treasury bonds and MBS. In response to a 100 bps rate drop, banks purchase Treasury bonds and MBS equal to 0.18% and 0.20% of total market size, respectively. Banks also increase corporate bond holdings,

[8] We later use alternative measures such as changes in the Fed Funds rate target and monetary surprises as robustness.

but the size is minimal compared to the total corporate bonds outstanding.

In contrast to mutual funds and banks, insurance companies decrease their Treasury and corporate bond holdings. As shown in Figure 5, capital flows to insurers do not correlate with monetary policy because they are primarily driven by the purchase of insurance policies, which depend more on long-term demographic and economic factors rather than short-term interest rate changes. As a result, in response to rate declines, they actually reduce their Treasury and corporate holdings, suggesting that they act as liquidity providers for mutual funds and banks.

Mutual funds and banks together purchase Treasury bonds, MBS, and corporate bonds equal to 0.30%, 0.38% and 0.20% of total market size, in response to a 100 bps rate drop. Who are the sellers, so that the market clears? The existing literature emphasizes dealers' role as liquidity providers,[9] Figure 2 shows that primary dealers are actually on the same side as mutual funds and banks at annual frequency, expanding their bond holdings when rates fall. Although primary dealers are pivotal in intermediating bond transactions by matching buyers and sellers, they do not seem to absorb demand and supply imbalances at long horizon. It is also helpful to note that the size of the primary dealer sector is too small in comparison to mutual funds, banks, and insurers. For instance, primary dealers only hold 1% of the $20 trillion Treasury market. In episodes where all investors trade in the same direction, primary dealers should find it impossible to meet the entire demand.

If primary dealers do not accommodate the majority of investor demand, who takes the other side? The accounting identity that purchases must equal the sum of sales and issuance has to hold after all. It turns out that most of the demand is met through new issuances by the Treasury Department, mortgage borrowers, and corporations. When the one-year Treasury rate declines, the Treasury Department, mortgage borrowers, and corporations issue more bonds (or repurchase less), at 0.32%, 0.47%, and 0.57% of total market size. The magnitude

[9] See for instance, the class of preferred habitat models following Vayanos and Vila (2021).

is comparable to the total purchases by mutual funds and banks. It is worth emphasizing that the results here are not mechanically driven by bond issuers redeeming bonds from investors at maturity or through call or prepayment options, which we carefully exclude.

There are several ways to interpret these stylized facts. One interpretation is demand-driven: when the Fed cuts rates, capital flows into intermediaries such as mutual funds and banks, which purchase more bonds, driving up bond prices and stimulating issuance. Another interpretation is supply-driven: lower rates make borrowing cheaper, prompting mortgage borrowers and corporations to issue more debt. Additionally, the Treasury Department tends to increase bond issuance, as monetary easing often coincides with fiscal expansion. In equilibrium, investors such as mutual funds and banks must absorb these assets. In reality, both channels may be at work. We will decompose the contributions of these various channels in Section 4.

3.2 Changes in portfolio characteristics

After examining holding amounts, we turn to changes in portfolio characteristics. We run a similar quarterly time series regression for each sector, separately for Treasury bonds, MBS and corporate bonds:

$$\Delta x_t = \alpha + \beta_1 \Delta r_t^{1Y} + \beta_2 q_t^{FED} + \epsilon_t \tag{2}$$

Δx denotes year-over-year change in the weighted average of credit rating (AAA = 0, CCC = 6) or option-adjusted duration across all bonds in the portfolio. Δr^{1Y} denotes year-over-year change in the one-year Treasury rate. Δq^{FED} denotes year-over-year change in the Fed's purchases of Treasuries and MBS, scaled by the outstanding amount of Treasuries and MBS combined. In addition to investor portfolios, we also analyze changes in the characteristics of all bonds outstanding, i.e. the market, which represents the weighted average of portfolio changes across all investors.

Results on changes in credit rating are shown in Panel B of Figure 2. In response to a 100 bps rate cut, the average credit rating of all corporate bonds outstanding in the market deteriorates by 0.06 of a letter grade. Relative to this market average, mutual funds' credit rating deteriorates more, by 0.09, consistent with the reaching-for-yield behavior documented in Choi and Kronlund (2018). In contrast, the average credit rating of insurers' bond holdings improves by 0.04, consistent with the motive to preserve regulatory capital due to the increase of unhedged insurance liabilities when rates decline (Li, 2024). The economic magnitude may seem small, but it reflects a change in the average portfolio rating. For this shift to occur, the credit ratings of newly purchased bonds must differ significantly from those in existing portfolios.

Results on changes in duration are shown in Panel C of Figure 2. The most salient result is that the option-adjusted duration of MBS declines substantially, by 0.33 years on average, in response to a 100 bps rate drop. This is known as mortgage convexity (Hanson, 2014) and can be explained by the increased propensity of households to refinance their mortgages at lower interest rates. This effect is largely homogeneous across investors, as it impacts the existing bonds in portfolios rather than arising from newly purchased bonds.

While the duration of their MBS holdings declines, most investors increase the duration of their Treasury and corporate bond holdings. For example, following a 100 bps rate drop, the duration of banks' Treasury and corporate bonds increases by 0.07 years, which is substantial given the size of banks' portfolios. This is consistent with the evidence that investors have duration targets and actively adjust their bond holdings in response to duration shocks in order to stay on those targets.

Of all the investors we consider, insurance companies are the most aggressive in increasing the duration of their bond holdings. This is because, in addition to hedging the duration decline of MBS holdings, insurers also need to hedge the duration increase of their long-term liabilities, which also feature convexity (Domanski et al., 2017). As a result, in response to

a 100 bps rate decline, the duration of insurers' Treasury bonds (corporate bonds) increases by 0.18 (0.15) years, or 3.6 (1.5) times the market average increase.

Due to the simultaneity of conventional and unconventional monetary policy, the Fed purchases more Treasury bonds and MBS that are typically newly issued. As a result, the Fed's portfolio duration increases significantly more—or decreases significantly less—relative to the market.

3.3 Portfolio adjustments to unconventional monetary policy

Portfolio responses to unconventional Fed policies — direct purchases or sales of Treasury bonds and MBS — are given by β_2 of Equation 1.[10] Results are shown in Figure 3. The patterns are very similar to those observed for conventional monetary policy. As shown in Panel B of Figure 5, bond mutual funds once again receive notable inflows in response to QE, reaching about 1% of their AUM one quarter after the Fed purchases 1% of the bond market and rising to 1.5% in four quarters. This pattern is again consistent with the idea that fund investors chase positive returns resulted from QE. Given the inflows, bond mutual funds increase their purchases of Treasury bonds, MBS and corporate bonds by 0.08%, 0.09% and 0.11%, respectively.

Banks also receive inflows of about 1% in a quarter and 2% in four quarters after the Fed purchases 1% of the bond market, as shown in Panel A of Figure 5. These deposit inflows may originate from non-banks that sell assets to the Fed. Facing the inflows, banks purchase Treasuries and MBS by 0.12% and 0.08% of the total bond market. These additional purchases act as a "helping hand" that amplifies the Fed's purchase programs.

From whom do the Fed and other investors buy the bonds? Primary dealers and insurance

[10]The Fed purchased corporate bonds through Secondary Market Corporate Credit Facility (SMCCF) in 2020. We do not analyze portfolio responses to these purchases as they are too small in quantity ($14 billion at peak) and have a very short history.

companies appear to be net sellers, supplying 0.05% and 0.04% of bonds outstanding in response to 1% of Fed purchases. The majority of the supply once again comes from bond issuers—namely, the Treasury Department, mortgage borrowers, and corporations. Following a 1% increase in Fed purchases, net issuance responds as follows: Treasuries increase by 0.74%, MBS by 0.54%, and corporate bonds by 0.23% of total bond market.

Finally, we examine how portfolio characteristics change following unconventional monetary policies. Changes in portfolio characteristics are also similar to those associated with conventional monetary policy. When the Fed purchases bonds, mutual funds increase their credit risk exposure, while insurance companies do the opposite. The effective duration of MBS declines, while the duration of Treasury and corporate bonds increases for mutual funds and insurance companies, with a particularly large effect on the latter. Interestingly, unlike in conventional monetary policy, where banks lengthen the duration of Treasury and corporate bonds to counteract the decline in MBS duration, under quantitative easing, banks instead shorten the duration of their Treasury and corporate bond holdings.

3.4 Understanding net issuance

In the stylized facts above, net issuance appears to be the primary counterparty to net purchases by the Fed and other investors. While it has been documented that mortgage borrowers and corporations adjust their supply in response to market demand (Greenwood, Hanson, and Stein, 2010; Ma, 2019), it is more surprising that the Treasury Department exhibits such flexibility. After all, conventional wisdom suggests that Treasury bond issuance follows a fixed schedule driven by fiscal policy, implying that the supply of government bonds should be largely inelastic to market price fluctuations. One possible explanation for the correlation between Fed purchases and Treasury issuance is the influence of omitted variables that drive both net issuance and Fed purchases. For instance, during periods of adverse

economic shocks, both expansionary monetary and fiscal policies are typically implemented, creating a mechanical correlation between Fed purchases and Treasury issuance.

To better understand the behavior of the Treasury supply, we run the following *panel* regression using maturity bucket-quarter observations for each group of investors:

$$\Delta q_{m,t} = \alpha + \beta \Delta q_{m,t}^{FED} + \gamma_m + \gamma_t + \epsilon_{m,t} \tag{3}$$

$\Delta q_{m,t}$ denotes net Treasury issuance of a certain maturity bucket m. $\Delta q_{m,t}^{FED}$ denotes Fed net purchases of Treasury bonds in the same maturity bucket. γ_m and γ_t correspond to maturity bucket fixed effects and time fixed effects, respectively. We follow the New York Fed's Primary Dealer Statistics for maturity bucket designations: less than 2 years, 2–3 years, 3–6 years, 6–7 years, 7–11 years, 11–21 years, and 21 years or longer.[11] The inclusion of time fixed effects removes time-series variation in macroeconomic conditions that might simultaneously influence monetary and fiscal policy decisions. Consequently, the regression primarily identifies the correlation between Treasury issuances and Fed purchases in the *cross-section* of bond maturity buckets.

Results are shown in Panel A of Figure 4. In a given week, month, quarterly or year, when the Fed purchases 1% of a certain maturity bucket of Treasury bonds, the Treasury Department issues nearly exactly 1% bonds in that particular maturity bucket. Net purchases by primary dealers and other investors, including the residual sector, are negligible. These fixed-effect regressions provide further evidence that when the Fed conducts QE and purchases Treasury bonds, there are simultaneous issuances from the Treasury Department, while the holdings

[11] Measuring net purchases at the maturity bucket level presents technical challenges. Since bond maturity naturally shortens over time, bonds may migrate between maturity buckets over quarterly or annual horizons, altering holdings within a bucket even without actual trades. To address this, we track changes in holdings on a bond-by-bond basis and aggregate these changes based on the bond's maturity bucket at the end of the period. This approach ensures that our measure captures only actual changes in holdings while excluding mechanical re-classifications. Unfortunately, this method is infeasible for banks and primary dealers, who report holdings only at the maturity bucket level. Nevertheless, we will show that our results remain consistent for investors with bond-level data, regardless of whether we use raw changes in maturity bucket-level holdings.

of other investors remain largely unchanged. This finding raises questions about the overall economic significance of the portfolio rebalancing channel of quantitative easing, which posits that the Fed purchases Treasuries from investors, inducing them to reallocate into riskier corporate bonds with similar maturities. Instead, the results suggest that the Treasury Department plays a more important role in adjusting to the Fed's purchases and sales in the Treasury market.

There are two possible interpretations of the comovement between Treasury net issuances and the Fed's purchases. First, the Treasury Department may issue bonds according to a fixed schedule dictated by fiscal policy, while the Fed strategically buys or sells bonds in maturity buckets where issuance occurs. Second, the Fed may conduct unconventional monetary policy based on an exogenous rule, while the Treasury Department strategically adjusts its bond issuance in response to the Fed's demand. To shed on light on the second possibility, we examine a scenario where large shocks to Treasury demand originate not from the Fed but from the mechanical buying and selling of passive bond mutual funds. Specifically, we run the same fixed-effect regression, replacing the Fed's purchases with flow-induced purchases of passive mutual funds, following Sammon and Shim (2024):

$$\Delta q_{m,t} = \alpha + \beta \Delta \hat{q}_{m,t}^{PASSIVE} + \gamma_m + \gamma_t + \epsilon_{m,t} \tag{4}$$

$\Delta \hat{q}_{m,t}^{PASSIVE}$ denotes purchases made by passive mutual funds if they proportionally scale their existing bond holdings in response to flows. The idea is that net purchases by passive mutual funds are supposed to be particularly inelastic, as these funds are mandated to mechanically translate inflows or outflows into purchases or sales of certain types of Treasuries. For example, if there are more flows to short-term passive bond funds than long-term passive bond funds, there should be more inelastic demand for short-term versus long-term Treasury bonds.

Results are shown in Panel B of Figure 4. When passive mutual funds are predicted to purchase 1% more in a maturity bucket of Treasury bonds due to inflows, their actual purchases are indeed almost exactly 1%. Active mutual funds actually buy more of the same Treasuries, presumably due to correlated flows. At the same time, the Treasury Department issues 1.35% more bonds in the same maturity bucket. This result suggests that the supply of Treasuries is indeed quite elastic and responds to changes in market demand.

How can the Department of Treasury be flexible in its borrowing policy? While its total borrowing amount is completely dictated by the congress, the Department of Treasury has large flexibility in choosing the *structure* of its debt, between bills, notes and bonds. According to its official website, the Department of Treasury actively communicates with primary dealers and bond investors and adjusts its auction sizes to meet market demand.[12]

Finally, we also examine what happens if passive funds purchase corporate bonds using the same specification as in equation 4, as a comparison. In defining buckets for corporate bonds, we again follow the New York Fed's Primary Dealer Statistics: less than 1 year, 1-5 years, 5-15 years, and more than 15 years, interacted with investment-grade vs. below-investment-grade. Similar to the Treasury results, issuance by corporations accommodate most of these purchases. Again, primary dealers and other investors play a limited role.

[12]According to the Treasury Quarterly Refunding Process: "Treasury debt managers begin the quarterly refunding process by soliciting advice and views from the private sector through questions to primary dealers... Following the primary dealer meetings, we solicit advice from the Treasury Borrowing Advisory Committee..." Treasury Borrowing Advisory Committee (TBAC)'s membership is "comprised of senior representatives from a variety of buy and sell side institutions, such as banks, broker-dealers, asset managers, hedge funds, and insurance companies." As an example of auction adjustment, the 2020Q1 Quarterly Refunding Statement states that: "... demand for this tenor is strong and market participants have provided significant positive feedback on the security. Accordingly, Treasury is also announcing increases of $5 billion to both the new and reopened 20-year bond auction sizes starting in August."

4 Demand System Framework

The reduced-form analysis above reveals several key stylized facts about portfolio adjustments following monetary policy actions:

1. When the Fed eases monetary policy by lowering short-term rates or purchasing safe assets, mutual funds experience capital inflows and increase their bond holdings.

2. Insurance companies lengthen portfolio durations to hedge liabilities.

3. Banks engage in both activities to accommodate deposit inflows and counteract the shortening duration of mortgages

4. Dealers play limited role in absorbing the demand. The demand is absorbed by mostly bond issuance.

This section develops a demand system in the style of Koijen and Yogo (2019) to jointly analyze both prices and quantities in equilibrium. The objective is to address key questions that are difficult to study using reduced-form methods. First, what are the demand and supply elasticities of major market participants? Second, how do the actions of different players influence equilibrium bond yields and the transmission of monetary policy? Third, given the structural changes in the financial system, how has the transmission of monetary policy in the bond market evolved?

The demand system framework is particularly suited to analyzing bonds for several reasons. First, many bond investors have a direct preference for certain bond characteristics. For example, life insurance companies prefer long-duration bonds that match the long duration of their insurance liabilities. Moreover, demand can be heterogeneous—a short-term bond mutual fund can have drastically different preferences for duration than a life insurer does. Lastly, many bond investors engage in buy-and-hold strategies and can be quite price inelastic

due to regulatory reasons (e.g. Fang, 2024), so quantity changes (e.g., fund flows) can have large price impacts.

4.1 Intuition

Before introducing the details of the demand system, it is helpful to consider a simplified supply-and-demand analysis using a representative long-term bond, as depicted in Figure 6. The vertical axis plots the negative of risk premia, such as term and credit spreads, while the horizontal axis plots the quantity of bonds outstanding.

Panel A illustrates the scenario within a textbook New Keynesian model, where the financial market is frictionless and acts merely as a veil. Here, asset demand is perfectly elastic. In this scenario, a rate cut increases the supply of bonds because a lower risk-free rate reduces the cost of capital, thus stimulating investment and subsequent bond issuance. Additionally, general equilibrium effects, such as increased aggregate demand for consumption, may enhance investment returns and further stimulate issuance. However, in this scenario, risk premia remain constant, and the only influence monetary policy exerts on long-term yields is through expected short-rate changes, which is insufficient to explain the observed large sensitivity of long-term yields to monetary policy.

This suggests that asset demand cannot be perfectly elastic; thus, a downward-sloping asset demand curve, as shown in Panel B, is necessary. However, inelastic asset demand alone also cannot resolve the excess sensitivity puzzle. If a rate cut merely increases bond supply and investors have limited risk-bearing capacity, equilibrium risk premia would need to rise to incentivize additional risk-taking (moving from point a to b). This outcome contradicts empirical data, where risk premia actually decrease following a rate cut. Thus, a rate cut must simultaneously stimulate asset demand (moving from point b to c). Importantly, the outward shift in asset demand must significantly exceed the shift in bond supply to cause a

decline in risk premia. This analysis implies that the "helping hand" channel, represented by the demand curve shift, likely plays a more critical role in bond issuance than conventional channels such as risk-free rate reductions and general equilibrium effects typically highlighted in textbook New Keynesian models.

This simplified framework also helps explain the reversal of yield responses at longer horizons documented by Hanson et al. (2021). As depicted in Panel C, we consider that the supply curve is initially inelastic in the short run. Consequently, a rate cut stimulating asset demand would significantly lower risk premia, as excess demand encounters limited bond supply (moving from a to b). Over the long run, issuers respond to lower risk premia (higher bond prices) by increasing bond issuance. As supply elasticity rises, yield sensitivity diminishes (moving from b to c). Additionally, a reduction in the risk-free rate itself further stimulates bond issuance. This analysis clarifies that the long-run yield response reversal does not diminish the importance of the "helping hand" channel; instead, it indicates that the stimulative effects translate into greater economic activity.

4.2 Assets

Bonds are indexed by $n = 1, ..., N$. Each bond has par amount outstanding $S_t(n)$, yield to maturity $y_t(n)$, and a vector of characteristics $\boldsymbol{x}_t(n)$, which includes rating, duration, coupon rate, and bid-ask spread. We focus on yield instead of price because bonds with different coupons or maturities can mechanically have different prices while having the same expected returns. For callable bonds without definitive cash flows (e.g. MBS), we calculate yield by simulation, where conditional prepayment behavior is inferred through historical data.[13]

We focus on the risk premium component of bond yields. To do this, we exclude the compo-

[13]Specifically, for each period, we simulate 10,000 scenarios of one-year Treasury rate, GDP growth, and CPI inflation over the next 30 years. For each period in each scenario, we calculate the predicted prepayment conditional on the realized macro variables, based on a prepayment model estimated using historical data.

nent of bond yield due to short-term risk-free rate and its expected path, which is assumed to be exogenously controlled by the Fed and can be measured using professional forecasts (Nagel and Xu, 2024). Details of how to measure the expected short rate component of bond yields y_f are described in the Appendix. The risk premium component $\tilde{y}$ is then simply measured as the residual $\tilde{y} = y - y_f$. Term spread is simply defined as $\tilde{y}$ for Treasury bonds. Credit spread is defined as the spread between the bond and a duration-matched Treasury, as conventionally done.

