Hidden Duration:
Interest Rate Derivatives in Fixed Income Funds *

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This Draft: 20 December 2024

First Draft: 19 June 2023

Abstract

Fixed income funds carry significant duration risk from their use of interest rate derivatives (IRDs). This duration risk is hidden, as funds have typically disclosed portfolio duration weighted by market values instead of notionals, concealing their true risk. We find substantial variation in IRD duration, both across funds and over time. The primary motive behind funds' use of IRDs is not to hedge interest rate risk or manage flow risk; rather, they are driven by risk-taking, closing the gap to the duration risk of their peers, and the desire for lower transaction costs. The performance of funds' IRD positions is not associated with manager skill—funds that outperformed due to high IRD duration in early 2020 performed particularly poorly during interest rate hikes in 2022 and 2023.

Keywords: Derivatives; Interest Rates; Fixed Income Funds; Leverage; Duration.

JEL Codes: G11; G12; G23.

*The authors would like to thank Fabian Dienemann, Phil Gharghori (discussant), John Heaton, Kristy Jansen, Anil Kashyap, Raymond Kim (discussant), Ralph Koijen, Philippe Mueller (discussant), Stefan Nagel, Lubos Pastor, Anna Pavlova, Nikolai Roussanov, Gabriele La Spada (discussant); conference participants at the FIRN Annual Conference, Financial Stability Conference at the Federal Reserve Bank of Atlanta, Chicago Booth Fama-Miller Conference, APAD, FMA Asia, and BI-SHoF Asset Pricing Conference; and seminar participants at the CFTC, ESMA, HEC Montreal, the University of Illinois, and the University of Melbourne. We also thank Benjamin Callen, Chunxiao Lu, Grace Meng, Yang Shi, Hanqing Tian, Ruhao Wang, Shuying Wu, and Zhibo Zhang for excellent research assistance, and AFAANZ for a generous research grant.

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1 Introduction

Fixed income mutual funds carry significant duration risk from their use of interest rate derivatives (hereafter IRDs). The goal of this paper is to show that IRDs are widely used by U.S. fixed income mutual funds; their exposure to IRDs can be very large; funds use them not just to hedge interest rate risk but often for risk taking and extending duration risk; and IRDs can substantially affect funds' portfolio returns, overshadowing returns on their non-IRD positions. Yet, this leverage is usually hidden because funds typically report the duration of their holdings weighted by market values, which can be very small compared with notional values, and can underrepresent their interest rate risk.

Our sample period covers July 2019 to September 2023, when interest rates changed at an unprecedented pace compared to past decades. At the start of 2020, the U.S. Federal funds rate was at 1.5% and was cut to zero in March 2020 (see Figure 1). Since March 2022, it has been raised by as much as 50 or even 75 basis points at a time to 5.25% by the end of our sample period, a level not seen since 2007. The fact that interest rate risk has been unusually high during these years makes our sample period a particularly interesting laboratory in which to examine fixed income mutual funds' use of IRDs, in terms of hedging that risk and speculating on rate cuts and hikes, and study the implications of funds' derivatives use for fund performance.[1]

Our data source for funds' derivatives use is the SEC's Form N-PORT filings data, which provide quarterly portfolio holdings, derivatives positions, and their profits and losses since 2019.Q3. We obtain 857 fixed income funds after merging CRSP and Morningstar mutual fund databases, encompassing government, investment-grade (IG), high-yield (HY), and global bond funds. We document several new facts about fixed income funds' use of IRDs. First, IRDs are widely used, with 56% of our sample funds holding at least one IRD in at least one quarter in our sample period. The notional amount of IRDs held by funds in aggregate is large, with an absolute notional of $404 billion in an average quarter, compared to $74 billion for credit derivatives and $183 billion for FX derivatives (see Table 1). At an individual fund level, the notional amount held in IRDs is also

[1] One example of return implications of IRDs observed during 2022 is the liability-driven investment (LDI) crisis in the UK. The UK government bond (gilt) yields spiked in September and October 2022 after the disastrous mini-budget announcement of the government. Pension funds and other asset managers who had employed highly levered LDI strategies experienced large losses in their IRD positions, requiring an increase in their collateral and margin requirements, which destabilized the gilt market.

substantial, constituting between 42% and 80% of total net assets on average, depending on the sector. Netting their long and short positions, funds' exposure of their IRDs to the risk of interest rate hikes grew from +\$37.6 billion in 2019.Q3 to +\$126.1 billion in 2023.Q3, or from +4.97% to +9.95% of TNA.