Instead of individual bonds, we work with portfolios of bonds. This is because we are primarily interested in aggregate bond yields (e.g. the yields on 5-year BBB-rated bonds), which have very different elasticities from individual bond yields (Li and Lin, 2024; Chaudhary, Fu, and Li, 2022). In our baseline framework, bonds are grouped into 3 classes (Treasury, corporate, MBS), 7 rating groups (AAA, AA, A, BBB, BB, B, CCC or lower), 30 maturity groups (1 year or less, ..., 30 years or longer), 11 coupon groups (0%, 1%, ..., 10% or higher), and callability (yes vs no). For MBS, instead of grouping by remaining maturity, we group by issuance year and original term (15, 20, or 30 years), which is the standard practice. We focus on this level of portfolio aggregation to strike a balance between having a large enough cross-section to identify demand coefficients and capturing investor elasticities at the aggregate level. Working with bond portfolios also greatly simplifies computation.[14]

We treat cash and cash equivalents (including deposits, money market instruments, Treasury bills, and Treasury notes and bonds with one year or less to maturity) as the base bond ($n = 0$). The yield on cash is exogenously controlled by the Fed, so the its supply is perfectly elastic. Cash carries zero risk premium, AAA rating, zero duration, 0% coupon, and 0% bid-ask spread.

Other bonds (e.g. foreign bonds) and other assets (e.g. equities) are outside our model.

[14] At a given point in time, there are approximately 300+ Treasury CUSIPs, 30,000+ corporate CUSIPs, and 500,000+ MBS CUSIPs outstanding.

We will treat investors' allocation between U.S. bonds (including cash) and other assets as a parameter and study the effect of changing this parameter on equilibrium bond yields – for example, how bond yields would change if investors rebalance from bonds to other assets. We make the deliberate decision not to treat these outside assets as cash, which is conventionally done, because they can have large returns due to monetary policy, and treating them as yield-less cash may severely bias the results.

4.3 Investors

Investors are indexed by $i = 1, ..., I$. We focus on four types of institutional bond investors for which we have detailed data on portfolio holdings: mutual funds, insurance companies, banks, and the Federal Reserve. Banks report coarser holdings, by bond classes and maturity buckets, and we assume that their portfolio weights within each coarse category are proportional to amount outstanding. Many investors hold a small set of bonds, which is problematic for estimation. To address this, we group individual investors, resulting in 79 mutual fund groups (by Morningstar Category and by active vs. passive), 20 insurance company groups (by life vs. P&C and by size decile) and 10 bank groups (by size decile). The residual investors are grouped together, and their holdings are calculated as the difference between the combined holdings of our four investor types above and the total amount outstanding for each bond.

Following Koijen and Yogo (2019), investor i's time t portfolio weight in bond n is modeled as:

$$w_{i,t}(n) = \frac{\exp\{\alpha_{i,t} y_t(n) + \boldsymbol{\beta}'_{i,t} \boldsymbol{x}_t(n) + \epsilon_{i,t}(n)\}}{\sum_m \exp\{\alpha_{i,t} y_t(m) + \boldsymbol{\beta}'_{i,t} \boldsymbol{x}_t(m) + \epsilon_{i,t}(m)\}} \tag{5}$$

Intuitively, the portfolio weight of a bond depends on its indirect utility, which is determined by its yield $y_t(n)$, characteristics $\boldsymbol{x}_t(n)$, and latent demand $\epsilon_{i,t}(n)$. Notice how bond n's portfolio weight $w(n)$ depends not only on its own yield $y(n)$ but also on the yields of all

other bonds $\{y(m)\}$. Latent demand for cash $n = 0$ is normalized such that $\exp\{\alpha_{i,t} y_t(0) + \boldsymbol{\beta}'_{i,t} \boldsymbol{x}_t(0) + \epsilon_{i,t}(0)\} = 1$.

This original form of demand specification implies a restrictive form of portfolio substitution pattern. Specifically, we can derive the semi-elasticity of portfolio weight with respect to yield as:

$$\frac{\partial w(m)/w(m)}{\partial y(n)} = \begin{cases} \alpha(1 - w(n)) & m = n \\ -\alpha w(n) & m \neq n \end{cases} \tag{6}$$

The cross-elasticity on the second line shows that when the yield on bond n changes, all other bonds' portfolio weights change by the exact same proportion, as m does not enter the expression at all. In other words, the investor simply scales up or down the rest of her portfolio. However, in reality, we should expect that the investor primarily substitutes bond n with the bonds that have similar characteristics, and the portfolio weights of bonds with disparate characteristics should not be affected as much (Chaudhary et al., 2022).

To capture the flexible portfolio substitution pattern, we use insights from the industrial organization literature (Berry et al., 1995) and introduce random coefficients: $\boldsymbol{\beta}_{i,t} \sim N(\mu_{i,t}, \Sigma_{i,t})$. Portfolio weights in Equation 5 then become an integral over the distribution of $\boldsymbol{\beta}$:

$$w_{i,t}(n) = \int \frac{\exp\{\alpha_{i,t} y_t(n) + \boldsymbol{\beta}'_{i,t} \boldsymbol{x}_t(n) + \epsilon_{i,t}(n)\}}{\sum_m \exp\{\alpha_{i,t} y_t(m) + \boldsymbol{\beta}'_{i,t} \boldsymbol{x}_t(m) + \epsilon_{i,t}(m)\}} dP(\boldsymbol{\beta}_{i,t}) \tag{7}$$

This allows demand across bonds to be correlated based on characteristics, with the correlation controlled by Σ. The semi-elasticity of portfolio weight to yield can be derived as:

$$\frac{\partial w(m)/w(m)}{\partial y(n)} = \begin{cases} \frac{\alpha}{w(n)} \int \tilde{w}(n)(1 - \tilde{w}(n)) dP(\boldsymbol{\beta}) & m = n \\ -\frac{\alpha}{w(m)} \int \tilde{w}(m)\tilde{w}(n) dP(\boldsymbol{\beta}) & m \neq n \end{cases} \tag{8}$$

where portfolio weight conditional on demand $\boldsymbol{\beta}$ is given by $\tilde{w}(n) = \frac{\exp\{\alpha x_t(n) + \boldsymbol{\beta}' \boldsymbol{x}(n) + \epsilon(n)\}}{\sum_m \exp\{\alpha y_t(m) + \boldsymbol{\beta}' \boldsymbol{x}_t(m) + \epsilon(m)\}}$. We can see that the cross-elasticity between two bonds now depends on the *covariance* of

the portfolio weights of the two bonds, where the probability space is over $\boldsymbol{\beta}$. As a result, if two bonds have similar characteristics, their portfolio weights will have higher covariance, and their cross-substitution will be stronger.

This portfolio flexibility is essential for us to capture portfolio substitution channels such as mortgage convexity (Hanson, 2014). To illustrate, consider an exogenous reduction in the duration of MBS (e.g. due to an unexpected rate cut), prompting banks to seek substitutes. Under the standard logit demand framework, a bank would reallocate funds proportionally across its portfolio. However, in reality, banks may prefer to reallocate more heavily into long-term Treasuries to compensate for the lost duration. The random demand coefficient model allows for this more flexible portfolio adjustment, enabling investors to allocate funds disproportionately toward assets with similar characteristics.

4.4 Issuers

On the supply side, issuers decide the quantity of bonds outstanding for each bond according to the supply curve:

$$S_t(n) = \exp\{\kappa_{n,t} \log P_t(n) + \boldsymbol{\zeta}'_{n,t} \boldsymbol{x}_t(n) + \nu_t(n)\} \tag{9}$$

For each bond n, $S_t(n)$ denotes the amount outstanding, $\log P_t(n)$ denotes the log bond price, $x_t(n)$ represents bond characteristics such as credit rating and duration, and $\nu_t(n)$ represents the latent supply. The price of a bond is the sum of its periodic coupon payments and its final principal payment, discounted by yield: $P = \sum_{\tau=1}^{T} Ce^{-y\tau} + e^{-yT}$. κ is the supply elasticity. If $\kappa = 0$, then the supply of bonds is inelastic to the valuation in the market. If $\kappa > 0$, then higher valuation induces issuers to issue more.

4.5 Equilibrium

In equilibrium, market clears, meaning that the demand by investors equals the market supply for each bond. The market clearing condition is:

$$S_t(n)P_t(n) = \sum_{i=1}^{I} A_{i,t} w_{i,t}(n) \tag{10}$$

where the left-hand side represents the market value of bond n outstanding, and the right-hand side represents total demand of bond n across all investors. Market clearing applies to all bonds except for cash ($n = 0$), where the supply is perfectly elastic.

Similar to Koijen, Richmond, and Yogo (2023), we endogenize investor AUM with respect to asset prices. Bond AUM obeys the following law of motion:

$$A_{i,t} = A_{i,t-1} R_{i,t} + T_{i,t} \tag{11}$$

The first component captures changes in bond AUM due to returns:

$$R_{i,t} = \sum_{n} w_{i,t}(n) R_t(n)$$

where bond return includes both coupon payments and price changes. Note that we use portfolio weights as of the current equilibrium because we want to endogenize the effects of current portfolio weights on prices.

The second component T captures changes in bond AUM due to net purchases and is measured by changes in par values Q and prices P:

$$T_{i,t} = \sum_{n} (Q_{i,t}(n) - Q_{i,t-1}(n)) P_{t-1}(n)$$

We further separate out net purchases that are driven by flows $T^F_{i,t} = A_{i,t-1} F^{\%}_{i,t}$ and other

net purchases $T^O_{i,t} := T_{i,t} - T^F_{i,t}$, where $F^{\%}_{i,t}$ denotes flows as the fraction of the investor's total AUM that includes both bonds and non-bonds $F^{\%}_{i,t} = F^{\$}_{i,t}/A^{total}_{i,t-1}$. In other words, T^F captures changes in bond AUM if the investor proportionally scale up or down its bond portfolio in response to flows. T^O captures portfolio shift to bonds versus other assets such as equities.

4.6 Identification

Latent demand ϵ are likely correlated with yield, so we need instruments for identification. We construct two sets of instruments. The first set of instruments consists of bond characteristics, based on the standard assumption that the supply of bonds and their characteristics are exogenous to investors. We include both the bond's own characteristics and those of its peers, where a peer is defined as bonds whose rating, duration, coupon are within one standard deviation of the target bond's.

Our second set of instruments is flow-induced trading by other investors (Lou, 2012; Gabaix and Koijen, 2021). The idea is that inflows into (and outflows from) an investor create disproportionate buying (or selling) pressure on the bonds that the investor already owns ex ante (e.g., due to investment mandates). Flows to other investors, after being residualized against common factors, are therefore plausibly exogenous shocks to yields for the investor of interest. Formally, investor i's idiosyncratic flows (scaled by lagged AUM) at time t are given by residuals from a principal component regression:

$$InvestorFlow_{i,t} = a + bPC_t + \tilde{InvestorFlow}_{i,t}$$

where PC_t denotes the first principal component of flows across all investors. These investor-level idiosyncratic flows are then aggregated for each bond, excluding flows to the investor of interest:

$$FIT_{-i,t}(n) = \frac{\sum_{j \neq i} AmountHeld_{j,t-1}(n) \tilde{InvestorFlow}_{j,t}}{AmountOutstanding_{t-1}(n)} \tag{12}$$

To verify the relevance of flow-induced trading as an instrument for bond yields, we follow Koijen and Yogo (2019); Bretscher et al. (2021) and run the following OLS regression for each investor at each time:

$$y_t(n) = \tilde{\beta} FIT_{-i,t}(n) + \tilde{\gamma} Controls + \tilde{\epsilon}_{i,t}(n).$$

Table A1 shows the average t-statistics of $\tilde{\beta}$ for different investor periods and time segments. The t-statistics are, on average, significantly higher than the 5% critical value in Stock and Yogo (2005). Similar to the characteristics, we include both the bond's own flow-induced trading and its peers' flow-induced trading, with peers being similarly defined as above. These instruments, which include characteristics and flow-induced trading on the bond and its peers, are denoted by $\boldsymbol{z}(n)$.

4.7 Estimation

We first estimate the demand coefficients, which include the sensitivity to yield $\alpha_{i,t}$ and the sensitivity and its dispersion to characteristics $(\boldsymbol{\mu}_{i,t}, \Sigma_{i,t})$ for each investor at each time. To simplify computation, we restrict Σ to be a diagonal matrix and only allow random coefficients on rating and duration. Because identification primarily comes from changes in demand over time Nevo (2000), we include not only the investor's current holdings but also their holdings in the quarter before and the quarter after. We closely follow the estimation procedure in Berry et al. (1995) and describe the details in the Appendix.

Figure A2 and Table 2 show our estimated demand coefficients. The mean coefficients $\boldsymbol{\mu}$ exhibit expected regularities.[15] High-yield funds have higher coefficients on credit rating

[15] The mean coefficients $\boldsymbol{\mu}$ can be roughly interpreted as semi-elasticities. For example, if a bond's duration increases by 1 year, its portfolio weight in a long-term bond fund's portfolio is expected to increase by 10-30% (e.g., from 1% to 1.1-1.3%). However, we note that the precise semi-elasticities vary from bond to bond depending on its substitutability, as can be seen from the integral in Equation 8.

(i.e. more credit risk) than investment-grade funds. Long-term funds have higher coefficients on duration than short-term funds. Insurance companies have low credit rating coefficients, similar to investment-grade funds, reflecting the fact that they are subject to rating-based capital regulation. Life insurance companies have high duration coefficients and high coupon coefficients, reflecting the characteristics of life insurance and annuity liabilities. Banks have low coefficients on the bid-ask spread, especially after the 2008 financial crisis, reflecting the increased stringency of bank liquidity regulations.

Our estimation shows that within-portfolio demand variation Σ is economically meaningful. For almost all investors and for both rating and duration, σ is well above zero and similar in magnitude to the mean coefficient. This means that, for example, life insurance companies not only prefer long-duration bonds *on average*, but also exhibit varying preferences *within each portfolio construction*. They sometimes tilt towards bonds with short duration (e.g., to match short-duration products sold, such as group term life insurance) and sometimes tilt towards bonds with long duration (e.g., to match long-term annuities and other products sold with distant payoffs).

Yield coefficients α are small and sometimes negative due to the valuation effect.[16] To better

[16]Consider an investor who is completely inelastic to yield; when a bond's yield increases, its price decreases, and its portfolio weight declines, resulting in the yield coefficient appearing as negative. This value effect is particularly pronounced for long-duration bonds, so α is mechanically lower for long-term investors than for short-term investors.

understand their economic magnitude, we calculate price elasticities based on Equation 8[17]:

$$\frac{\partial q(m)/q(m)}{\partial p(n)/p(n)} = \begin{cases} -1 - \frac{100\alpha}{w(n)d(n)} \int \tilde{w}(n)(1-\tilde{w}(n))dP(\boldsymbol{\beta}) & m = n \\ \frac{100\alpha}{w(m)d(n)} \int \tilde{w}(m)\tilde{w}(n)dP(\boldsymbol{\beta}) & m \neq n \end{cases} \tag{13}$$

The equation shows that price elasticity varies across pairs of bonds. Indeed, a key feature of our framework is that cross-elasticities can vary depending on the bonds' similarity in characteristics. Bonds with similar characteristics exhibit higher covariance in conditional portfolio weight $\tilde{w}$, which leads to increased cross-substitution. Instead of presenting cross-elasticities for all millions of pairs of bonds, we group bonds by rating letters (AAA, AA, ..., CCC) and duration buckets (1-3Y, 3-5Y, ..., 15-30Y) and calculate the average cross-elasticities.

Table 3 shows estimated own-price and cross-price elasticities, averaged across bonds and bond pairs with the given rating letters or duration buckets and separately for mutual funds, insurance companies, or banks over time. The diagonal numbers show own-price elasticities according to Equation 13, with $m = n$. Own-price elasticities are almost always negative and generally less than 5 in magnitude. Mutual funds and banks have the largest own-price elasticities, whereas insurers have the smallest price elasticities. The average own-price elasticity across funds, insurers, and banks, weighted by their AUM, is -2.17. The average elasticity without funds is -1.22, meaning that a 1% mutual fund flow-induced demand shock implies -0.82% return, or +8.2 bps in 10-year bond yield. Our estimated price elasticity is very similar to that of Chaudhary et al. (2022), who finds that the average price elasticity

[17] Similar to Bretscher et al. (2021), portfolio weight $w(m)$ and amount of par value held $q(m)$ are connected through:

$$w(m) = p(m)q(m)/A$$

and bond n's duration $d(n)$ approximates the relationship between yield and price:

$$\frac{d(n)}{100} = -\frac{\partial p(n)/p(n)}{\partial y(n)}$$

(the reciprocal of price multiplier) is 0.8 at the level of coarse rating × short/medium/long-term maturity portfolios and 3 at the level of detailed rating *times* quarters to maturity portfolios. Our portfolios at the coarse rating × years to maturity × rounded coupon rate level is in the middle, and our estimated price elasticity is also in the middle.

The off-diagonal numbers show cross-price elasticities according to Equation 13, with $m \neq n$. More specifically, the cell in row m and column n shows the percent change in the holding of a bond in row m due to a one-percent change in the price of a bond in column m, averaged across all bond pairs with the given combinations of rating letters or duration buckets. As a key feature of our innovation to incorporate random coefficients, cross-elasticities vary significantly across bond pairs. Notably, the largest cross-elasticities occur close to the diagonal. This means that cross-elasticities are largest among bonds that are most similar in rating or duration. This localized substitution pattern has been demonstrated to be a key feature of the bond market (Chaudhary et al., 2022) and, to the best of our knowledge, we are the first to achieve this in a structural model, through the incorporation of random coefficients.

To illustrate the difference with the original fixed coefficient framework, we calculate the same elasticity tables when demand coefficients β are fixed at their means μ. In other words, coefficient variation σ is set to zero. Table A2 shows that, consistent with the prediction in Equation 6, fixed coefficients produce rigid homogeneous cross-substitution, as the cross-elasticity numbers are essentially invariant for each column.[18]

We next discuss the supply elasticity estimates. We take log and then first difference of the supply equation (9). We estimate the price elasticity of net issuance through the following

[18] Cross-elasticity is not exactly the same within each column because of variation in group composition and duration adjustment (Equation 13).

regression, run separately for each class of bonds:

$$\Delta \log S_t(n) = \kappa \Delta \widehat{\log P_t}(n) + \zeta' x_t(n) + \nu_t(n)$$

where, for each bond portfolio n, $\Delta \log S_t(n)$ denotes the log change in the amount outstanding, $\Delta \widehat{\log P_t}(n)$ denotes the log change in yield instrumented with contemporaneous flow-induced trading (Equation 12), and $x_t(n)$ represents bond characteristics such as credit rating and duration.

Panel A of Figure A3 shows the average price elasticity for all sectors. Panel B scales price elasticity by the size of each sector, which provides a clearer understanding of each sector's contribution to total market elasticity. Existing literature often focuses on the role of dealers in meeting investors' demand. However, their small scale limits their contribution to overall market elasticity even though they exhibit high elasticity relative to their own assets under management (AUM). In contrast, issuers are quantitatively more important in contributing to the total market elasticity due to the large size of the issuance. Even without scaling by size, bond issuance elasticity remains comparable in magnitude to demand elasticity, which echos the existing evidence that governments, households, and corporations react significantly to credit market conditions (e.g. Greenwood et al., 2010; Ma, 2019).

4.8 Decomposition

The market clearing condition (10) presents the equilibrium yields $\boldsymbol{y}$ as an implicit function of investor AUM $\boldsymbol{A} = \{A_i\}$, investor demand coefficients $\boldsymbol{\Theta} = \{(\alpha_i, \boldsymbol{\mu}_i, \Sigma_i)\}$, investor latent demand $\boldsymbol{E} = \{\epsilon_i(n)\}$, bond characteristics $\boldsymbol{X} = \{\boldsymbol{x}(n)\}$, and bond amount outstanding $\boldsymbol{S} = \{S(n)\}$:

$$\boldsymbol{y} = \boldsymbol{g}(\boldsymbol{A}, \boldsymbol{\Theta}, \boldsymbol{E}, \boldsymbol{X}, \boldsymbol{S}). \tag{14}$$

We use the following procedures to derive counterfactual market-clearing bond yields numerically. First, we take an initial guess at yields $\boldsymbol{y}$ (e.g., the actual yields from the last period). Then, given bond characteristics $\boldsymbol{X}$, investor demand coefficients $\boldsymbol{\Theta}$, and latent demand $\boldsymbol{E}$, we obtain portfolio weights $\{w_i(n)\}$. Given bond investor AUM $\boldsymbol{A}$ and portfolio weights $\{w_i(n)\}$, investors' total dollar demand for bond n is $\sum A_i w_i(n)$, the right-hand side of Equation 10. If total investor demand is higher (lower) than market value of bond supply, the yield needs to be adjusted downward (upward) to close the gap.

We perform an empirical decomposition of bond yield changes into different channels, following Koijen and Yogo (2019). For each channel c, we derive the market-clearing bond yields before and after its change while holding all other channels fixed:

$$\Delta \boldsymbol{y}_t(c) := \boldsymbol{g}(c_t, -c_{t-1}) - \boldsymbol{g}(c_{t-1}, -c_{t-1}) \tag{15}$$

where c refers to the channel of interest and $-c$ refers to the collection of all other channels. For example, to quantify changes in yields from $t-1$ to t that are due to changes in amount outstanding $\boldsymbol{S}$, we separately feed the model $\boldsymbol{S}_{t-1}$ and $\boldsymbol{S}_t$ while holding all other parameters ($\boldsymbol{A}$, $\boldsymbol{\Theta}$, $\boldsymbol{E}$, $\boldsymbol{X}$) fixed at their values as of $t-1$, and we calculate the market-clearing bond yields $\boldsymbol{g}(\boldsymbol{A}_{t-1}, \boldsymbol{\Theta}_{t-1}, \boldsymbol{E}_{t-1}, \boldsymbol{X}_{t-1}, \boldsymbol{S}_{t-1})$ and $\boldsymbol{g}(\boldsymbol{A}_{t-1}, \boldsymbol{\Theta}_{t-1}, \boldsymbol{E}_{t-1}, \boldsymbol{X}_{t-1}, \boldsymbol{S}_t)$ from Equation 14. The differences $\Delta \boldsymbol{y}_t(\boldsymbol{S})$ are attributed to changes in amount outstanding $\boldsymbol{S}$.

Changes in bond AUM come from bond returns or changes in par amounts. Bond returns are driven by changes in expected short rates y_f — which are exogenously controlled by the Fed — or changes in risk premium $\tilde{y}$ — which are endogenous and characterized in Equation 11. For the counterfactual analyses, we focus on changes in par amounts and further separate out flow-induced net purchases T^F and other net purchases T^O, as described in Section 4.5. Intuitively, T^F shows changes in bond AUM if the investor proportionally scales up or down its bond portfolio in response to flows. Any remaining changes in bond AUM T^O represent

the allocation between bonds and other non-bond assets (e.g., equities).

We can further refine the decomposition to capture heterogeneity across investors and across bonds. For example, we calculate yield changes separately for mutual fund flows, insurance company flows, and bank flows. As another example, rather than lumping together yield changes due to all demand changes, we partition yield changes into changes in demand coefficients on 1) credit rating, 2) duration, 3) coupon rate, and 4) bid-ask spread.

Changes in credit ratings are reflected in the reconstitution of bond portfolios based on updated ratings while keeping all other bond characteristics unchanged. For example, suppose there is a widespread credit migration from AA to BB; in this case, the amount outstanding of the AA portfolios would shrink, while that of the BB portfolios would expand. Bonds that are redeemed during the process are assumed to have unchanged ratings and bid-ask spreads.

Bonds mature over time, so duration naturally shortens, and amount outstanding naturally disappears at maturity. We focus on "active" changes in duration, defined as duration changes for callable bonds (e.g. MBS) due to changes in conditional prepayment rates. We pool together the natural maturing process with changes in the amount outstanding (e.g., new issuance and early redemption). To see why, suppose that there is a representative firm that borrows equally across the maturity spectrum, from 1 year to 30 years. This means that every year an equal amount of bonds will mature, an equal amount of new 30-year bonds will be issued, and duration shortens by 1 for all other bonds. In this case, it is clear that the amount outstanding is constant, and we should not separate natural redemption from new issuance.

5 Dissecting Monetary Transmission to Bond Yields

With our demand system framework laid out in the previous section, we set out to measure how much each channel (e.g. changes in investor demand for duration) contributes to the sensitivity of bond yields to short rates (i.e. one-year Treasury rates). The contribution of channel c to yield sensitivity to monetary policy is measured through the following regression:

$$\Delta y_t(c) = \alpha + \beta \Delta r_t + \gamma X_t + \epsilon_t \tag{16}$$

where $\Delta y_t(c)$ denotes year-over-year changes in aggregate yields (e.g. averaged across Treasury bonds with 10-year duration) attributable to channel c according to Equation 15, Δr_t year-over-year changes in the one-year Treasury rate, and X_t macroeconomic variables including contemporaneous GDP growth, inflation rate, unemployment rate changes, and changes in VIX. We focus on year-over-year changes (e.g., from 2010Q2 to 2011Q2) because some channels, such as fund flows, operate at relatively low frequency. Standard errors are adjusted for serial correlation with four lags (Newey and West, 1994).

5.1 Term spread

Figure 7 presents our decomposition of the monetary sensitivity of the 10-year term spread, defined in Section 4.2 as 10-year Treasury yield minus the expected short rate component. Panel A shows the contributions by each channel. The black bar on the right displays the observed sensitivity of the 10-year term spread to monetary policy: consistent with the existing literature, a 100 basis point increase in the one-year Treasury yield is associated with a 41 basis point increase in the 10-year term spread at the quarterly frequency, and a 20 basis point increase at the annual frequency. There are two puzzles be addressed: how does monetary policy affect term premia and generate the excess sensitivity of long-term

yields, and why it diminishes at low frequency.

The remaining red and blue bars in Panel A represent estimated contributions from specific channels, where red (blue) indicates a positive (negative) contribution. These effects accumulate from left to right; the top of a red bar or the bottom of a blue bar reflects the cumulative contribution up to that point. For instance, the top of the red bar labeled "Other" captures the total contribution of all preceding channels. Figure A4 provides a more granular breakdown by investors and by characteristics.

Investor flows are a leading factor in amplifying the monetary sensitivity of bond yields, increasing the term spread sensitivity by 27 basis points. Demand for characteristics also amplifies the sensitivity by 16 basis points, primarily through duration demand (14 bps), with an additional effect from coupon rate demand (3 bps). Allocation between bonds and other assets slightly dampens sensitivity by 5 basis points. Changes in characteristics amplify sensitivity by 10 basis points, largely due to the duration effect of callable bonds (14 bps). In contrast, net issuances of bonds substantially dampen sensitivity, reducing it by 32 basis points. During monetary easing (tightening), bond issuance increases (decreases), raising (lowering) bond yields and offset demand-side pressures.

Panel B provides a further decomposition of demand-side channels by investor type – bond funds, balanced funds, life insurers, P&C insurers, and banks. Each demand channel is represented by a colored bar, stacked vertically within each investor category. Channels that amplify yield sensitivity appear above the horizontal axis; those that dampen it appear below. Unlike Panel A, the effects in Panel B are not accumulated from left to right. The net contribution of each investor type is given by the difference between bars above and below the axis.

Investor flows are primarily driven by bond mutual funds (13 bps) and banks (11 bps). During monetary easing (tightening), these investors receive large inflows (outflows), creating

significant buying (selling) pressure (Drechsler et al., 2017; Fang, 2023; Darmouni et al., 2024). Balanced funds are the main contributors to the dampening effect from allocation, as their flexible mandates lead them to rebalance toward (away from) equities when bond prices rise (fall) during monetary easing (tightening) (Lu and Wu, 2023). The amplification from demand for duration largely comes from life insurance companies. As monetary policy eases (tightens), the duration of liabilities lengthens (shortens), prompting these investors to adjust the duration of their bond holdings accordingly (Domanski et al., 2017; Ozdagli and Wang, 2019). All investors, in particular banks, tilt towards long-term banks when duration on callable bonds shortens.

Panel C reports the decomposition of demand and supply-side channels for each maturity bucket. The format is similar to Panel B, except that the observed sensitivity in the data is shown as a black line. Consistent with existing literature (e.g. Hanson and Stein, 2015), the black line indicates that monetary policy has a large effect on term spreads many years into the future. The effect is hump-shaped, with a slightly higher impact in the 5-10 year range, but remains above zero for durations beyond 15 years.

The colored bars show contributions from the top channels and suggest that the importance of a channel is heterogeneous across durations. Investor flows are more important for short-duration term spreads than for long-duration term spreads, reflecting the fact that mutual funds and banks invest more in short-duration bonds compared to other bond investors, such as insurance companies.

Demand for duration is more important for long-duration term spreads and can even have a negative contribution to short-duration term spreads. This is likely because when insurers and pension funds reach for duration, they simultaneously sell short-term bonds and buy long-term bonds, which twists the term structure instead of lifting it upwards everywhere.

Duration changes mainly amplify monetary sensitivity in the 5-10 year range. This is because

callable bonds, such as MBS, have a median duration of 7.53 (Table 1), so changes in their duration mainly affect bonds in the nearby duration. During monetary easing (tightening), the duration of callable bonds decreases (increases), which leads to portfolio substitution towards (away from) other bonds with a 5-10 year duration, pushing down (up) their yields.

The effect of net issuances is concentrated in the 5-15 year range, which coincides with the most common duration of new issuance of corporate bonds. The effect of the amount outstanding is lowest in the shortest-duration range. This is partially because, during monetary easing, firms and households issue new long-term bonds to preemptively refinance bonds that are about to mature, which lowers the amount outstanding of short-duration bonds and lowers their yields.

5.1.1 Quarterly v.s. annual frequency

In addition to the year-over-year frequency, we show our yield sensitivity decomposition at the quarter-over-quarter frequency in Panel A of Figure 8. Issuance plays a much smaller role at the quarterly frequency. This limited short-run dampening effect helps explain why long-term yields exhibit greater sensitivity in the short run. Taken together, our results provide a coherent explanation for both of the puzzles we highlighted at the beginning of the section: following a rate cut, demand for long-term bonds rises, but the supply response is delayed, leading to a sharp decline in long-term yields in the short run. As issuance gradually increases, the yield movement partially reverses.

This finding has important policy implications. Without accounting for issuance, one might conclude that the long-run reversal implies that the large impact of monetary policy on long-term yields is merely a liquidity effect, gradually eroded by arbitrage over time. For example, Hanson et al. (2021) write, "Our findings suggest that the recruitment channel may not be as strong as Stein (2013) speculates since a portion of the resulting shifts in term

premia are transitory..." A key implication of our result is that the reversal actually reflects a substantial impact of monetary policy on bond issuance, which aligns with the objectives of policymakers.

One might ask whether sophisticated investors, such as dealers, could anticipate future issuance and price in the expected supply increase, thereby preventing large short-run yield movements. As Panel B of Figure A3 shows, dealers are too small to absorb the excess demand from other investors. As a result, it is difficult to fully arbitrage away the supply–demand imbalances that generate excess short-run sensitivity and the subsequent long-run reversal of long-term yields.

5.1.2 Early v.s. late period

The financial system has undergone significant structural changes—for instance, the bond mutual fund sector has expanded rapidly in recent decades. It is natural to expect that the strength of these transmission channels can vary over time, contingent upon different levels of the underlying state variables. To analyze *changes* in different transmission channels over time, we split the sample in half: one from the beginning of 2003 to the end of 2012, and the other from the beginning of 2013 to the end of 2022. We perform our decomposition exercise separately for these two periods.

Panel B of Figure 8 shows the results. The amplification effects from bond mutual funds have increased significantly in the latter half of our sample, from 8 to 19 basis points. This reflects the secular rise of bond mutual funds relative to insurance companies and banks (Ma et al., 2025).[19] Consequently, changes in the short-term rates are associated with larger quantities of flow-induced bond demand relative to bonds outstanding.

[19] One reason for the growth of mutual funds is the secular shift from defined-benefit to defined-contribution pension plans, where retirees directly select mutual funds in their 401k accounts, instead of delegating to a pension manager.

The dampening effect of net issuances has almost doubled, from -22 to -38 basis points. Bond issuance by corporations and mortgage borrowers has become more sensitive to market conditions, which counteracts the amplification effects from investors. As a result, the net effect of investor demand and net issuance has declined over time, from 27 basis points in the first half of our sample to 19 basis points in the second half of our sample. Our results provide an explanation for the puzzling findings in Hanson et al. (2021) regarding the decline of bond yield sensitivity to monetary policy at an annual frequency. Rather than a sign of weakened monetary transmission, we show that the decline in yield sensitivity is partly attributable to the increase in issuance sensitivity, a sign of strengthened transmission to the real sector.

5.2 Credit spread

Figure 9 shows our decomposition of monetary sensitivity for the 10-year BBB credit spread, which is the difference between the average yield of 10-year BBB-rated corporate bonds and the average yield of 10-year Treasury bonds. Panel A presents the observed sensitivity of the credit spread to monetary policy (black bar) and the estimated contributions from specific channels (red for positive, blue for negative). These contributions are accumulated from left to right, with the top or bottom of each bar reflecting the cumulative effect up to that point.

Investor flows amplify the sensitivity of credit spreads by 3 basis points, as shown by the first red bar in Panel A. Demand for characteristics also contributes meaningfully, increasing sensitivity by 4 basis points. In contrast, issuance significantly dampens sensitivity. The effect is large enough that the cumulative contribution of all channels results in a negative overall sensitivity—meaning that a rate cut leads to a widening of credit spreads. This pattern matches the empirical sensitivity shown by the black bar and suggests that, in the pricing of credit risk, the supply curve shifts more than the demand curve.

Panel F of Figure A5 further decomposes the issuance channel by bond class. It reveals

opposing effects from corporate and government bond supply. During monetary easing (tightening), corporations issue more (fewer) bonds, which raises (lowers) credit spreads and reduces overall sensitivity. In contrast, governments and government-sponsored mortgage borrowers—who bear minimal credit risk—also increase (decrease) issuance, widening the gap between risk-free and corporate yields.

Panel B of 9 breaks down the demand-side channels by investor type. Each demand channel is represented by a colored bar, stacked within investor categories. Net contributions are measured vertically—the difference between bars above and below the horizontal axis—and are not accumulated from left to right. Panel B shows that the amplification from investor flows is primarily driven by active mutual funds. This contrasts with the term spread case, where both mutual funds and banks contributed, since banks hold relatively few corporate bonds and thus play a smaller role here.

Demand for characteristics in Panel B, particularly for credit ratings, exhibits heterogeneous effects across investor types. During monetary easing, life insurers reduce credit risk exposure due to tighter regulatory constraints (Li, 2024), dampening sensitivity. In contrast, mutual funds tend to shift toward lower-rated bonds to "reaching for yield" (Choi and Kronlund, 2018), which compresses credit spreads and amplify their sensitivity to monetary policy. Orthogonal to credit rating, investors appear tilt towards high-coupon bonds to "reach for income" (Daniel, Garlappi, and Xiao, 2021).

Panel C shows monetary sensitivity across the credit spectrum, from AAA to CCC or lower. Here we focus on bonds with a 5-year duration, as there are few speculative-grade bonds with longer durations.[20] The observed monetary sensitivity, represented by the black line, is mostly negative and downward sloping with respect to credit risk. This is consistent with the negative correlation between credit spreads and risk-free rates (e.g. Duffee, 1998).

[20] A typical speculative-grade bond is issued with 10 years to maturity and 7.8 of duration.

The colored bars indicate that the impact of a channel can exhibit significant heterogeneity across the credit spectrum. The effect of investor flows concentrates on A-rated and BBB-rated bonds. This reflects the fact that during monetary easing (tightening), there are substantial inflows to (outflows from) investment-grade bond funds, but not as much to high-yield bond funds (Fang, 2023). Insurer demand for credit ratings increases the sensitivity of A-rated bonds to monetary policy and decreases the sensitivity of other lower-rated bonds. During monetary easing, insurers become more constrained by regulatory capital and tilt towards bonds with lower regulatory charges, and A-rated bonds offer the highest yields while still having relatively low regulatory charges (Becker and Ivashina, 2015). Net issuances have a large negative effect on the credit spread sensitivity to monetary policy across the credit spectrum. The effect is largest for BB-rated firms, reflecting the combined forces of: 1) the issuance and redemption of these firms being highly sensitive to monetary policy; 2) the weak substitution between BB-rated bonds and other bonds, which means quantity shocks can have particularly large price effects.

5.3 Bond issuances

This section quantifies the importance of the "helping hand" channels relative to traditional textbook channels of monetary policy transmission, such as those operating through the risk-free rate and general equilibrium effects. As illustrated in Panel B of Figure 6, the "helping hand" channel – driven by bond investors – is represented by shifts in the demand curve, while the risk-free rate and general equilibrium effects are reflected as shifts in the supply curve.

In response to 100 bps decrease in one-year Treasury rate, 10-year bond yield is expected to decrease by 16 bps, solely due to changes in current and expected short rates. Figure 7 shows an additional 48 bps decrease in 10-year term spread due to investor demand and changes in

bond characteristics (e.g. MBS duration). Figure 9 shows that the "helping hand" channels contribute another 7 bps to the decrease in 10-year credit spread.

Figure 10 estimates how much corporate bond issuances are associated with these yield changes, based on estimated issuance elasticity in Table A3. In response to a 16 bps decline in the 10-year yield due to changes in the expected risk-free rate, corporate issuance is expected to increase by $0.16 \times 6 \times 0.447 = 0.43\%$, where 6 is the average bond duration and 0.447 is the estimated supply elasticity. This 0.43% represents the portion of issuance attributable to the expected path of the risk-free rate. Similarly, issuance driven by investor demand through term spreads is $0.48 \times 6 \times 0.447 = 1.29\%$, and issuance driven by credit spreads is $0.07 \times 6 \times 0.447 = 0.19\%$. The contribution of other transmission channels – such as general equilibrium effects – is captured by the residual between the observed issuance sensitivity to monetary policy of 1.97% (the black bar) and the sum of the above components: $1.97\% - 0.43\% - 1.29\% - 0.19\% = 0.06\%$.

Two key takeaways emerge. First, the "helping hand" channel is approximately three times as large as the effect of the risk-free rate. This result is robust and does not depend on specific supply or demand elasticity estimates—it follows directly from the decomposition of the yield response to monetary policy into risk-free and risk premia components. Second, although our framework cannot directly quantify general equilibrium effects, the residual suggests there is limited scope for them to play a major role.