Second, there exists substantial heterogeneity in the cross section and time series in funds' IRD positions. Pooled across funds and time, funds' IRD duration[2], as a proxy for interest rate risk exposure, has a standard deviation of 2.23%, a substantial proportion of the mean (median) duration of their bond portfolios of 5.02% (4.66%). We find that some funds hold an extremely large number of IRDs, with 5% of the fund-quarter observations involving funds which hold 67 or more positions. We also find that funds' IRD durations tend to be persistent: funds that had higher IRD returns in 2020 when interest rates were cut, kept longer duration IRD portfolios in 2022 when interest rates rose, and subsequently had lower IRD returns.

Third, on average, funds do not use IRDs to hedge risks in their non-IRD portfolios. Instead, funds may manage their IRD and bond portfolios somewhat independently. We find that the correlation between returns on funds' IRD positions and non-IRD positions is, on average, close to zero and widely dispersed in both positive and negative values. If funds tended to use IRDs for hedging purposes, we would expect to find mostly negative correlations between these two return components. Similarly, the durations of IRD and non-IRD positions are minimally correlated and also close to zero. Thus, funds do not rebalance their IRD duration to hedge their non-IRD duration, further indicating that our sample funds do not necessarily use IRDs for hedging purposes.

Having documented these stylized facts, we further investigate what explains the use of IRDs, focusing on the following three hypotheses: (a) risk-taking and duration seeking, (b) liquidity and flow management, and (c) transaction cost minimization. In the risk-taking scenario, funds would exploit the implicit leverage in IRDs. Many IRDs, including Treasury futures and interest rate swaps, require posting margins or collateral with market values close to zero. Funds can boost their duration by taking IRDs with large notional amounts. Additionally, funds might employ IRDs to compensate for low interest rate exposure if they allocate their cash positions to credit securities like high-yield bonds, which we refer to as duration seeking. In the liquidity and flow

[2]IRD duration is measured as the dollar duration of a 1% change in interest rates (DV100), as a percentage of total net assets.

management scenario, funds would use derivatives to handle redemption needs from their investors. By employing derivatives, funds do not need to tie up their capital, and this financial flexibility can be used to cushion investor redemption requests. In the transaction cost scenario, trading derivatives is preferred to cash bond trading because transaction costs of IRDs tend to be lower than those of cash bonds.

Our evidence largely supports the risk-taking and duration seeking hypotheses. We find that funds that engage in reaching for yield by holding higher-yielding bonds tend to take on more IRDs. As shown by Choi and Kronlund (2018), reaching for yield is a strong indicator of risk-taking in bond funds, and bonds that reach for yield are likely to hold more IRD positions. Relatedly, funds tend to use IRDs to increase interest rate risk exposure when their duration is lower than that of their peer funds. These results are consistent with the notion that funds compensate for reduced duration from reaching for yield (because high-yield bonds tend to have short maturities) by using IRDs to lengthen duration while also taking on credit risk. We find that younger funds are more likely to hold more than thirty IRD contracts. Young funds have little reputation to lose, and thus their downside is relatively limited, while they can gain substantial investor flows if they are successful in their risk-taking. High yield corporate bond funds with higher expense ratios are more likely to hold at least thirty derivative contracts, which may be associated with a greater appetite for risk-taking (see Chevalier and Ellison (1997) and Livingston et al. (2019)). We also find that funds in the bottom 20% in performance rankings compared with their peer group are more likely to hold larger IRD positions, consistent with funds' incentives to climb the ladder to attract more flows. We show that larger funds are more likely to hold at least one IRD, having greater access to, and preferential pricing for, over-the-counter derivatives compared to smaller funds, consistent with the theory of Duffie et al. (2005).

We also find results consistent with the transaction cost hypothesis. To test this, we exploit contract-level information in our dataset to explain funds' opening of IRD contracts using hypothetical transaction costs that would be incurred if funds instead traded Treasury bonds to achieve the same level of duration exposure as the IRD contracts. We find that funds are more likely to open larger numbers of IRDs if their hypothetical Treasury transaction costs are particularly high. In contrast, we do not find any evidence supporting the liquidity management hypothesis. We employ several proxies that represent funds' need for liquidity, such as lagged flows, flow volatility, and cash positions. We do not find any reliable empirical relationships between these proxies and funds' use of IRDs.