5.4 Dissecting unconventional monetary policies

In this sub-section, we use our framework to dissect the transmission of quantitative easing (QE). There have been four QE episodes:

- QE1: from November 2008 to March 2010, $300 billion Treasury bonds, $1,250 billion

agency MBS, and $175 billion agency direct obligations

- QE2: from November 2010 to June 2011, $600 billion Treasury bonds
- QE3: from September 2012 to October 2014, $790 billion Treasury bonds and $823 billion agency MBS
- QE4: from March 2020 to March 2022, $3,000 Treasury bonds and $1,200 agency MBS

In order to make the different episodes comparable to each other, we rescale everything to correspond to bond purchases that equal 1% of the total market outstanding. For the four episodes, 1% of the market outstanding is $149 billion, $204 billion, $234 billion, and $336 billion, which corresponds to 9%, 34%, 15%, and 8% of the actual purchases, respectively. We apply these scaling factors to the estimated total contributions from different channels. For example, for QE1, we derive bond yield changes due to total investor flows during the episode, apply the scaling factor of 9%, and define the product as the contribution from investor flows to bond yield changes in response to QE1.

We focus on the first half of each QE episode to exclude changes in expectations of future policies. For example, during a congressional hearing in May 2013, which took place in the middle of QE3, the Fed Chair Ben Bernanke disclosed the intention of tapering future asset purchases. This announcement led to large bond fund outflows and significant increases in bond yields, a phenomenon known as the "Taper Tantrum."

Figure 11 shows the results. The gray bars on the right indicate term spread changes attributable to decreases in the amount outstanding solely due to Fed purchases, while all other channels (e.g., investor AUM) are held constant at their values at the beginning of each episode. They show that, when the amount of bonds outstanding decreases by 1% due to Fed purchases, the term spread decreases by 26-32 bps. The magnitude depends on two factors: the specific assets purchased and aggregate investor elasticity. Investor elasticity is

lower during crisis periods, leading to significant yield changes per unit of Fed purchase.

The other colored bars show contemporaneous yield changes attributable to, respectively, investor flows, demand for duration, changes in callable bond duration, and changes in the amount outstanding due to issuance and redemption. It is clear that the total effect of QE depends not only on the Fed's purchases themselves but significantly on the other channels we consider. When the Fed's purchases push down long-term yields, they can lead to return-chasing retail inflows to mutual funds and banks, an increase in the duration of insurance or pension liabilities, a shortening of the duration of callable bonds, and more bond issuance, similar to the effects of decreases in short-term interest rates. These changes in demand and supply, in turn, exert further pressure on bond yields.

The strengths of these channels vary considerably over the four episodes. For example, investor flows amplify rate declines by another 16 bps during QE1; this number drops to 7 and 8 for QE2 and QE3, and it soars to 32 for QE4. This is because: 1) investor elasticity is considerably smaller during crisis periods, and 2) inflows to bond mutual funds and banks were particularly large in 2009 and 2020. The results here echo our earlier findings with conventional monetary policy and emphasize the state dependency of how demand and supply channels respond to monetary policy.

In summary, we quantify yield changes attributable to different channels in response to direct bond purchases by the Federal Reserve. The direct effect from changes in the amount outstanding is relatively small compared to the total effects resulting from changes in investor demand or issuer supply.

6 Conclusion

In this paper, we use portfolio holdings data to dissect the bond market transmission of monetary policy. We document several stylized facts regarding the transmission of monetary policy through investors' portfolios. In response to expansionary monetary policy, mutual funds increase bond purchases driven by capital inflows, insurance companies extend portfolio duration to hedge liabilities, and banks engage in both strategies to manage deposit inflows and counteract the duration shortening of mortgages. This additional investor demand reinforces the Fed's influence on long-term yields, acting as a "helping hand." The resulting excess demand is largely met by new issuance from the Treasury, mortgage borrowers, and corporations, while primary dealers play a more limited role. The demand and supply responses happen at different speeds, which explains the twin puzzles of the excess sensitivity of long-term yields and the long-run reversal. We argue that the long-run reversal does not imply the effect is merely transitory or unimportant. Rather, it reflects an active supply-side response: borrowers take advantage of lower yields by issuing more debt, which gradually offsets initial price pressure. Far from diminishing the macroeconomic impact of monetary policy, this response is a key part of its transmission—one that aligns with the objectives of policymakers.

To quantify these effects, we estimate a random-coefficient asset demand system using the full panel of portfolio holdings. We find that flows to mutual funds and banks, preferences for credit ratings and duration, and changes in callable bond duration all significantly contribute to the yield response. These effects vary across the term structure and credit spectrum, depending on time-varying factors such as investor composition and elasticity. Overall, the "helping hand" effect of monetary policy is three times as important as changes in risk-free rates in driving bond issuance.

Our findings highlight the importance of the financial channels of monetary policy trans-

mission. They suggest that the impact of monetary policy on bond markets is not solely determined by direct interest rate changes but is also shaped by the responses of different investor classes. The heterogeneity in investor behavior, combined with the interaction between portfolio adjustments and bond issuance, underscores the complexity of monetary policy's effects on financial markets. Future research could further explore how these mechanisms evolve under different macroeconomic conditions and regulatory environments, as well as their implications for financial stability and policy design.

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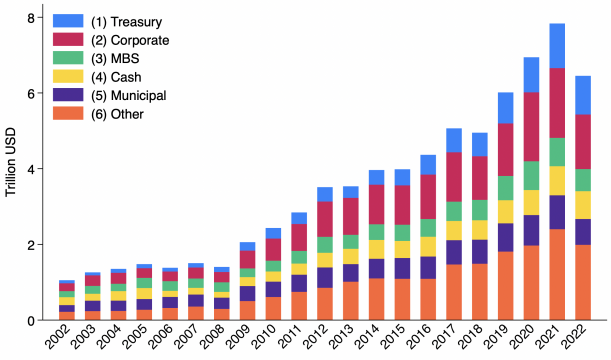
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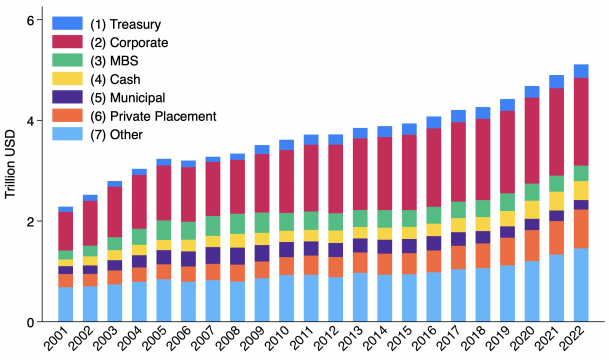
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Figure 1: **Investor Holdings.** The figures show holdings by the investors for which we have granular portfolio data: mutual funds and ETFs, insurance companies, banks, primary dealers, and the Federal Reserve. We focus on securities holdings and exclude holdings of real estate, mortgages and loans.

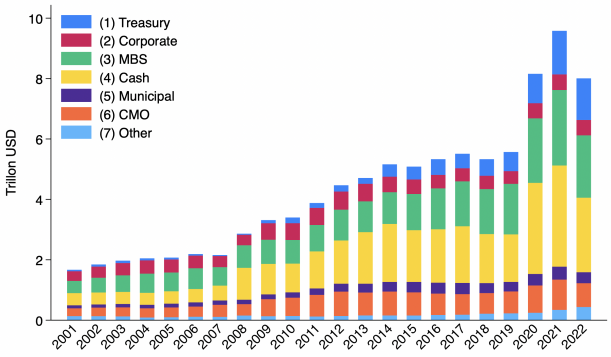
Panel A: Fixed Income Funds



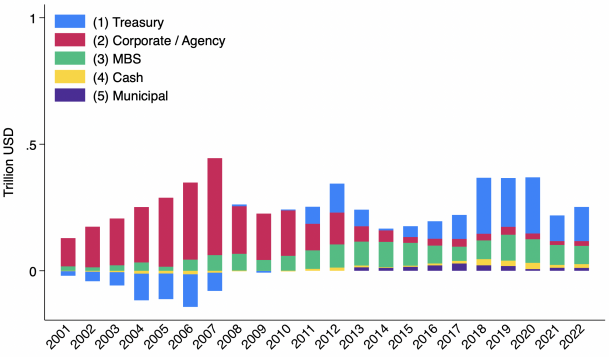
Panel B: Insurance Companies



Panel C: Banks



Panel D: Primary Dealers



Panel E: Federal Reserve

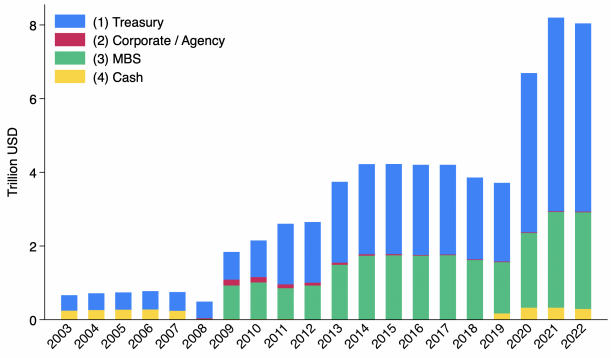
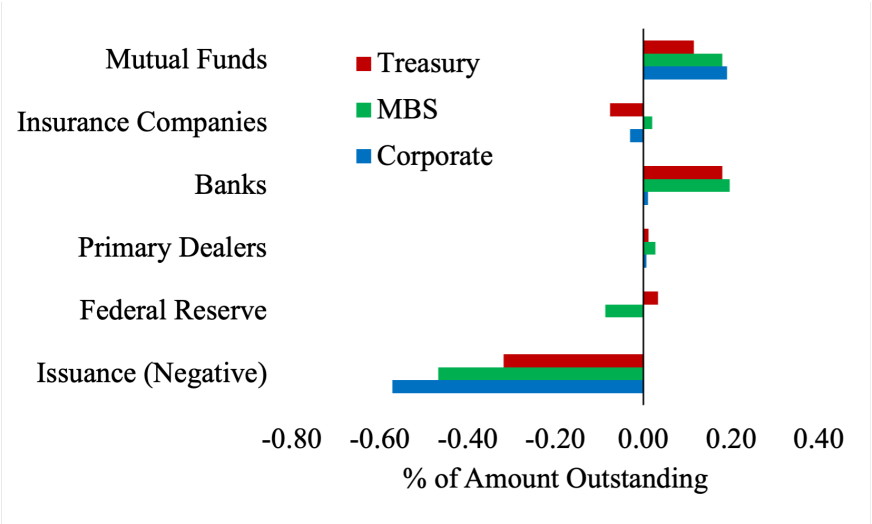
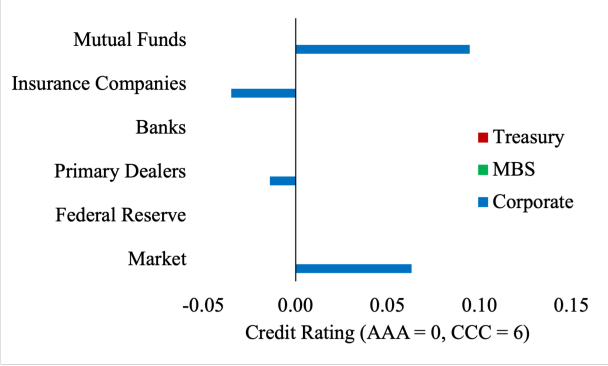


Figure 2: **Portfolio Changes to 100 bps Drop in One-Year Treasury Rate.** These figures report $-\beta_1$ from the quarterly time series regression (1): $\Delta q_t = \alpha + \beta_1 \Delta r_t^{1Y} + \beta_2 \Delta q_t^{FED} + \epsilon_t$ where Δq denotes year-over-year change in holding amount (relative to total bond market), change in portfolio credit rating (AAA = 0, CCC = 6), or change in portfolio duration (year), Δr^{1Y} denotes change in one-year Treasury rate (%), and q^{FED} denotes Fed purchases (relative to total bond market). The regression is run separately for each sector and for each bond class.

Panel A: Amount



Panel B: Credit Rating



Panel C: Duration

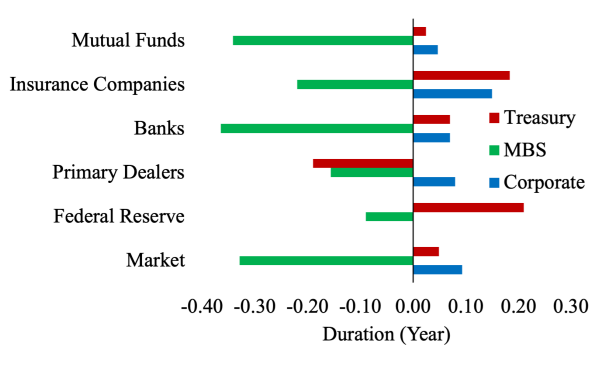
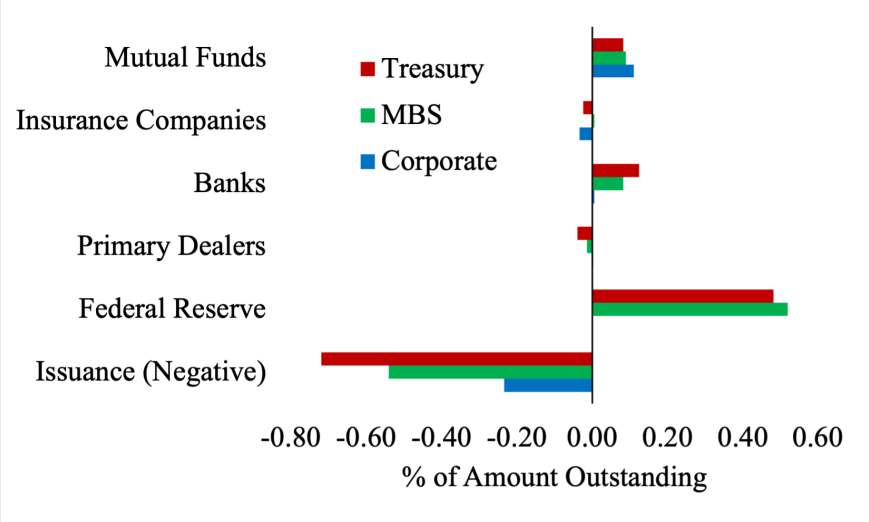
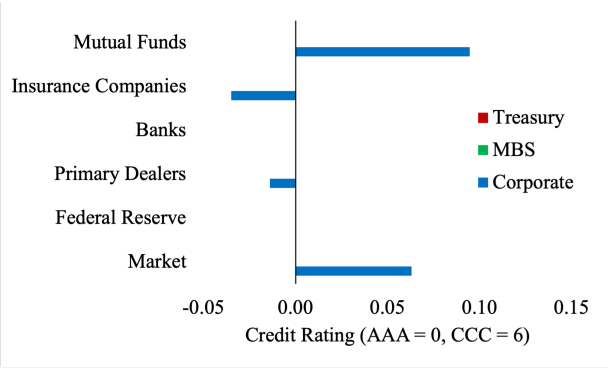


Figure 3: **Portfolio Changes to 1% Bond Purchases by the Federal Reserve.** These figures report β_2 from the quarterly time series regression (1): $\Delta q_t = \alpha + \beta_1 \Delta r_t^{1Y} + \beta_2 \Delta q_t^{FED} + \epsilon_t$ where Δq denotes year-over-year change in holding amount (relative to total bond market), change in portfolio credit rating (AAA = 0, CCC = 6), or change in portfolio duration (year), Δr^{1Y} denotes change in one-year Treasury rate (%), and q^{FED} denotes net purchases of Treasury bonds and MBS by the Federal Reserve (relative to total bond market). The regression is run separately for each sector and for each bond class.

Panel A: Amount



Panel B: Credit Rating



Panel C: Duration

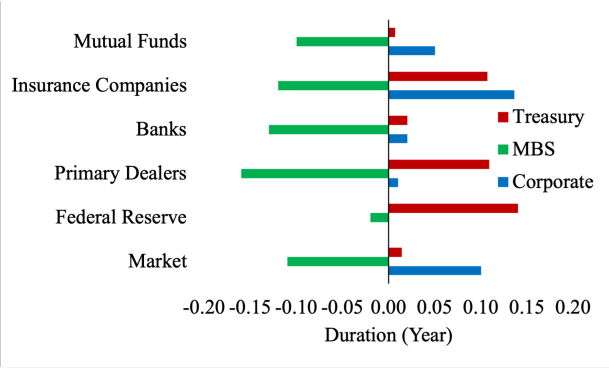
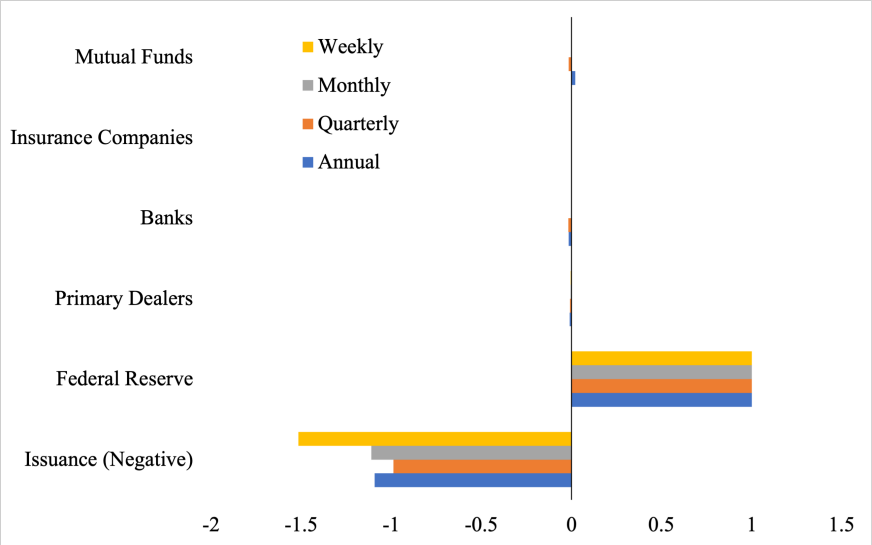


Figure 4: **Portfolio Changes across Maturity Buckets.** These figures report β from the panel regressions (3) and (4) with maturity bucket-quarter observations: $\Delta q_{m,t} = \alpha + \beta \Delta q_{m,t}^{FED/PASSIVE} + \gamma_m + \gamma_t + \epsilon_{m,t}$ where Δq denotes net purchases by the sector (relative to amount outstanding), $q^{FED/PASSIVE}$ denotes net purchases by the Federal Reserve or predicted net purchases by passive mutual funds due to flows (relative to amount outstanding), and γ_m and γ_t denote maturity bucket and time fixed effects. The regression is run separately for each sector and for each bond class.

Panel A: Fed Treasury Purchase



Panel B: Flow-Induced Passive Purchase

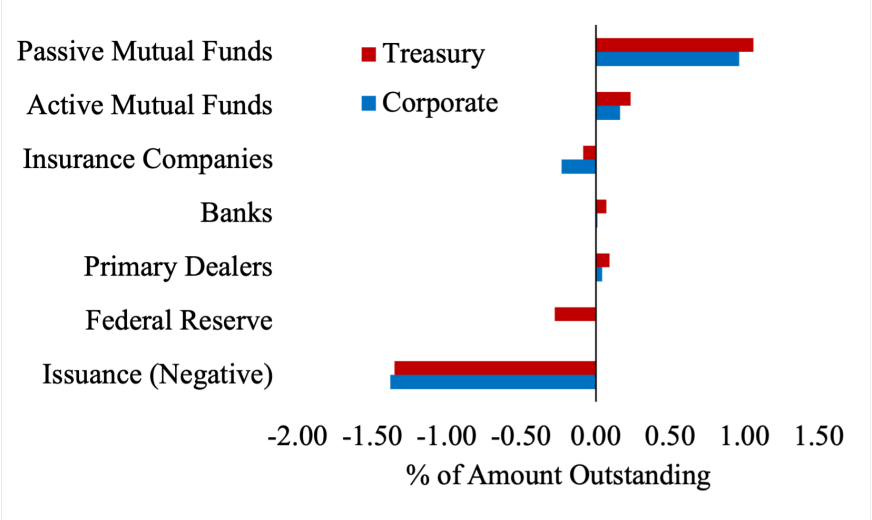
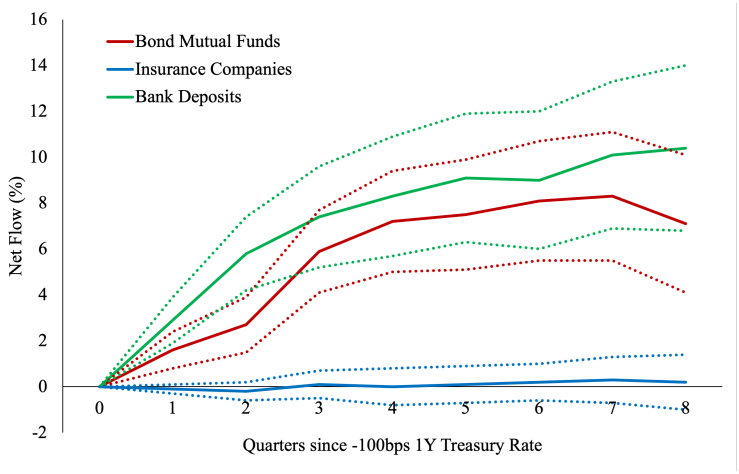


Figure 5: **Investor Flow Response to Monetary Policy.** The figures show impulse responses of net flows of bond mutual funds, insurance companies, and bank deposits to monetary policy, estimated as β_h from the following quarterly regression for different horizon h: $NetFlow_{t,t+h} = \alpha_h + \beta_{1,h}\Delta r_{t,t+1} + \beta_{2,h}\Delta q^{FED}_{t,t+1} + \epsilon_{t,t+h}$ Panel A shows $\beta_{1,h}$, net flow responses to a -100 bps drop in the one-year Treasury rate. Panel B shows $\beta_{2,h}$, net flow responses to 1% Fed purchases of Treasury bonds and MBS.

Panel A: Conventional Monetary Policy



Panel B: Unconventional Monetary Policy

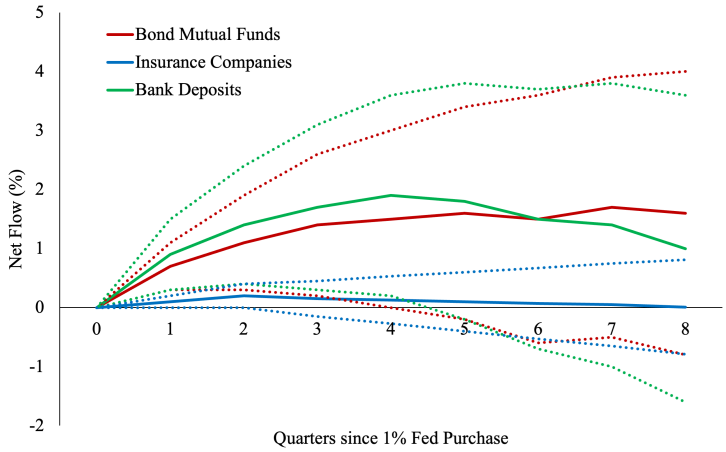
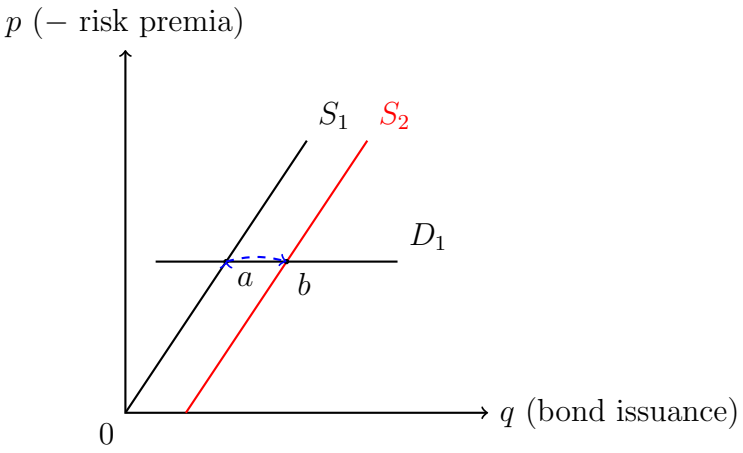
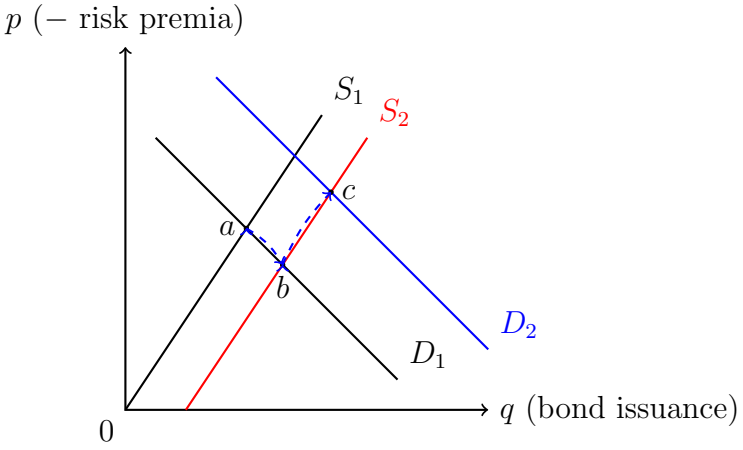


Figure 6: **Illustration of Supply and Demand of Bonds Following a Rate Cut.** The figures show supply and demand curves of long-term bonds following a rate cut. The vertical axis is negative of the risk premia. The horizontal axis is bond issuance.

Panel A: Constant Risk Premia



Panel B: Realist Asset Demand



Panel C: Short-run vs. Long-run

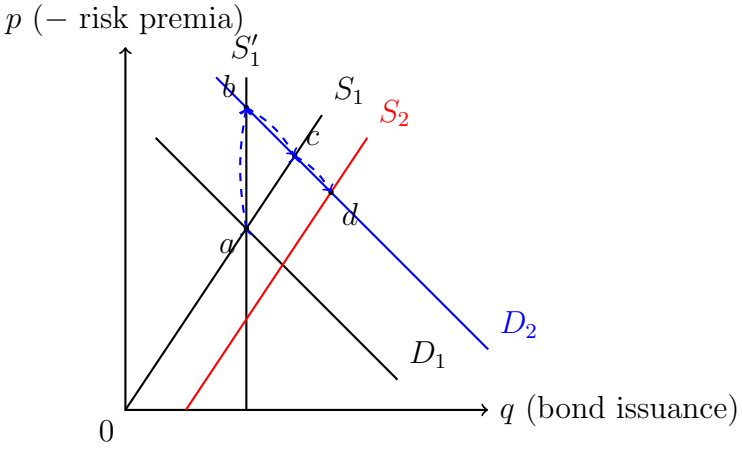
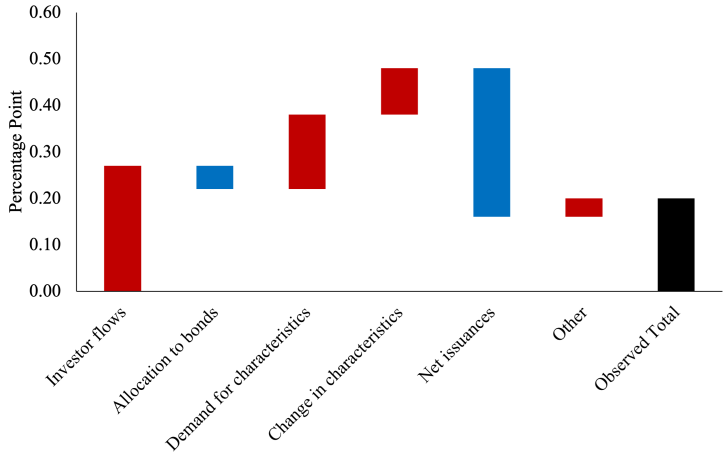
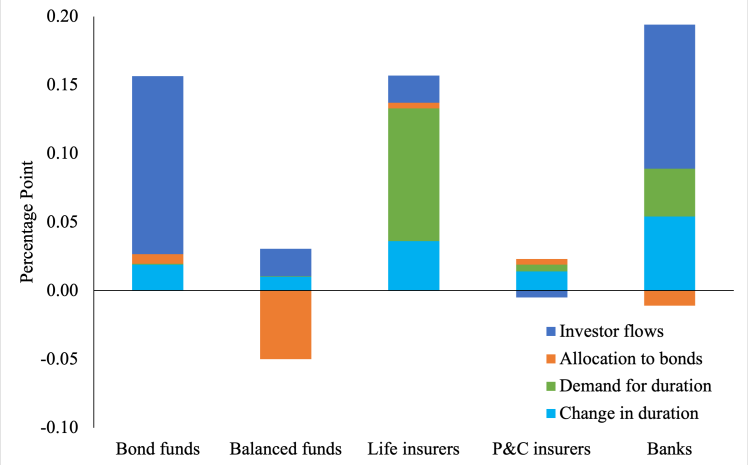


Figure 7: **10-Year Treasury Term Spread Sensitivity to Monetary Policy.** These figures show contributions from different channels to the monetary sensitivity of 10-year term spread (over expected short rates), according to our method described in Section 5.

Panel A: By Channel



Panel B: By Institution



Panel C: By Maturity

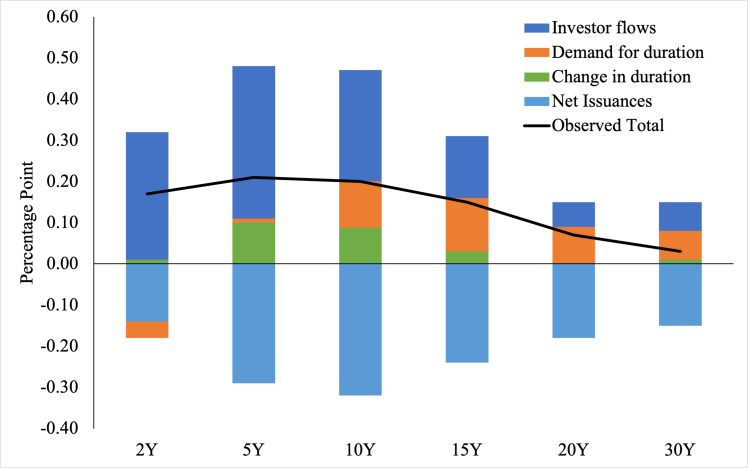
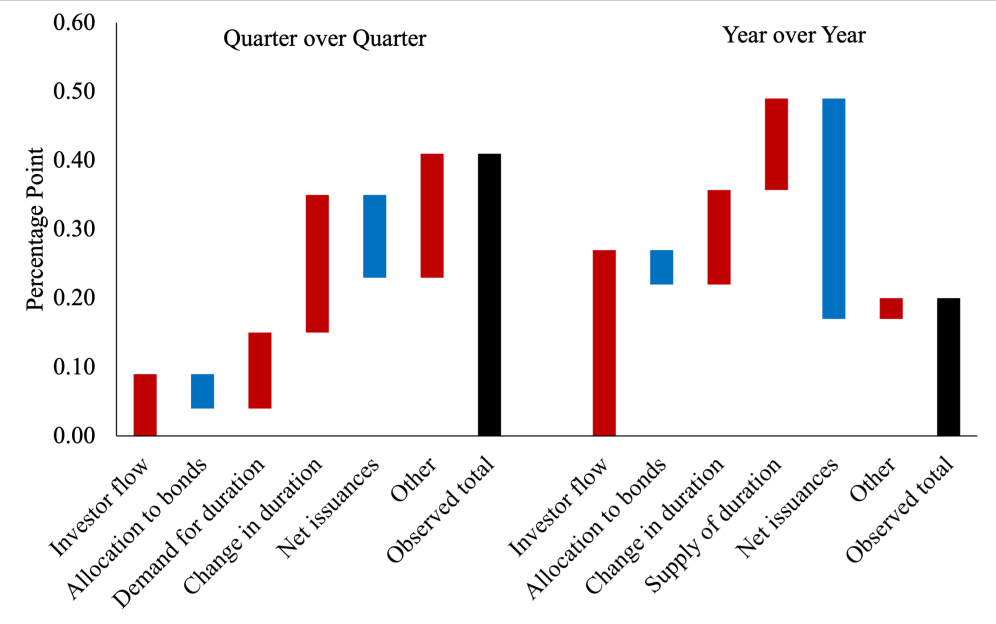


Figure 8: **Term Spread Sensitivity to Monetary Policy: Quarterly v.s. Annual, Early v.s. Late.** The figures compare the estimated contributions from the top channels to monetary sensitivity of 10-year term spread in quarterly v.s. annual frequency (Panel A) and using early v.s. late sample (Panel B), according to our method described in Section 5.

Panel A: Quarterly v.s. Annual



Panel B: Early v.s. Late

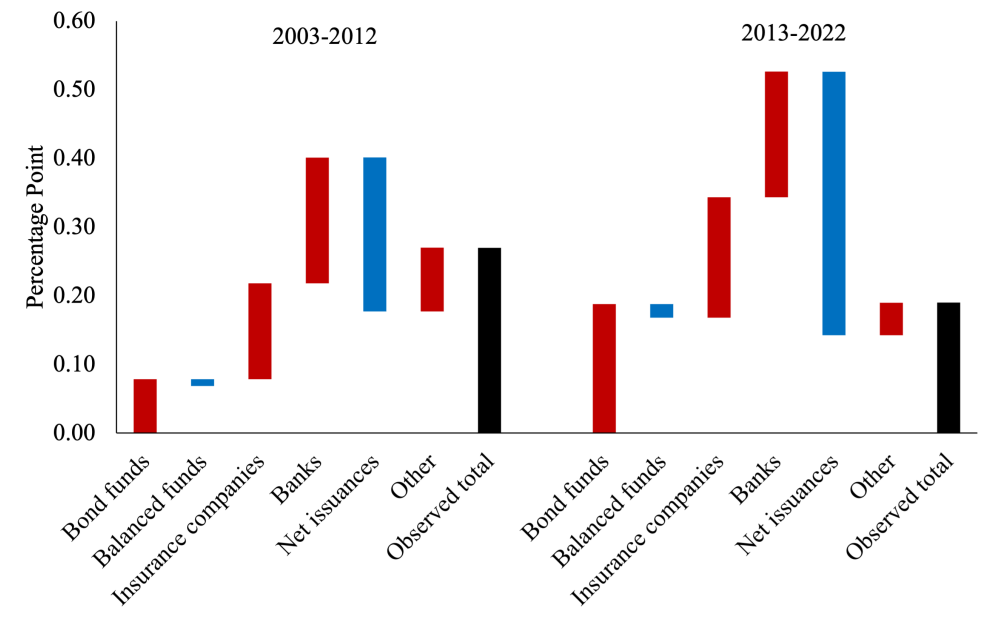
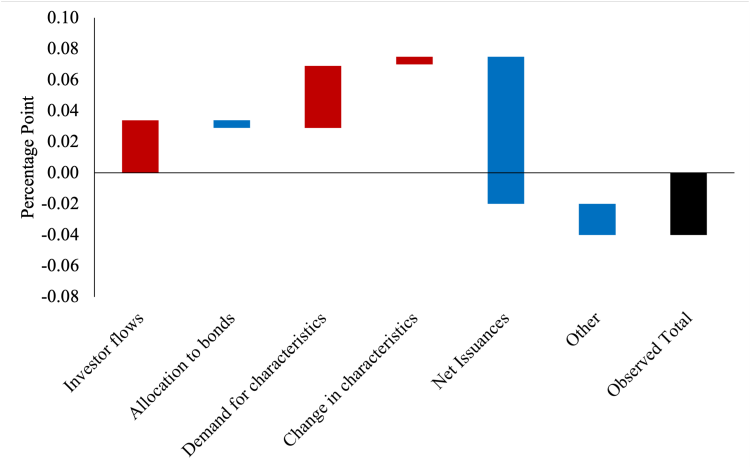
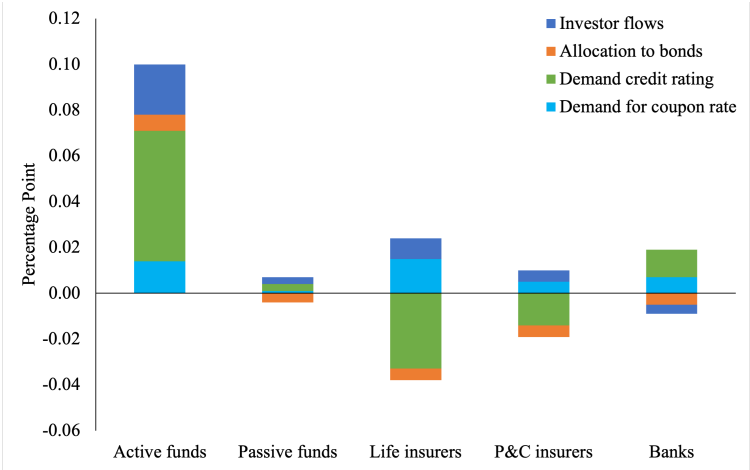


Figure 9: **10-Year BBB Credit Spread Sensitivity to Monetary Policy.** These figures show contributions from different channels to the monetary sensitivity of 10-year BBB spread (over 10-year Treasury yield) according to our method described in Section 5.

Panel A: By Channel



Panel B: By Institution



Panel C: By Credit Rating

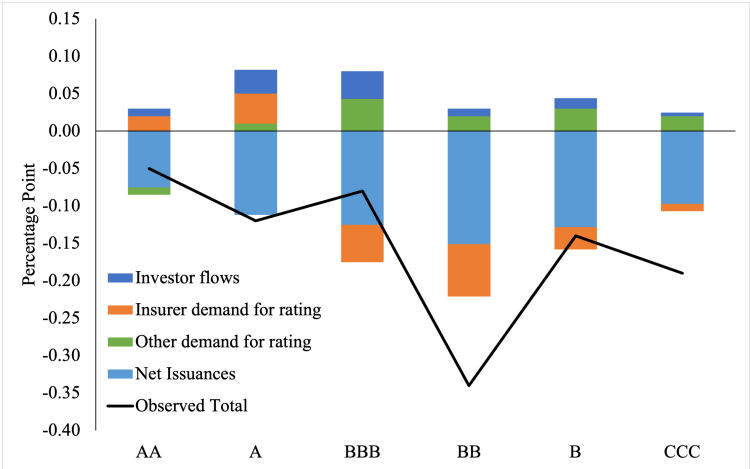


Figure 10: **Decomposition of Drivers of Corporate Bond Issuance.** The figure illustrates the decomposition of factors driving bond issuance. The black bar indicates the observed sensitivity of bond net issuance to monetary policy. Each red bar shows the contribution from a specific channel.