If fixed income funds are not necessarily employing IRDs for hedging but instead for speculation or amplifying their risk exposure, it is important to examine the extent to which this IRD use contributes to fund performance. Our results suggest that IRD returns can be a substantial portion of total fund returns, overshadowing non-IRD returns. We reach this conclusion by investigating fund returns based on their IRD exposure in the past quarter. In Phase 1 of our sample, from July 2019 to June 2020, a period during which interest rates were cut substantially, we find that the average IRD return for funds in the highest duration quintile is 0.20% per quarter, while that for funds in the lowest duration quintile is -0.34% per quarter, a result of the lower interest rates during this period. More interestingly, we find that the non-IRD returns of the highest quintile duration funds are also higher, at 0.64% per quarter, resulting in a 0.56% higher total fund return than the lowest quintile funds. In other words, high IRD duration funds not only have higher IRD returns but also higher non-IRD returns. In Phase 3, from October 2021 to September 2023, a period of interest rate hikes, we find that IRD returns and total returns are lower for high duration funds. These results are somewhat surprising, as IRD returns account for a substantial portion of total fund performance, which is unexpected for mutual funds that are primarily long-side investors, unlike hedge funds. Our unique data also shed light on which IRDs are behind these performance results. Government bond futures are the largest contributor, consistent with recent anecdotes that asset managers are increasingly engaging in Treasury basis trades using futures contracts.

We examine whether funds that employ IRDs tend to exhibit greater skill. To test this hypothesis, we condition on funds' IRD performance in 2020.Q1—a period when interest rates were dramatically cut following the pandemic—and examine their subsequent IRD performance in the following periods, especially through Phase 3, during which interest rates were hiked substantially. This period provides a robust environment to test management skill. If these fund managers are skilled, we would likely observe them changing course and reducing their IRD positions. However, we find that funds' IRD durations tend to be sticky, and high IRD duration funds tend to maintain high IRD duration exposure. Additionally, funds that outperformed in their IRD positions up to 2020.Q1 perform particularly poorly in both their IRD and non-IRD positions in subsequent periods, resulting in 0.32% lower returns per quarter compared to funds that underperformed in IRDs during 2020.Q1.

Lastly, we examine the determinants of margin calls on funds' IRD positions, which occur more when funds' IRD returns are lower, cash reserves are lower, or funds hold more IRDs. Margin calls spike during the interest rate cuts of 2020 and hikes of 2022 and 2023. We find that they are driven by funds' positions in government bond futures, rather than interest rates swaps or other IRDs.

Related literature. Our paper adds to the literature documenting funds reaching for yield, across a range of investor types, asset classes, and stages of the business cycle. In a low interest-rate environment, corporate bond mutual funds tilt their portfolios towards higher yield bonds (Choi and Kronlund (2018)), particularly large funds (Chen et al. (2023)), and money market funds invest in riskier asset classes (Di Maggio and Kacperczyk (2017)). Becker and Ivashina (2014) and Hanson and Stein (2015) find evidence of reaching for yield amongst insurance companies and commercial banks, respectively. Our paper is also related to the literature on unobserved risks in the mutual fund sector e.g. Kacperczyk et al. (2008) and Chen et al. (2021). We contribute to these literatures by showing that interest rate derivatives are another tool that can be used for reaching for yield, and that some funds' have substantial interest rate risk exposure from their derivative holdings which is hidden by funds disclosing their duration weighted by market, instead of notional, value.

Acharya and Naqvi (2019) and Campbell and Sigalov (2022) motivate reaching for yield theoretically. Empirically, Brown et al. (1996), Kempf and Ruenzi (2008), and Schwarz (2012) find that mutual funds take on more risk to improve their tournament rank, though Busse (2001) finds that this result depends on return frequency. More generally our paper is related to the literature on risk-taking incentives of mutual funds, e.g. Grinblatt and Titman (1989), Chevalier and Ellison (1997), Elton et al. (2003), Massa and Patgiri (2009), Chen and Pennacchi (2009), and Huang et al. (2011). Our unique dataset allows us to decompose fund returns into those from IRDs versus non-IRD holdings, and to see that this tournament behavior is somewhat segregated between the two parts of funds' portfolios. For instance, we find that funds tend to increase duration using IRDs following lower IRD returns, but not following lower non-IRD returns.

Our paper benefits from having access to granular data on funds' derivative holdings that earlier papers (e.g. Deli and Varma (2002), Fong et al. (2006), Cao et al. (2011), Aragon and Martin (2012), Cici and Palacios (2015), Natter et al. (2016)) did not. Kaniel and Wang (2022) and Qi (2022) used the recently available N-PORT data to analyse mutual funds' derivative use more broadly. Focusing on the period around the Covid-19 crisis, Kaniel and Wang (2022) show that equity mutual funds used derivatives mostly to amplify their returns, rather than hedge them, which was suggested by earlier survey data from investment managers in Koski and Pontiff (1999). Qi (2022) shows that corporate bond mutual funds which were using derivatives to speculate liquidated more corporate bonds to satisfy their margin calls. We also find evidence of speculation with IRDs: many fixed income mutual funds use derivatives to speculate on interest rates being cut and not just hedging against them being hiked. We go further by showing that as interest rates increase, speculator funds with a positive duration ratio subsequently have significantly lower returns.