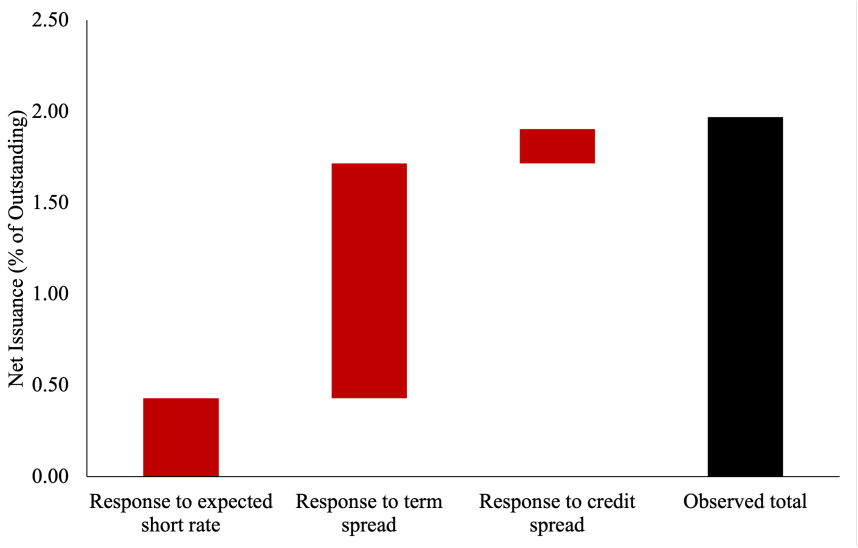
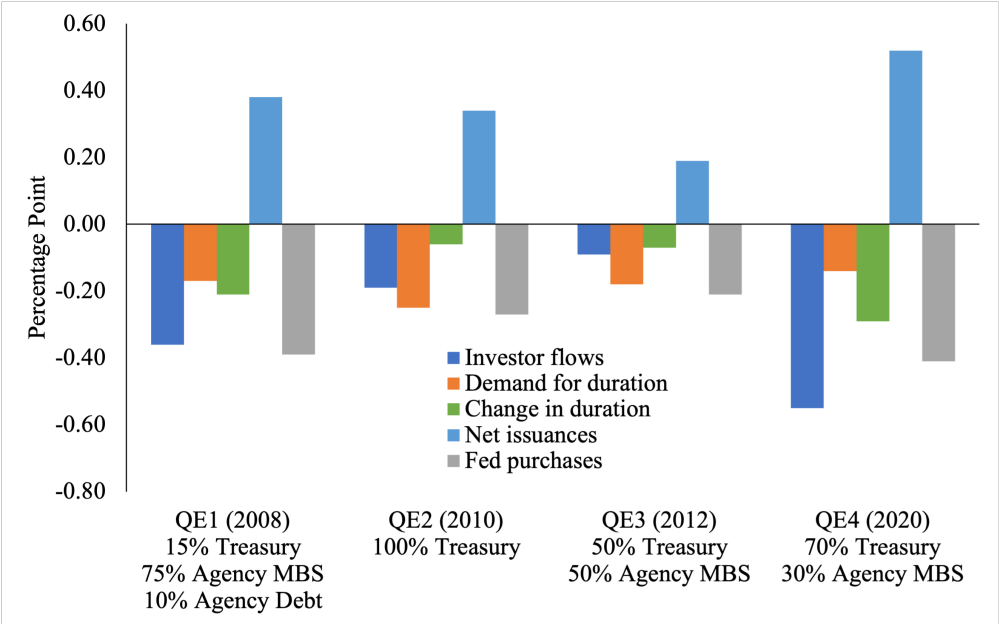


Figure 11: **Transmission of Quantitative Easing.** The figures show our estimated contributions of the top channels to the monetary sensitivity of 10-year term spread (Panel A) and 10-year BBB credit spread (Panel B) during each of the four quantitative easing episodes. All estimates are scaled so that the Fed's purchases are equal to 1% of total bond market outstanding.

Panel A: 10-Year Term Spread



Panel A: 10-Year BBB Spread

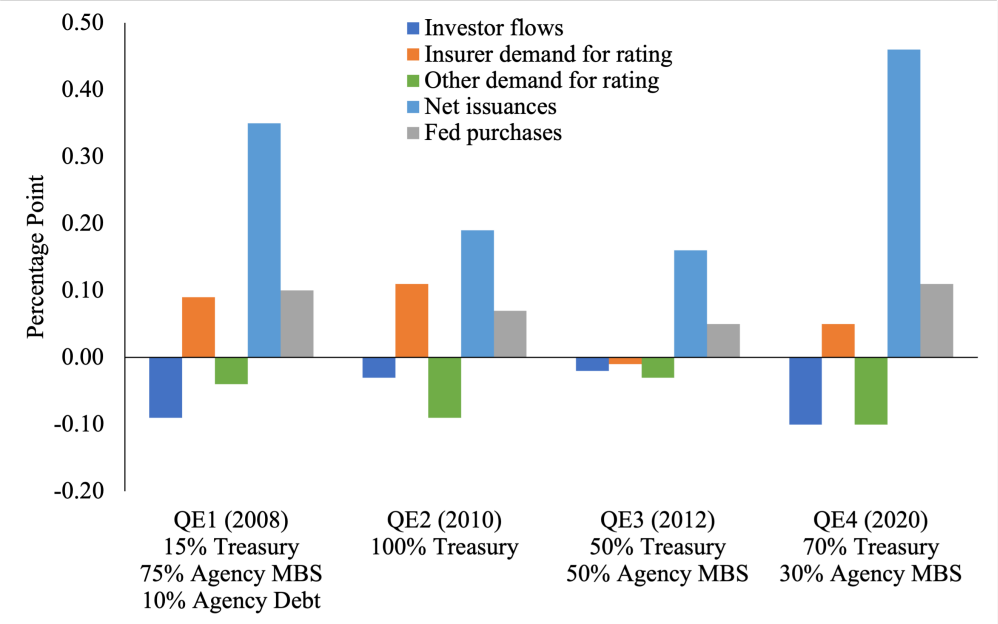


Table 1: **Bond Portfolio Summary Statistics.** This table shows summary statistics of our bond portfolios. Bond portfolios are formed by grouping together bonds that have similar credit rating, coupon rate, time to maturity and callability, separately for Treasury bonds, corporate bonds, municipal bonds, and agency MBS. The reported statistics include credit rating (ranging from 0 for AAA to 6 for CCC), duration (years), coupon rate (%), callability (0 or 1), bid-ask spread (%), and amount outstanding (billion USD). All statistics are calculated using amount outstanding as frequency weight.

	Mean	SD	P10	P50	P90
	538 Treasury Bond Portfolios				
Credit Rating	0.00	0.00	0.00	0.00	0.00
Duration	5.04	5.77	1.00	2.93	6.00
Coupon Rate	2.13	1.96	0.50	2.00	3.00
Callability	0.00	0.05	0.00	0.00	0.00
Bid-Ask Spread	0.04	0.03	0.02	0.04	0.05
Amount Outstanding	737	1217	90	236	772
	2132 Corporate Bond Portfolios				
Credit Rating	2.18	1.61	1.00	2.00	3.00
Duration	6.53	5.73	2.77	4.67	7.94
Coupon Rate	4.90	2.38	4.00	4.00	6.00
Callability	0.13	0.33	0.00	0.00	0.00
Bid-Ask Spread	0.49	0.56	0.20	0.34	0.55
Amount Outstanding	58	58	14	39	83
	1753 Municipal Bond Portfolios				
Credit Rating	1.22	0.86	1.00	1.00	2.00
Duration	9.39	5.83	4.54	8.71	13.59
Coupon Rate	5.19	1.71	4.00	6.00	6.00
Callability	0.72	0.45	0.00	1.00	1.00
Bid-Ask Spread	1.15	0.73	0.61	1.01	1.56
Amount Outstanding	14	12	4	11	19
	537 Agency MBS Portfolios				
Credit Rating	0.00	0.00	0.00	0.00	0.00
Duration	7.53	2.47	5.51	7.95	9.49
Coupon Rate	4.21	1.40	3.00	4.00	5.50
Callability	1.00	0.00	1.00	1.00	1.00
Bid-Ask Spread	0.06	0.03	0.04	0.06	0.07
Amount Outstanding	260	322	57	165	322

Table 2: **Estimated Demand Coefficients.** This table shows estimated demand coefficients for our investor groups. There are 79 mutual fund groups (by Morningstar Category and by active vs passive), 20 insurance company groups (by life vs P&C and by size decile) and 10 bank groups (by size decile). The reported statistics include AUM (billion USD), mean coefficients (μ) for yield (%), credit rating (from 0 for AAA to 6 for CCC), duration (year), coupon rate (%) and bid-ask spread (%), and variation in coefficient (σ) for credit rating and duration.

Panel A: Mutual Funds

	Mean	SD	P10	P50	P90
Bond AUM	45	84	0.1	12	123
Mean Coefficients (Mu)					
Yield	0.14	0.33	-0.48	0.24	0.73
Credit Rating	-0.04	1.13	-1.92	-0.01	1.36
Duration	0.03	0.21	-0.32	0.08	0.31
Coupon Rate	0.27	0.31	-0.29	0.04	0.41
Bid-Ask Spread	0.29	0.30	-0.29	0.27	0.41
Coefficient Variation (Sigma)					
Credit Rating	0.23	0.05	0.21	0.26	0.37
Duration	0.22	0.08	0.17	0.26	0.42

Panel B: Insurance Companies

	Mean	SD	P10	P50	P90
Bond AUM	106	296	0.07	5	230
Mean Coefficients (Mu)					
Yield	-0.08	0.27	-0.19	0.01	0.41
Credit Rating	-0.39	0.73	-1.26	-0.51	0.65
Duration	0.04	0.19	-0.05	0.07	0.30
Coupon Rate	0.24	0.37	0.03	0.16	0.49
Bid-Ask Spread	0.21	0.44	-0.05	0.14	0.45
Coefficient Variation (Sigma)					
Credit Rating	0.26	0.03	0.23	0.26	0.32
Duration	0.49	0.09	0.33	0.49	0.63

Panel C: Banks

	Mean	SD	P10	P50	P90
Bond AUM	351	1139	5	24	2971
Mean Coefficients (Mu)					
Yield	0.12	0.18	-0.03	0.11	0.29
Credit Rating	0.01	0.53	-0.70	0.01	0.73
Duration	-0.02	0.08	-0.11	-0.01	0.08
Coupon Rate	-0.15	0.10	-0.27	-0.14	-0.05
Bid-Ask Spread	-0.77	0.48	-1.34	-0.71	-0.24
Coefficient Variation (Sigma)					
Credit Rating	0.21	0.03	0.17	0.21	0.25
Duration	0.43	0.06	0.35	0.42	0.50

Table 3: **Estimated Own- and Cross-Price Elasticities.** These tables display estimated own- and cross- price elasticities, according to Equation 13. The diagonal cells show average own-price elasticities for all bonds with the given rating or duration, across all periods and across all mutual funds (Panel A), insurance companies (Panel B), or banks (Panel C). The off-diagonal cell in row m and column n shows percent change in the holding of bond m with one-percent change price of bond n, averaged across all bond pairs with the given rating or duration combination, across all periods and across all mutual funds (Panel A), insurance companies (Panel B), or banks (Panel C).

Panel A: Mutual Funds

	AA	A	BBB	BB	B	CCC
AA	-2.42	2.59	1.28	0.11	0.31	0.01
A	1.21	-2.78	2.93	0.87	0.08	0.07
BBB	0.93	1.35	-4.03	2.04	1.49	0.03
BB	0.14	0.18	1.25	-1.96	1.22	1.02
B	0.28	1.27	0.02	2.98	-2.06	1.00
CCC	0.03	0.34	0.94	0.08	1.12	-1.58

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-3.12	2.01	1.98	0.34	0.53	0.54
3-5Y	3.23	-3.54	2.44	1.72	0.11	0.31
5-7Y	1.88	2.44	-4.72	2.90	1.03	0.82
7-10Y	1.32	0.29	1.92	-2.52	1.45	0.06
10-15Y	0.02	0.43	0.44	1.53	-1.27	1.03
15-30Y	0.11	0.03	0.44	0.36	1.34	-0.84

Panel B: Insurance Companies

	AA	A	BBB	BB	B	CCC
AA	-0.54	1.66	0.77	0.19	0.03	0.01
A	1.21	-1.01	1.42	0.42	0.26	0.07
BBB	0.93	0.89	-1.54	1.04	0.85	0.04
BB	0.14	0.14	1.76	-0.77	0.93	0.37
B	0.28	0.06	1.03	1.28	-0.29	0.43
CCC	0.03	0.01	0.02	0.08	1.12	-0.03

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-0.47	1.02	0.78	0.55	0.53	0.23
3-5Y	0.54	-1.04	1.54	1.03	0.11	0.01
5-7Y	0.88	0.59	-0.98	1.88	1.03	0.27
7-10Y	0.23	0.91	1.25	-1.24	1.46	1.23
10-15Y	0.05	0.20	1.03	1.96	-1.93	1.22
15-30Y	0.01	0.14	0.58	0.31	1.34	-0.92

Panel C: Banks

	AA	A	BBB	BB	B	CCC
AA	-2.14	1.52	1.46	0.26	0.72	0.03
A	0.67	-2.01	1.23	0.28	0.83	0.13
BBB	0.19	1.02	-1.02	0.39	0.97	0.48
BB	0.28	0.20	0.49	-1.34	1.43	0.08
B	0.06	0.40	1.02	0.41	-1.23	0.15
CCC	0.01	0.07	0.09	0.08	0.97	-0.77

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-3.22	2.05	0.93	1.05	0.28	0.02
3-5Y	2.32	-2.44	1.99	1.72	0.11	0.09
5-7Y	1.79	2.46	-1.49	2.24	1.03	0.43
7-10Y	1.03	1.25	2.03	-2.03	1.46	1.45
10-15Y	0.57	0.56	1.54	1.58	-3.17	1.03
15-30Y	0.11	0.18	0.43	0.45	1.34	-2.79

Internet Appendix

Details on estimating the expected short rate component of bond yields

We assume that forecasters model the short rate process as AR(1):

$$i_{t+1} - \mu = \gamma(i_t - \mu) + \eta_{t+1}$$

which implies:

$$E_t i_{t+n+1} - \mu = \gamma(E_t i_{t+n} - \mu)$$

where $E_t i_{t+n}$ denotes the time t median forecast of short rate i at n quarters ahead. We assign μ to be the long-range forecast of short-term interest rate between 7 to 11 years ahead and estimate γ through an OLS regression in the cross section of forecast horizon n (without constant). For example, to estimate γ as of 2018Q1, we take forecasts of 1-quarter ahead, 2-quarter ahead, ..., 5-quarter ahead, subtract the long-range forecast between 7 to 11 years ahead, and run an autoregressive regression with 4 observations. We thank Nagel and Xu (2024) for directly providing us with estimated μ and γ, and the expected short rate component of the yield of a bond maturing in T quarters is:

$$y_f^T = \frac{1}{T}\sum_{n=1}^{T} E_t i_{t+n} = \frac{1}{T}\sum_{n=1}^{T}(\gamma^{n-1}(E_t i_{t+1} - \mu) + \mu)$$

Details on estimating demand coefficients

We follow the estimation procedure in Berry et al. (1995). Specifically, we define the mean utility of a bond as $\delta := \alpha y + \boldsymbol{\mu}'\boldsymbol{x} + \epsilon$ and rewrite Equation 7 as:

$$w_{i,t}(n) = \int \frac{\exp\{\delta_{i,t}(n) + \boldsymbol{\eta}'_{i,t}\boldsymbol{x}_t(n)\}}{\sum_m \exp\{\delta_{i,t}(m) + \boldsymbol{\eta}'_{i,t}\boldsymbol{x}_t(m)\}} dP(\boldsymbol{\eta}_{i,t})$$

where $\boldsymbol{\eta} = \boldsymbol{\beta} - \boldsymbol{\mu}$. In other words, $\boldsymbol{\eta}$ is the random part of $\boldsymbol{\beta}$. We can invert the equation above to express mean utility as a function of portfolio weights. This inversion does not have an analytical solution but can be solved via contraction mapping:

$$\delta^{h+1} = \delta^h + \log(w) - \log(w(\delta^h))$$

where w is the observed portfolio weight and $w(\delta^h)$ is the portfolio weight under the current guess of mean utility δ^h. After obtaining mean utility δ, we can then perform a linear IV GMM regression of the form:

$$\delta(n) = \alpha y(n) + \boldsymbol{\mu}'\boldsymbol{x}(n) + \epsilon(n)$$

Denote $\theta = (\alpha, \boldsymbol{\mu}, \Sigma)$. Moments are then constructed by interacting the estimated latent demand $\epsilon(n)$ with the instruments $\boldsymbol{z}(n)$ to form:

$$g(\theta) = \frac{1}{N} \sum \boldsymbol{z}(n)'\epsilon(n)$$

The GMM problem is:

$$\min_\theta g(\theta)' W g(\theta)$$

where W is the weighting matrix.

State-dependent effects of transmission channels

The early v.s. late sample analysis in Panel B of Figure 8 suggests that the strength of a monetary transmission channel depends on the relevant state variables. To further understand this state dependency, we ask what changes would occur in bond yields in response to a unit increase in the short-term interest rate when some state variables are set at different percentiles of their distributions. Counterfactual bond yields are derived in the same manner as before (Section 4.8), and all other parameters are held fixed. For example, we will quantify the contribution of bond fund flows for different degrees of bond fund flow sensitivity to monetary policy, while investors' AUM, their demand for characteristics, and the characteristics and amount of bonds outstanding are held fixed at their values as of year-end 2022.

The results are shown in Table A4. We focus on the 10-year term spread and the four channels that ranked the highest in our previous decomposition exercise: bond fund flows, insurer demand for duration, changes in MBS duration, and the amount of corporate bonds outstanding. Starting with Panel A, the middle cell shows the average contribution of bond fund flows to the 10-year term spread in response to a 100 bps increase in the policy rate, when all bond funds experience an 8% outflow (which is the average monetary sensitivity across funds over time) and each investor's elasticity is set to its median level over time. The contribution (20 bps) is higher than that from our decomposition exercise (16 bps), reflecting the fact that bond funds account for a larger share of the bond market in 2022 than in earlier periods. The other cells show bond fund flow contributions when the two state variables are set to different values. The northeast cell shows that when bond fund flows are twice as sensitive to monetary policy as the observed average, and when the elasticity of other investors is at the lowest decile of the distribution, the contribution from bond fund flows rises to almost four times as large. On the other hand, when bond fund flows are half as sensitive to monetary policy and other investors are much more elastic to any price impacts created by bond fund flows, the amplification effect of bond fund flows is significantly weakened.

Panel B focuses on changes in insurer demand for duration. On average, when the short-term rate increases by 100 bps, the mean coefficient (μ) of insurer demand for duration falls by 0.12, as shown by the middle cell. The associated decline in demand for long-term bonds leads to an 8 bps increase in the 10-year term spread when other investors' yield coefficients are at historical means. This effect is greatly amplified (dampened), when the sensitivity of insurer demand for duration increases (decreases) or when investor elasticity decreases (increases), as shown by the northeast (southwest) corner of the table.

Panel C focuses on the level of MBS duration. When the short-term rate increases, the duration of MBS increases by 20 bps on average, as refinancing activities are expected to fall. This relationship, known as mortgage convexity, depends on the past path of mortgage rates (Eichenbaum, Rebelo, and Wong, 2022). If past mortgage rates were high and most outstanding mortgages carry high coupon rates, then additional increases in mortgage rates

would not significantly discourage refinancing activities. Indeed, the sensitivity of MBS duration to the one-year Treasury rate can be as high as 0.49 during the recent 2022-23 rate hike and nearly zero during the 2003-07 rate hike, when many outstanding mortgages still carried high coupons from the previous rate cycles. The estimates show the amplification effect of the MBS duration channel depends critically on MBS convexity, as well as investor elasticity, i.e. how much yield effects are required to offset the supply gap created by MBS duration changes.