Previous papers have focused on mutual funds' holdings of other derivatives: credit default swaps (Adam and Guettler (2015), Aragon et al. (2019), Jiang et al. (2020)), foreign exchange derivatives (Eun and Resnick (1988), Glen and Jorion (1993), and Sialm and Zhu (2021)), and equity derivatives (Frino et al. (2009)). In this paper we focus on the gap in the existing literature: interest rate derivatives. Their use by fixed income mutual funds is not only less studied, but they also represent the largest class of derivatives that fixed income funds hold, as measured by notional amount. Interest rate risk is likely to be a greater concern for fixed income fund managers than equity fund managers, as the relationship between interest rates and bond prices is much more direct than for equity prices, which is another reason why we focus on fixed income funds.

The rest of the paper is organized as follows. Section 2 describes the institutional background and regulation pertaining to mutual funds' use of derivatives. Section 3 describes our data and variable construction. Section 4 describes some new facts about how fixed income funds use interest rate derivatives. Section 5 tests what determines interest rate derivative use. Section 6 discusses the implications for fund returns. Section 7 looks at the determinants of marginal calls on IRD positions. Section 8 concludes.

2 Institutional Background: Regulations on Mutual Funds' Derivative Use

The regulation governing mutual funds' use of derivatives is borne from Section 18 of the Investment Company Act of 1940, which lays out three ways that the general restrictions on mutual funds' investment decisions applies to funds' derivatives positions. Specifically, the embedded leverage subjects funds to the aggregate limit on a fund's actual and implied leverage (up to 33.3% of the gross asset value); the diversification requirement prohibits concentrated single-counterparty exposure (below 5% of total assets); and the full-commitment requirement states that the notional amount of total derivatives may not exceed 100% of the total value of the fund. SEC Release 10666 in 1979 relaxed the limits on particular senior securities such as reverse repurchase agreements, short sales, and derivatives. Registered investment companies could be exempt from the 300% asset coverage ratio requirement if their funds segregated sufficient liquid assets to cover potential future losses of their derivative positions.

In 2020, the SEC adopted new rule 18f-4 "designed to provide an updated, comprehensive approach to the regulation of funds' use of derivatives,"[3] with a compliance date of August 19th 2022. The rule requires funds to do the following:

1. Have a written derivatives risk management program, to identify potential derivatives risks, including leverage, market, counterparty, liquidity, operational, and legal risks, including risk guidelines, stress testing, backtesting, internal reporting and escalation, and periodic program review.

2. Comply with limits on fund leverage, specifically funds' Value-at-Risk (VaR) must not exceed 200% of the VaR of the fund's designated reference portfolio. The VaR model must use a confidence level of 99%, a time horizon of 20 trading days, and be based on at least three years of historical market data.

3. Comply with board oversight and reporting requirements, including the approval of a derivatives risk manager, program implementation effectiveness reporting, and regular board reporting.

Funds that limit their derivatives exposure to 10% of their net assets are exempt.

With an effective date of December 11th, 2023, the SEC has recently amended the regulations on funds' disclosure of their derivatives holdings.[4] Under a broader amendment, titled "Investment Company Names", funds must invest at least 80% of the value of their assets with an investment focus that the fund's name suggests. For derivatives, that means funds will have to use their

[3] https://www.sec.gov/news/press-release/2020-269

[4] https://www.sec.gov/files/rules/final/2023/33-11238_conforming-version-combined-w_33-11238a-correction.pdf

notional amount, rather than market value, for the purpose of determining compliance with the 80% investment policy, to more accurately represent funds' risk exposures. There are three exceptions. First, currency derivatives used for hedging can be excluded. Second, for options, their notionals will be delta-adjusted, since for instance deep out-of-the-money options with large notionals may have less risk exposure than in-the-money options with small notionals. Third, IRDs will be converted to their 10-year bond equivalents, to target adjusted notional amounts which allow comparison of exposure to interest rate changes across derivatives with different maturities.

3 Data and Variable Construction

In this section, we first provide the description of our main data sources for funds' derivatives positions and returns. We then explain how we construct our key variables that measure duration for IRDs and non-IRDs.

3.1 The SEC Form N-PORT Data

We construct a new dataset from mutual funds' mandatory SEC filings via Form N-PORT, which provides granular information on funds' derivative holdings at a quarterly frequency and both realized and unrealized profits and losses of derivative positions by instrument at a monthly frequency. Our sample period starts in July 2019, when N-PORT data first became available, and ends in September 2023. Our focus is on funds' use of interest rate derivatives during this period, which observes large fluctuations in interest rates.

There are several advantages of using N-PORT data. First, N-PORT's requirement for reporting in a structured data format provides complete coverage of funds' derivative holdings, split into seven instrument categories: forwards, futures, options, swaps, swaptions, warrants, and others. The N-PORT filings data improves the coverage of derivative positions compared to other datasets employed in the previous literature. For example, census information on N-SAR does not require funds to report their derivative positions on interest rate swaps and swaptions, which account for 37% of the total counts of IRD positions by fixed income funds in our sample.[5]

The rich information set in N-PORT allows us to estimate the direction and size of interest rate

[5] See Panel C of Table 1 for the counts of IRD positions by derivative instrument and position.

risk exposure in the derivative positions. Specifically, for each security, we collect the derivative instrument category, name of the reference asset, maturity (for the derivative and reference asset, separately), marked-to-market derivative position, portfolio weight, currency, and notional or principal amount. This greatly improves our ability to measure interest rate risk exposure compared to other mutual fund holdings datasets. For instance, in Morningstar, notional amount is not separately recorded from market value, and position-level information is not included, which are necessary to measure interest rate risk exposure using derivatives. Specifically, for swaps, N-PORT further provides information on both legs whether the fund pays and receives a fixed or floating interest rate; the spread in the case of a floating rate; and upfront payments and receipts in each position. In Figure 2, we provide a snapshot of Form N-PORT for a swap position in PIMCO Total Return Fund in 2020.Q2. For futures, we further obtain information on the their payoff profiles and the underlying reference assets: the futures' and underlying assets' maturities, and whether the fund holds a long or short position in each derivative position.[6]

Moreover, we can directly measure fund returns that are induced by derivative positions by utilizing realized and unrealised profits and losses by instrument at a monthly frequency from N-PORT. With this, we can decompose fund returns into returns that are attributed to IRD holdings and returns attributed to the rest of the asset holdings in each fund by instrument at a monthly frequency.

We also obtain security-level information on other holdings from N-PORT such as corporate bonds, government bonds, short-term investment vehicles (such as cash, repo agreement, and money market fund), and registered funds. With this, N-PORT provides a complete picture of holdings at each fund-quarter level. Specifically, we obtain information on the asset type, maturity, market value, portfolio weight, and currency. In Table A1, we document asset composition of portfolio holdings by asset class.

3.2 Fund-Level Data

We employ mutual fund returns, total net assets (TNA), index fund flag, and other fund-level characteristics at monthly frequencies from CRSP for the same sample period as for the N-PORT data. We additionally obtain *Morgningstar Category* from Morningstar Direct to identify peer

[6] We describe the definition of long/short position for each instrument category in Section 3.4.

funds that are often used for rankings with similar investment alternatives in fixed income mutual funds.

We exclude passive funds that are mandated to track an index, which have limited capacity to hedge or amplify the interest rate risks inherent in their portfolios using derivatives.

We then classify active mutual funds into four sectors based on *Lipper Objective Code* obtained from CRSP to government, investment-grade (IG) corporate, high-yield (HY) corporate, and global bond mutual funds following Choi and Kronlund (2018).[7]

Finally, in our sample, there are 1,812 active fixed income mutual funds across the four sectors in CRSP between July 2019 and September 2023. We manually match 71% (1,292 out of 1,812) of the CRSP funds to N-PORT funds by fund name. To confirm the quality of the matching, we cross-check that the difference in TNAs between CRSP and N-PORT is less than $100,000.

3.3 U.S. Federal Funds Rate and Treasury Bond Yields

In Figure 1, we plot the U.S. Federal funds rate and Treasury bond yields from January 2019 to September 2023, which shows substantial and frequent changes. From March 3rd to March 15th 2020 the U.S. Federal funds rate was cut from 1.5% to zero, in order to stimulate the U.S. economy as the world was mostly locked down to contain the Covid-19 pandemic. The Fed funds rate stayed at its lower bound of zero for two years until March 16th 2022, when it was raised to 25 basis points. Since then it has been raised multiple times to combat inflation. By the end of our sample period in September 2023 the Fed funds rate was 5.25%, a level not seen since 2007. These interest rate increases have typically been by as much as 50 or even 75 basis points at a time. These increases were much larger and more frequent compared to the 2015-2018 period when the Fed raised interest rates from zero following the recovery from the 2008-2009 Global Financial Crisis.[8] So our sample period gives us a unique opportunity to study the consequence of IRD use by fixed income funds.