Lastly, Panel D shows the distribution of effects from corporate bond issuance and redemption. On average, 100 bps increase in the short-term rate is associated with 4% reduction in corporate bond outstanding. This sensitivity has increased over time, as shown in Figure 8. On average, corporate bond issuance and redemption dampen bond yield sensitivity to monetary policy by 18 bps, as shown in the middle cell. This effect is significantly magnified (reduced) when bond issuers are more (less) sensitive to rate changes and when investors are less (more) elastic, as more (less) yield changes are required for investors to adjust the quantity of their demand.

The effect of investor composition on monetary transmission

Investor composition has been shown to be an important state variable for the bond market (Coppola, 2022; Li and Yu, 2022; Fang, 2023). There has been a secular rise in bond mutual funds and ETFs relative to other bond investors, and this trend is poised to continue. Our next exercise asks: what would be the bond yield sensitivity to monetary policy if bond funds become larger or smaller relative to other investors? To make the analysis tractable, we examine the counterfactual outcomes of reallocating bond AUM between bond funds and life insurers, keeping their total bond AUM constant at its value as of year-end 2022. All other state variables, such as other investors' AUM and their demand coefficients, are also set to their year-end 2022 values. The responses of state variables to monetary policy, such as bond fund flow sensitivity to monetary policy, are set to their means estimated using the entire sample period.

The results are shown in Table A5. Panel A focuses on term spread sensitivity to monetary policy. In the middle column, we reallocate bond fund AUM and life insurer AUM such that they are in a 1:1 ratio, which is very close to reality at year-end 2022. In response to a 100 bps policy rate hike, our framework predicts an 18 bps increase in the 10-year term spread, combined across all the channels. If more bond AUM is reallocated to bond funds so that the ratio between bond fund AUM and life insurer AUM is 2 (shown in the rightmost column), then term spread sensitivity to monetary policy will be significantly amplified; conversely, if bond AUM is reallocated away from bond funds, the sensitivity will decrease.

More importantly, the shift in investor composition has heterogeneous effects across the term structure, as shown by the vertical direction. The reallocation of AUM towards bond funds—which corresponds to moving from left to right—amplifies term spread sensitivity for short-term bonds (the top rows) but dampens it for long-term bonds (the bottom rows). This is because bond funds and life insurers tilt towards different ends of the term structure. Therefore, a shift in AUM towards bond funds will amplify the yield sensitivity of short-term bonds more, through the bond fund flow channel, whereas a shift in AUM towards life insurers will primarily amplify the yield sensitivity of long-term bonds, through the insurer duration hedging channel.

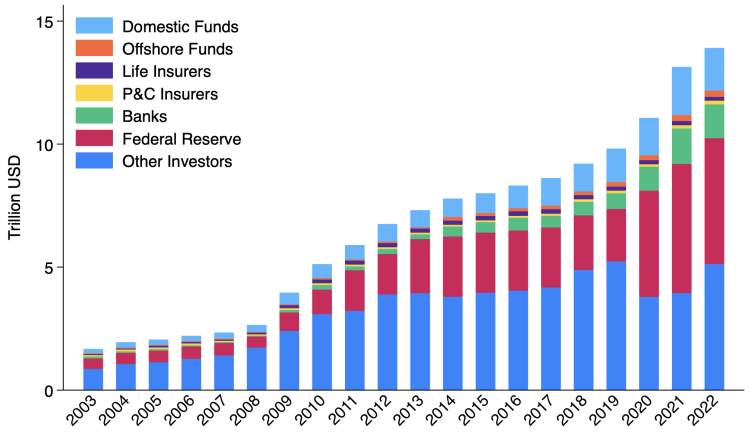
Panel B of Table A5 focuses on 5-year BBB spread sensitivity. Similarly, changes in the relative AUM of bond funds and life insurers will change the relative weights of the underlying transmission channels. In response to monetary tightening, bond funds tend to decrease credit risk-taking and reduce the portfolio weights of low-rating bonds relative to high-rating bonds (Choi and Kronlund, 2018). Life insurers tend to do the opposite due to the relaxation of capital constraints (Li, 2024). Therefore, an increase in the AUM of bond funds relative to life insurers (from left columns to right columns) will raise credit spreads during monetary tightening, especially for bonds with lower credit ratings (the bottom rows).

In summary, this section demonstrates that the contribution of a channel can vary significantly over time, depending on the relevant state variables. Investor elasticity is a partic-

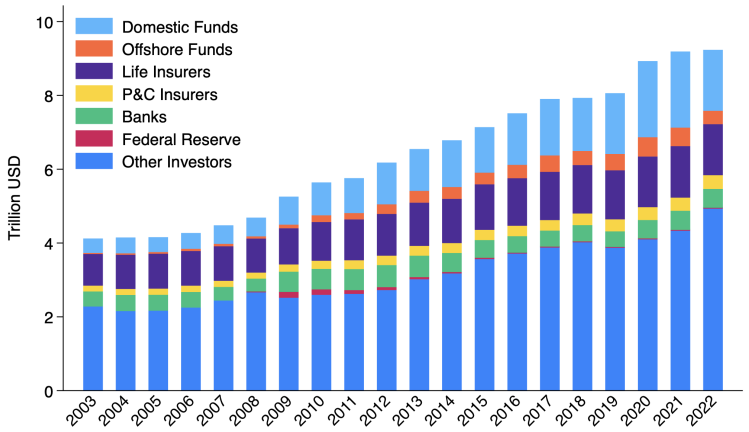
ularly important state variable across all channels, as it determines the magnitude of price impacts required to absorb imbalances between demand and supply. We illustrate how our demand system framework can be used to analyze why a specific monetary policy episode has experienced weak or strong transmission. Additionally, it can be easily parametrized to make predictions for future monetary policy actions.

Figure A1: **Bond Ownership.** The figures show investor composition for Treasury bonds, corporate bonds, and agency MBS. We restrict to straight USD-denominated bonds (including callable bonds) with more than one year to maturity.

Panel A: Treasury Bonds



Panel B: Corporate Bonds



Panel C: Agency MBS

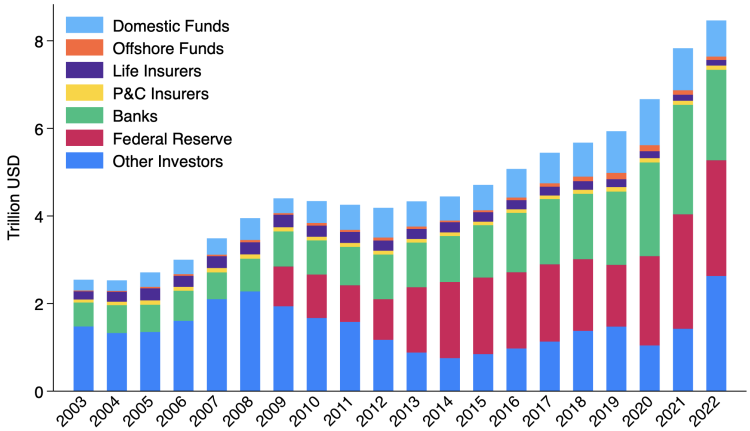
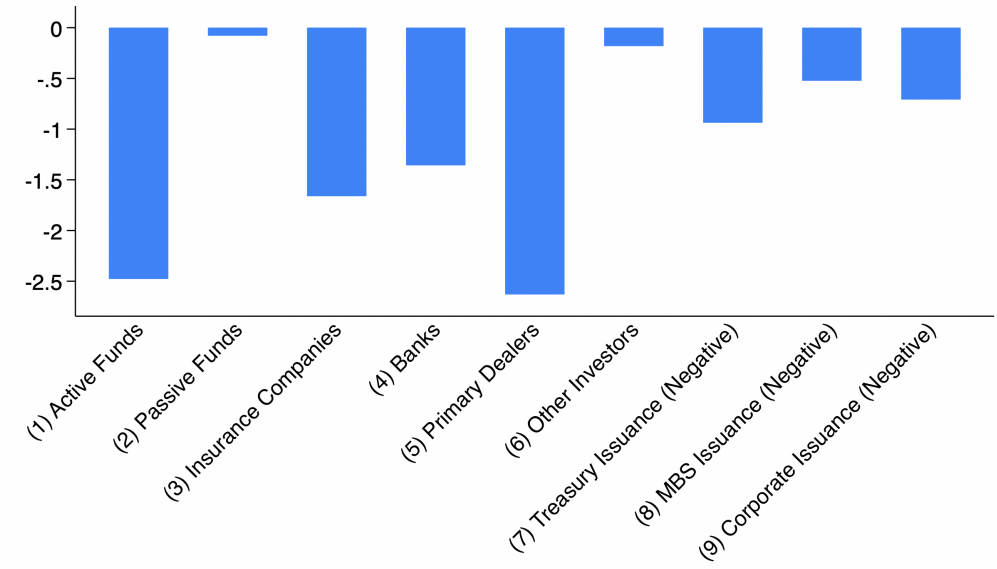


Figure A2: **Estimated Demand Coefficients.** These figures display estimated demand coefficients (μ, Σ) on credit rating (from 0 AAA to 6 CCC), duration (year), coupon rate (%), and bid-ask spread (%), using the procedures described in Section 4.7.



Figure A3: **Estimated Elasticities across Sectors.** The figures show our estimated elasticities across different investor groups and bond issuers.

Panel A: Price Elasticity



Panel B: Contribution to Market Elasticity

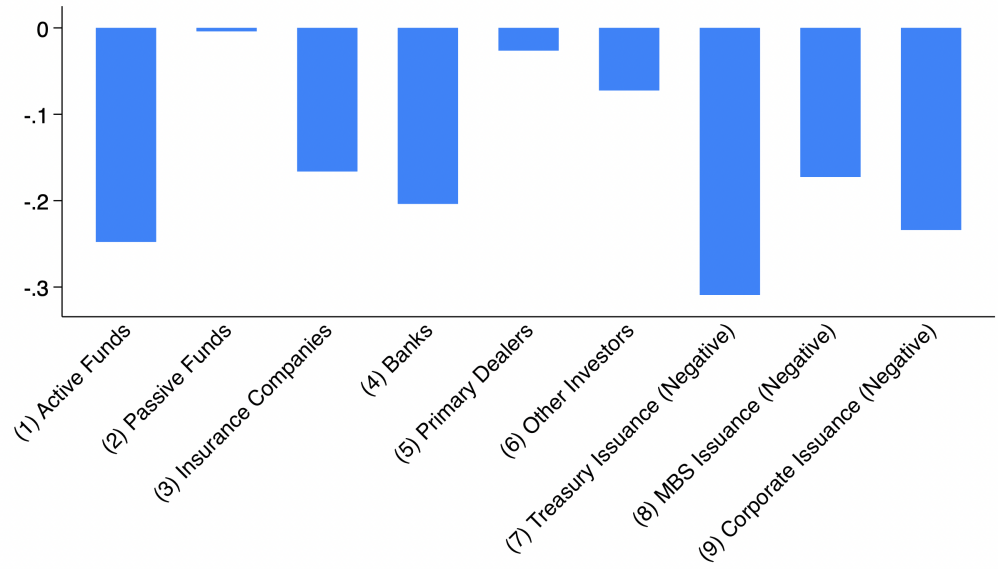
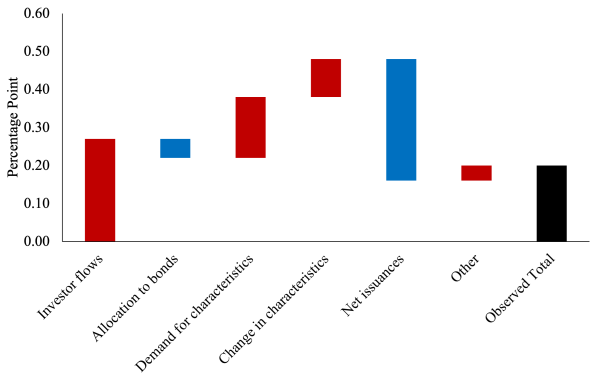
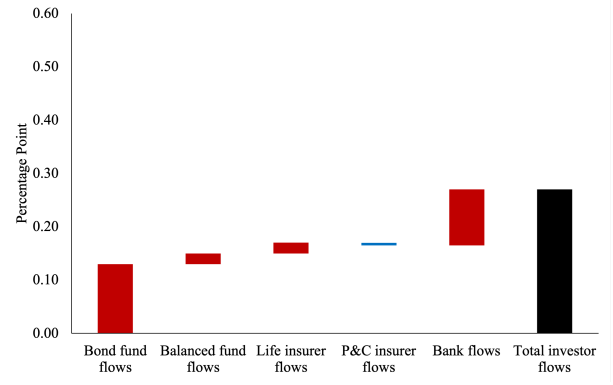


Figure A4: **10-Year Term Spread Sensitivity to Monetary Policy.** These figures show contributions from different channels to the monetary sensitivity of 10-year term spread according to our method described in Section 5.

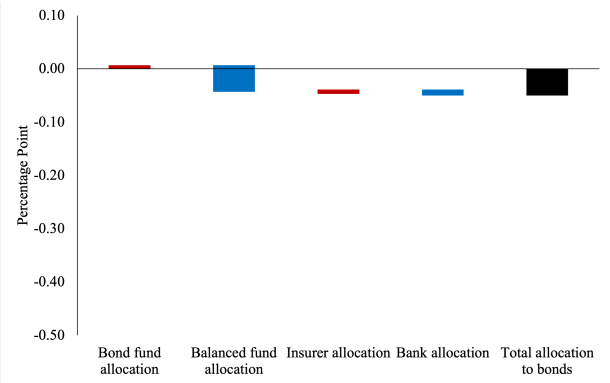
Panel A: All Channels



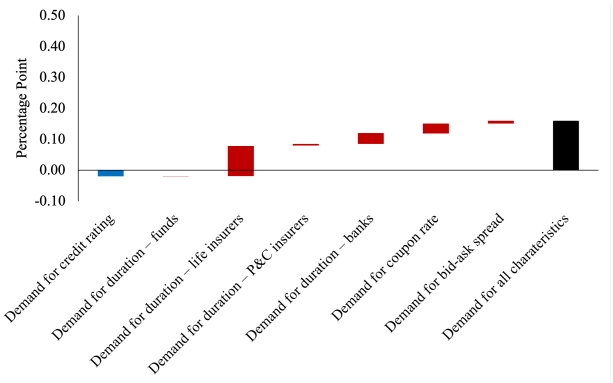
Panel B: Investor Flows



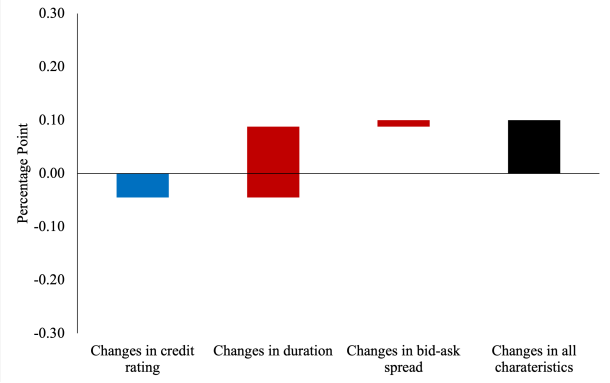
Panel C: Allocation to Bonds



Panel D: Demand for Characteristics



Panel E: Change in Characteristics



Panel F: Net Issuance

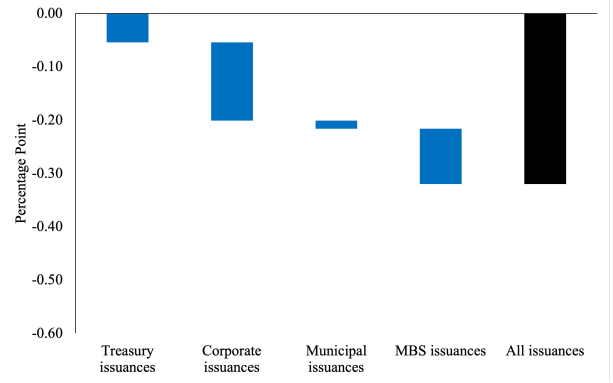
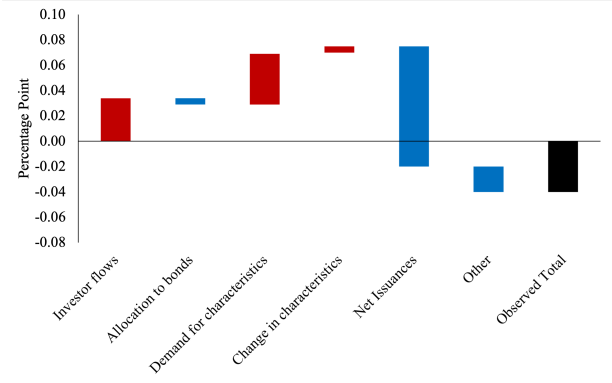
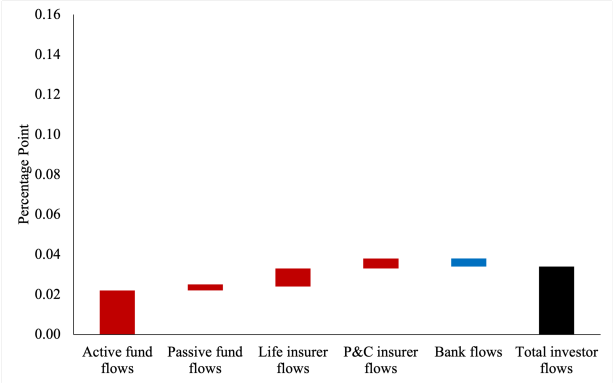


Figure A5: **10-Year BBB Credit Spread Sensitivity to Monetary Policy.** These figures show contributions from different channels to the monetary sensitivity of 10-year BBB spread (over 10-year Treasury yield) according to our method described in Section 5.