[7] Specifically, we classify mutual funds into four sectors as follows. If *Lipper Objective Code* equals 'ARB', 'GUS', 'GUT', 'SIU', 'IUG', 'SUS', 'SUT', or 'IUT', then we classify the fund as a government bond fund. If *Lipper Objective Code* equals 'A', 'BBB', 'IID', 'SII', 'SID' or 'USO', then we classify the fund as an investment-grade (IG) corporate bond fund. If *Lipper Objective Code* is 'HY', 'GB', 'FLX', 'MSI', 'SFI', or 'SHY', then we classify the fund as a high-yield (HY) corporate bond fund. If *Lipper Objective Code* is 'EMD', 'EML', 'GHY', 'GLI', 'INI', then we classify the fund as a global bond fund.

[8] The Fed raised interest rates in a much slower and more predictable manner: after a 25 basis point increase in December 2015, it raised them by 25 basis points virtually every quarter between December 2016 and December 2018.

3.4 Calculating Interest Rate Risk Exposure

For interest rate risk exposure that each fund faces, their portfolio duration is a first-order approximation. In N-PORT, we do not observe the durations of derivative positions directly, but we can estimate them using the features of the derivatives and their reference securities. We compute DV100, which is the dollar duration of a 100 basis point change in interest rates at all horizons.

Classifying Long and Short Positions

Broadly we classify the direction of interest rate risk exposure as follows: it is long (or positive) if an increase in interest rates would decrease its value, and short (or negative) if an increase in interest rates would increase its value. We chose this classification to align with the classification used for funds' bond holdings. Specifically, we define a long/short position for each derivative contract as follows. For government bond futures, we classify a fund having a long (short) position if the fund is long (short) the futures contract. For interest rate swaps, we decompose them into two legs, and classify a long (short) position as one where the fund pays (receives) a floating rate or receives (pays) a fixed rate. We focus on government bond futures and interest rate swaps, as they are the most frequently held IRDs by fixed income funds in our sample, as seen in Table 1.

Duration for Different Instruments

We compute duration for funds' bond holdings and IRDs, for their most commonly held asset types, for all currencies. Specifically, for fund's bond holdings we include fixed-rate and floating-rate bonds, and asset-backed securities (ABS) and mortgage-backed securities (MBS). For IRDs we include government bond futures, interest rate swaps, excluding cross-currency swaps, and swaptions, for the 6 most common currencies: USD, EUR, JPY, GBP, AUD, and CAD. Since swaps and futures have zero value at initiation, rather than duration itself we compute dollar duration for each asset, specifically DV100, i.e. the dollar increase in value for a 100 basis point parallel increase in yields at all horizons, which we scale by total net assets.

Fixed-rate Bonds

For fixed-rate bonds we first compute the standard measure of Macaulay duration as the average time to funds receiving coupon and principal payments, weighted by the present value of those cashflows as a proportion of the total bond price. In N-PORT, fixed-rate debt is identified as asset category (*assetcat*) 'DBT', and debt security coupon kind (*debtseccouponkind*) 'Fixed'. Most of the information needed to compute fixed-rate bonds' duration is provided explicitly in N-PORT, except for their coupon frequency which we assume is semi-annual, and their yield y which we impute numerically from the following equation:

$$\text{Bond price} = N\left(\frac{1}{(1+y/2)^{t_T}} + \sum_{s=1}^{T}\frac{c/2}{(1+y/2)^{t_s}}\right). \tag{1}$$

using the price of the bond holding in U.S. dollars (*valusd*), principal N (*balance*), and annualized coupon rate c (*debtSecAnnualizedRt*/100) from N-PORT. For the coupon dates $t_1,,,t_T$, we set the time to maturity t_T equal to the time from the fund's fiscal reporting date (*formdata_geninfo_reppddate*) to the bond's maturity date (*debtSecMaturityDt*), and then set the time to the other coupon dates $t_{T-1},...,t_1$ as 6-month multiples back from the maturity date, since we assume a semi-annual frequency for the coupons. Since the bond's time to maturity date may not be a multiple of 6 months, sometimes the time to the first coupon is less than 6 months. If the bond price is zero, or the implied yield is larger than 99% or less than -99%, then we exclude those bonds from our duration calculation, since there is likely a typo in N-PORT for that bond.

Having solved for the yield, we plug it in to the formula for a bond's Macaulay duration, and finally modified duration, which is the first-order approximation of the percentage change in price for a 1% increase in interest rates at all horizons:

$$\text{Macaulay duration} = N\left(\frac{t_T/(1+y/2)^{t_T} + \sum_{s=1}^{T}(c/2\cdot t_s/(1+y/2)^{t_s})}{\text{Bond price}}\right) \tag{2}$$

$$\text{Modified duration} = \frac{\text{Macaulay duration}}{1+y/2} \tag{3}$$

Some entries in N-PORT have bond notional amounts and/or bond prices which are negative. In those cases, if the funds have sold the debt short (*payoffprofile* is 'Short'), we use the absolute value of notional amounts and bond prices, and then calculate the duration to be the negative of the formula above. If the payoff profile is 'Long', and the bond notional amounts and/or bond prices are negative, we mark them and duration as missing.

Floating-rate Bonds

We assume that floating-rate bonds have no interest rate risk after their first payment, since any change in interest rates would be mirrored by the same change in their coupon rates.[9] So their Macaulay duration is just the time to that first payment.

We assume a coupon frequency of 6 months. As with fixed-rate bonds, we work back from the maturity date in multiples of 6 months to find the time to the first coupon date t_1.

$$\text{Macaulay duration of floating-rate bond} = \text{time to next payment} = t_1 \tag{4}$$

Since we assumed a coupon frequency of 6 months, that is the maximum time to the next coupon payment, and therefore also the maximum Macaulay duration of a floating-rate bond. We compute the modified duration as in equation (3), where the yield y is imputed as the return from the bond's price to the sum of the notional amount and first coupon.

ABS & MBS

Macaulay or modified duration would overstate the interest-rate sensitivity of asset-backed and mortgage-backed securities, because they ignore prepayment risk. So we use the "roll-up roll-down" method of Breeden (1991), also described as "coupon curve duration" in Fabozzi (2016). This is a model-free method of computing duration using market prices to observe empirically how much ABS and MBS prices change for a given change in interest rates. It uses the assumption that if yields were 1% higher, or lower, then the price of an ABS with coupon rate $c\%$ would be equal to the price of an ABS with coupon rate $(c-1)\%$, or $(c+1)\%$, respectively. The formula for duration

[9] Floating-rate bonds are priced at par immediately after each coupon payment, and their cashflows can be replicated by a dynamic strategy of buying single-period par-value bonds with maturity equal to the time to the next coupon, and rolling the proceeds into the next single-period bond. Since the cashflows of this strategy and a floating-rate bond are equal, their durations must also be equal.

is given by:

$$\text{Duration of ABS/MBS at time } t = \frac{\hat{P}_t(c+1) - \hat{P}_t(c-1)}{2P_t(c)} \times 100. \tag{5}$$

where $P_t(c)$ is the time-t price of the ABS or MBS with its current coupon rate c (*debtSecAnnualizedRt* in N-PORT), and $\hat{P}_t(c+1)$ and $\hat{P}_t(c-1)$ are estimates of the time-t ABS or MBS prices, if the coupon rate were higher or lower by 100 basis points, respectively.

To estimate these prices, each quarter we pool ABS and MBS with maturities within a 1-month window of each other, and regress their prices on their coupon rates.[10] To account for credit risk, we run regressions separately where the issuer category (*issuercat*) is a government agency (*USGA*) or government-sponsored entity (*USGSE*), versus a corporate issuer (*CORP*). Implicitly we are assuming that the credit risk within each issuer category is similar. For government agencies and government-sponsored entities, this credit risk is likely close to zero. The regression specification is given by:

$$P_{i,a,t,\tau(a,t)} = \alpha_{i,\tau} + \beta_{1,t,\tau(a,t)} \times \text{coupon rate}_{a,t} + \varepsilon_{i,a,t,\tau(a,t)} \tag{6}$$

for issuer category i which issued ABS or MBS a, which is in 1-month maturity group τ in quarter t. To reduce the estimation error from outliers, we winsorize the prices and coupon rates at the 1% level, and require at least 10 data-points in each regression. Having estimated the intercepts α and slopes β, we use the implied estimates $\hat{P}_t(c+1)$ and $\hat{P}_t(c-1)$, and plug them in to equation (5) to estimate duration for ABS and MBS. As expected, this coupon curve duration estimate of duration is smaller in magnitude than modified duration, which ignores prepayment risk. Our duration measure for ABS and MBS is a weighted average of coupon curve duration and modified duration, weighting 10% on modified duration to reduce estimation error and the frequency of negative durations, though these are theoretically possible.

Finally, for fixed- and floating-rate bonds, ABS, and MBS, we compute DV100 by multiplying the duration by the security's market value.

[10] As robustness we also include the coupon rates squared to account for any concavity, and the estimates of duration are similar.

Swaps

We decompose swaps into their pay and receive legs, and compute the duration as the difference in durations of the two legs. For instance, a T-year swap receiving (paying) an annualized fixed rate c with notional amount N dollars has the same cashflows as a portfolio containing two positions:

1. a long (short) position in a T-year fixed-rate bond with coupon rate c and par value N dollars; and

2. a short (long) position in a T-year floating-rate note with par value N dollars.