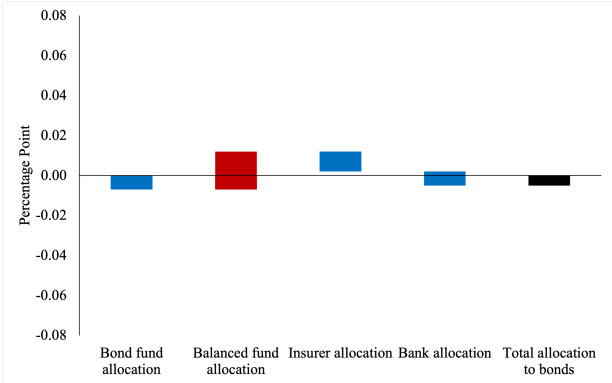
Panel A: All Channels



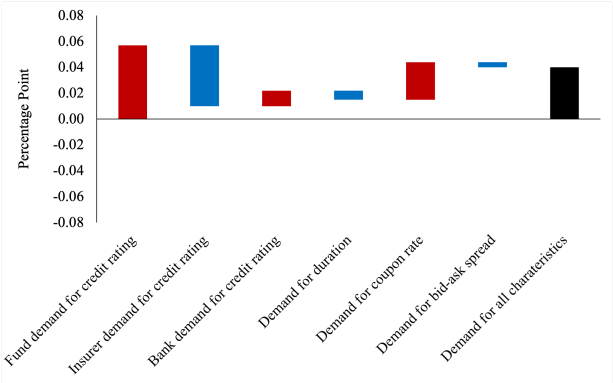
Panel B: Investor Flows



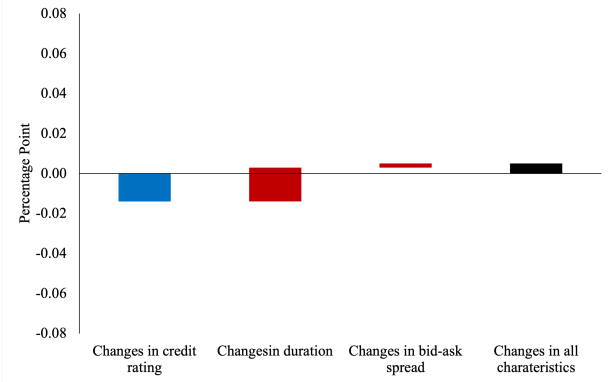
Panel C: Allocation to Bonds



Panel D: Demand for Characteristics



Panel E: Change in Characteristics



Panel F: Net Issuances

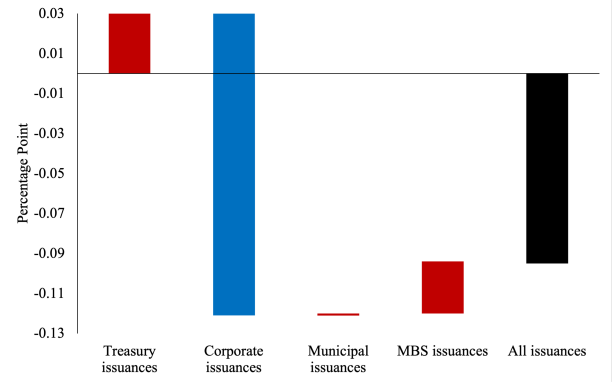
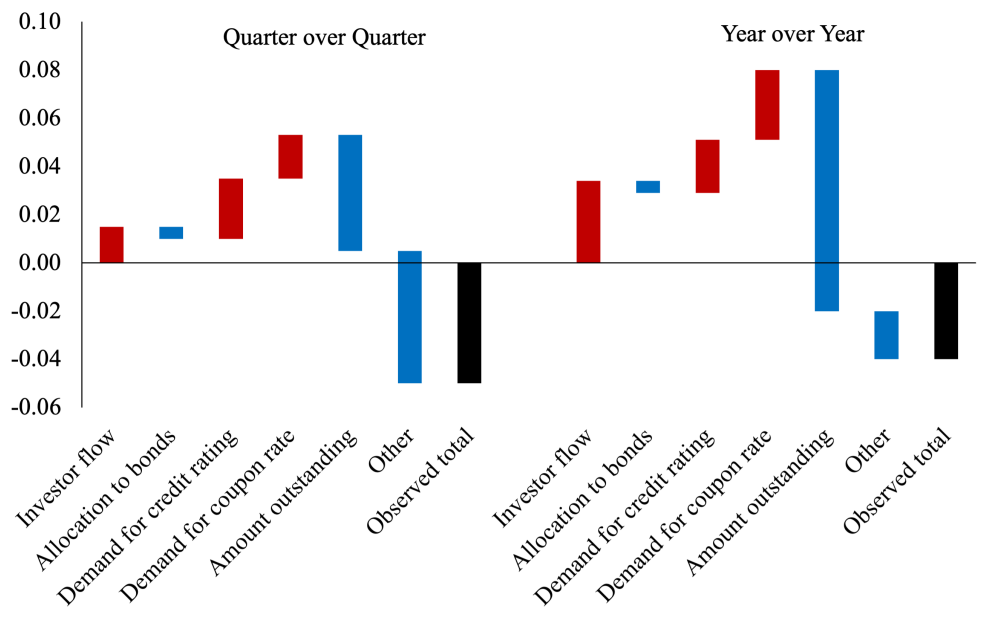


Figure A6: **Credit Spread Sensitivity to Monetary Policy: Quarterly v.s. Annual, Early v.s. Late.** The figures compare the estimated contributions from the top channels to monetary sensitivity of 10-year BBB credit spread in quarterly v.s. annual frequency (Panel A) and using early v.s. late sample (Panel B) according to our method described in Section 5.

Panel A: Quarterly v.s. Annual



Panel B: Early v.s. Late

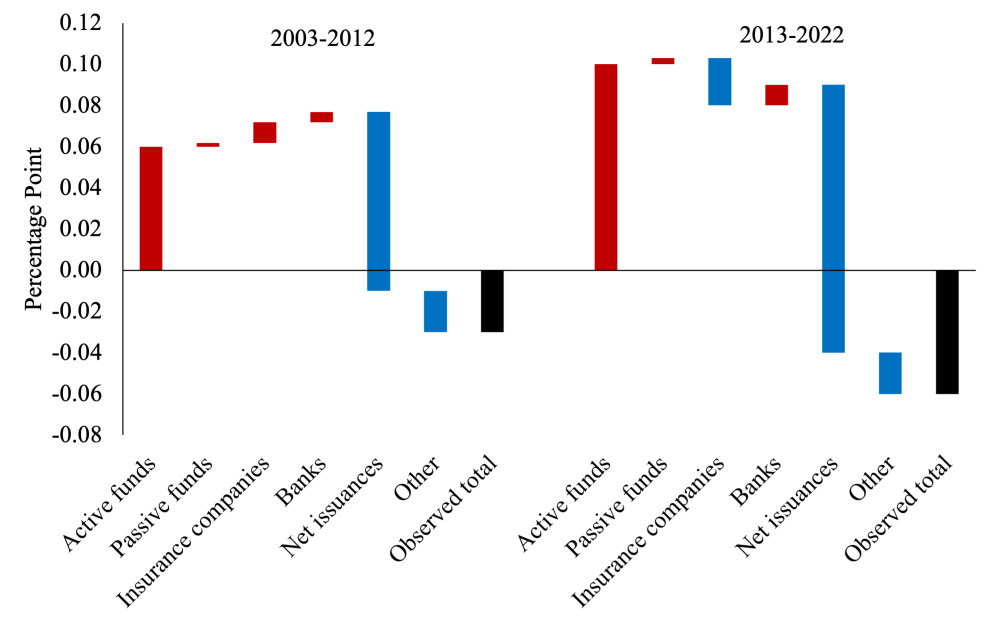
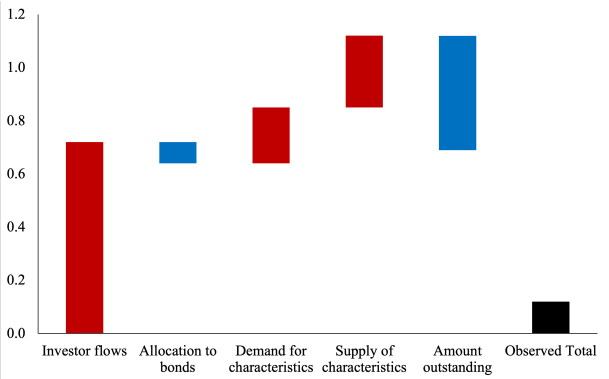
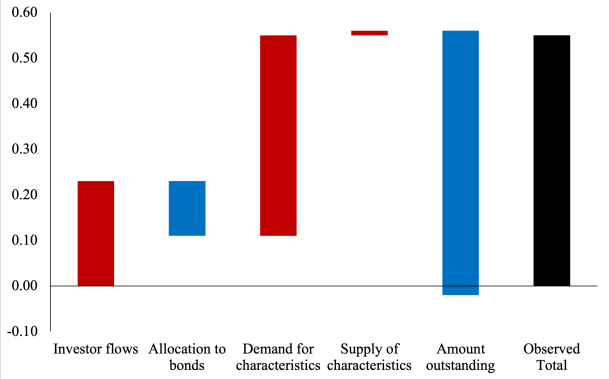


Figure A7: **Robustness with Monetary Policy Shocks.** The figures show decomposition of yield sensitivity with respect to monetary policy shocks constructed by Bu et al. (2021). Panel A (Panel B) shows the decomposition of the monetary sensitivity 10-year term spread (10-year BBB spread). Panel C (Panel D) shows the decomposition of the monetary sensitivity of term spread across duration (credit spread across ratings).

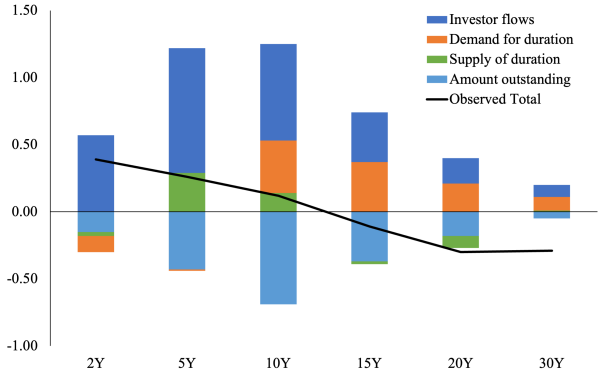
Panel A: 10-Year Term Spread



Panel B: 10-Year BBB Spread



Panel C: Term Structure



Panel D: Credit Spectrum

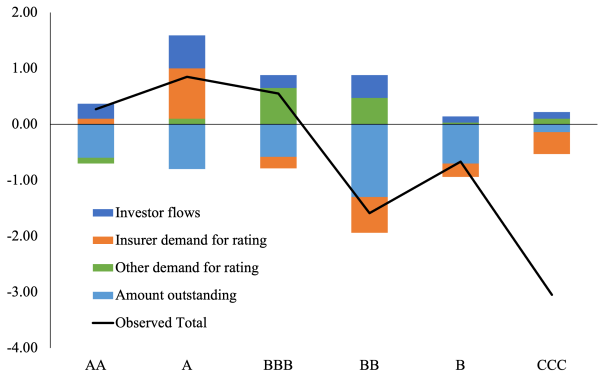


Table A1: **Flow-Induced Trading as Yield Instrument.** The tables examine the relevance of flow-induced trading (FIT, Equation 12) as instrument for bond yields. Specifically, they show the median t-statistic for $\tilde{\beta}$ for each investor type (Panel A) or each time segment (Panel B) from the following regression, run separately for each investor i at each time t: $y_t(n) = \tilde{\beta} FIT_{-i,t}(n) + \tilde{\gamma} Controls + \tilde{\epsilon}_{i,t}(n)$

Panel A: By Investor Type

Bond mutual funds	-6.43
Other mutual funds	-5.54
Life insurance companies	-7.07
P&C insurance companies	-6.58
Banks	-4.03

Panel B: By Time Segment

2003-2005	-4.72
2006-2008	-4.38
2009-2011	-7.23
2012-2014	-6.49
2015-2017	-6.01
2018-2020	-9.98
2021-2022	-6.36

Table A2: **Own- and Cross-Price Elasticities in Fixed Coefficient Logit Model.** These tables are the counterparts of Table 3 but coefficient variation σ is set to zero. The diagonal cells show average own-price elasticities for all bonds with the given rating or duration, across all periods and across all mutual funds (Panel A), insurance companies (Panel B), or banks (Panel C). The off-diagonal cell in row m and column n shows percent change in the holding of bond m with one-percent change price of bond n, averaged across all bond pairs with the given rating or duration combination, across all periods and across all mutual funds (Panel A), insurance companies (Panel B), or banks (Panel C).

Panel A: Mutual Funds

	AA	A	BBB	BB	B	CCC
AA	-2.40	1.29	1.32	1.36	1.00	0.46
A	0.58	-2.72	1.41	1.34	1.02	0.51
BBB	0.70	1.24	-3.95	1.27	0.87	0.49
BB	0.62	1.24	1.31	-1.92	0.96	0.53
B	0.70	1.18	1.42	1.28	-1.99	0.60
CCC	0.58	1.27	1.46	1.22	0.93	-1.56

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-3.04	1.12	1.46	1.48	1.05	0.60
3-5Y	1.43	-3.51	1.53	1.57	1.02	0.59
5-7Y	1.42	1.19	-4.64	1.45	0.95	0.65
7-10Y	1.47	1.13	1.62	-2.45	0.96	0.72
10-15Y	1.41	1.04	1.58	1.48	-1.25	0.62
15-30Y	1.45	1.05	1.64	1.56	1.03	-0.79

Panel B: Insurance Companies

	AA	A	BBB	BB	B	CCC
AA	-0.51	0.73	1.19	0.71	0.72	0.22
A	0.59	-0.95	1.18	0.74	0.73	0.30
BBB	0.66	0.56	-1.54	0.68	0.68	0.32
BB	0.61	0.69	1.03	-0.71	0.73	0.35
B	0.64	0.74	1.03	0.70	-0.27	0.36
CCC	0.70	0.72	1.16	0.73	0.70	-0.04

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-0.44	0.59	1.15	1.22	0.96	0.78
3-5Y	0.37	-0.98	1.14	1.18	1.06	0.64
5-7Y	0.37	0.60	-0.91	1.32	0.97	0.77
7-10Y	0.37	0.75	1.09	-1.19	0.90	0.73
10-15Y	0.51	0.65	1.12	1.16	-1.83	0.65
15-30Y	0.41	0.58	1.16	1.24	0.96	-0.85

Panel C: Banks

	AA	A	BBB	BB	B	CCC
AA	-2.12	0.67	1.05	0.35	1.07	0.24
A	0.28	-1.93	0.93	0.42	1.15	0.33
BBB	0.43	0.80	-1.00	0.38	1.08	0.23
BB	0.33	0.69	1.02	-1.24	1.07	0.21
B	0.32	0.75	1.00	0.38	-1.14	0.27
CCC	0.40	0.71	0.96	0.47	0.99	-0.73

	1-3Y	3-5Y	5-7Y	7-10Y	10-15Y	15-30Y
1-3Y	-3.14	1.31	1.57	1.47	0.91	0.70
3-5Y	1.25	-2.41	1.52	1.57	0.88	0.64
5-7Y	1.25	1.48	-1.41	1.47	1.03	0.72
7-10Y	1.34	1.41	1.53	-2.02	0.98	0.77
10-15Y	1.34	1.35	1.57	1.52	-3.08	0.76
15-30Y	1.16	1.34	1.42	1.46	0.94	-2.75

Table A3: **Estimated Price Elasticity of Net Issuances.** The table estimates the price elasticities of the net issuance of Treasury bonds, corporate bonds, and agency MBS. We run the following regression, separately for each class of bonds: $\Delta \log S_t(n) = \tilde{\alpha} \widehat{\Delta \log P_t(n)} + \tilde{\beta}' x_t(n) + \tilde{\epsilon}_t(n)$ where, for each bond portfolio n, $\Delta \log S_t(n)$ denotes log change in amount outstanding, $\widehat{\Delta \log P_t(n)}$ change in price instrumented with contemporaneous flow-induced trading from Equation 12, and $x_t(n)$ bond characteristics including credit rating, duration, coupon rate, callability and bid-ask spread. t-statistics are reported in parentheses. *, **, and *** denote p-values less than 0.10, 0.05, and 0.01, respectively.

	Δlog(S)		
	Treasury	Corporate	MBS
	(1)	(2)	(3)
Instrumented Δlog(P)	0.613***	0.447***	0.369***
	(3.336)	(3.793)	(4.447)
Credit Rating (log)		0.013***	
		(5.086)	
Duration (log)	-0.010*	0.016***	0.026***
	(-2.268)	(6.183)	(8.169)
Coupon Rate (%)	-0.018***	-0.012***	-0.003***
	(-16.516)	(-8.304)	(-3.851)
Callability	0.002	-0.038***	
	(0.351)	(-9.424)	
Bid-Ask Spread (%)	-0.388	-0.010***	0.243
	(-1.287)	(-10.157)	(1.025)
Quarter Fixed Effects	Y	Y	Y
Standard Errors		clustered by quarter	
Observations	5837	41087	10144
R2	0.113	0.059	0.240

Table A4: **State Dependency of Monetary Transmission Channels.** The tables illustrate state dependency for each of the top channels through which monetary policy transmits to bond yields. For each channel, we quantify its contribution to 10-year term spread sensitivity to monetary policy given a range of 1) investor yield elasticities ($\{\alpha\}$) on the vertical axis, and 2) the sensitivity of the underlying state variable to monetary policy. All other state variables are held constant at year-end 2022.

Panel A: Bond Fund Flow

		∂Bond Fund Flow / ∂1Y Treasury Rate				
		-4.0%	-6.0%	-8.0%	-12.0%	-16.0%
Yield Coeff	10th Pct	0.18	0.28	0.37	0.57	0.72
	25th Pct	0.14	0.20	0.26	0.33	0.50
	Median	0.11	0.15	0.20	0.30	0.42
	75th Pct	0.09	0.13	0.18	0.25	0.26
	90th Pct	0.05	0.09	0.13	0.19	0.25

Panel B: Insurer Demand for Duration

		∂Insurer Demand for Duration / ∂1Y Treasury Rate				
		-0.06	-0.09	-0.12	-0.16	-0.24
Yield Coeff	10th Pct	0.11	0.13	0.18	0.25	0.33
	25th Pct	0.07	0.12	0.15	0.21	0.28
	Median	0.05	0.06	0.08	0.11	0.15
	75th Pct	0.02	0.05	0.07	0.09	0.14
	90th Pct	0.01	0.03	0.04	0.09	0.10

Panel C: MBS Duration

		∂MBS Duration / ∂1Y Treasury Rate				
		0.10	0.15	0.20	0.30	0.40
Yield Coeff	10th Pct	0.11	0.17	0.20	0.30	0.39
	25th Pct	0.08	0.12	0.16	0.24	0.33
	Median	0.08	0.10	0.14	0.18	0.19
	75th Pct	0.08	0.09	0.11	0.15	0.21
	90th Pct	0.03	0.06	0.10	0.15	0.17

Panel D: Corporate Bond Issuance

		∂Corporate Bond Outstanding / ∂1Y Treasury Rate				
		-2%	-3%	-4%	-6%	-8%
Yield Coeff	10th Pct	-0.16	-0.24	-0.33	-0.50	-0.66
	25th Pct	-0.11	-0.17	-0.23	-0.35	-0.46
	Median	-0.08	-0.13	-0.18	-0.26	-0.36
	75th Pct	-0.07	-0.11	-0.15	-0.22	-0.31
	90th Pct	-0.05	-0.08	-0.11	-0.16	-0.21

Table A5: **The Dependency of Monetary Transmission on Investor Composition.** The tables show our estimated monetary sensitivity of term spread (Panel A) and 10-year credit spread (Panel B) for different relative sizes of bond funds versus life insurers. All state variables are set to their year-end 2022 values and their responses to monetary policy are set to their means estimated using the whole sample period.

Panel A: 10Y Treasury Term Spread

	Relative Bond Ownership between Bond Funds vs Life Insurers				
	0.50	0.75	1.00	1.50	2.00
2Y	-0.06	0.03	0.11	0.20	0.28
5Y	0.03	0.11	0.20	0.33	0.41
10Y	0.13	0.16	0.18	0.22	0.25
15Y	0.07	0.08	0.08	0.09	0.10
20Y	0.05	0.02	-0.01	-0.03	-0.04
30Y	0.06	0.03	0.02	0.00	-0.02

Panel B: 10Y BBB Credit Spread

	Relative Bond Ownership between Bond Funds vs Life Insurers				
	0.50	0.75	1.00	1.50	2.00
AA	0.00	-0.01	-0.03	-0.04	-0.04
A	0.02	-0.01	-0.03	-0.04	-0.06
BBB	-0.10	-0.08	-0.05	-0.01	0.03
BB	-0.18	-0.15	-0.12	-0.07	-0.03
B	-0.11	-0.09	-0.09	-0.05	-0.02
CCC	-0.05	-0.04	-0.04	-0.02	0.00