So the duration of a fixed-for-floating swap is the difference in durations of a bond and a floating-rate bond with the same maturity and principal as the swap, where the bond's coupon rate is equal to the swap's fixed rate. Similarly we compute the duration of fixed-for-fixed and floating-for-floating swaps as the difference in the durations of each leg. For each leg we compute DV100 by multiplying the duration by the market value of the fixed leg (which is equal to the value of the floating leg by assumption). The market value of the fixed leg is computed as the sum of the discounted cashflows, discounted at the prevailing government bond yields (for the fixed leg currency) on the report date for each cashflow horizon. We remove cross-currency swaps from our sample, as we are focused on interest rate, rather than currency, risk.

N-PORT provides the notional amount for swaps (*swp_nonfx_notionalamt*), whether there are fixed or floating payments (*swp_nonfx_pmnt_fixedorfloating*) and receipts (*swp_nonfx_rec_fixedorfloating*), and the fixed rates for payments (*swp_nonfx_pmnt_fixed_fixedrt*) and receipts (*swp_nonfx_rec_fixed_fixedrt*). Though it provides the value of fixed-rate and floating-rate bonds, it does not provide the value of each leg of a swap. So we estimate those as the sum of the present value of their cashflows, using government bond yield curve data. We focus on the six most common currencies for swaps in N-PORT: USD, EUR, JPY, GBP, AUD, and CAD. For USD we use the zero-coupon Treasury yield, which is available at a daily frequency from the U.S. Federal Reserve website[11] at horizons of 1, 3, and 6 months and 1, 2, 3, 5, 7, 10, 20, and 30 years. For any missing days, we use the yield from the previous day, if available, or the most recent date that is. To compute yields at maturities in between those available from the Fed, we linearly interpolate them from the closest

[11] https://www.federalreserve.gov/datadownload/Choose.aspx?rel=H15

two maturities. For maturities less than 1 month or above 30 years, we use the 1-month and 30-year yield, respectively. For the other 5 non-USD currencies, we use government bond yield data from Refinitiv at the same maturities. For EUR, we use yield data for German government bonds; since data for 1-month yields is unavailable, we use the 3-month yield.

Futures

N-PORT provides various details on funds' holdings of bond futures contracts, including the expiry date t_0 (*fut_expdate*), notional N (*fut_notionalamt*), payoff profile (*fut_payoffprof*) as long or short, the reference asset, and the mark-to-market value of the contracts (*valusd*) on each reporting date. However, the maturity, the coupon rate, and the coupon frequency of the underlying government bonds are not provided, which we need to impute the duration of the futures contracts. We extracted the maturity from the field *title* where available. Since the coupon rates of the underlying government bonds are not provided in N-PORT, we assume a coupon rate of 0% for Treasuries with a maturity of up to one year, and 6% for longer maturities since that is the futures contract standard.[12] We assume the government bonds pay coupons semi-annually. Though the strike price is not provided explicitly, it is a feature of futures contracts that their strike price is set such that the contract value is zero when the contract is initiated. Since futures are marked to market daily, after funds settle their margin positions the contracts have zero value going forward, which allows us to determine a long-short replicating portfolio.

If interest rates are constant, the duration of the futures is the same as that of a forward. The strike price for each is set equal to the forward price, so that at initiation of the contract it has zero value. The cashflows of a forward, where the underlying Treasury is bought at the forward's expiry date t_0 and matures at date t_T, can be replicated by the portfolio containing the following two positions:

1. a long position in the underlying government bond, coupon rate c, maturity t_T, and price $p(c, t_T)$; and

2. borrowing an amount equal to $p(c, t_T)$ until time t_0, by going short $\frac{p(c,t_T)}{p(0,t_0)}$ units of zero-coupon government bonds with maturity of t_0 and price per unit $p(0, t_0)$.

[12] https://www.cmegroup.com/education/files/understanding-treasury-futures.pdf

We compute the price of the first leg by summing its discounted cashflows using government bond yield data. That tells us the borrowing cost in the second leg. We compute the duration of the first leg using equation (3) for fixed-rate bonds. The duration of the second leg is $-t_0$. The duration of the futures is the difference in the durations of each leg of its replicating portfolio. We compute DV100 by multiplying the duration by the market value of the long leg (which is equal to the value of the short leg by assumption), i.e. the notional amount multiplied by the price per unit $p(c, t_T)$.

Swaptions

To compute the duration of interest rate swaptions, we assume that their prices follow the Black (1976) model. We compute deltas using the formulas, and Bloomberg data for forward swap rates and implied volatilities, described in detail in Sen (2023). The rest of the data is from N-PORT: the strike (*osw_exerciseprice*), option expiry (*osw_expdt*), fixed rate (*ref1_pmnt_fixedrt* or *ref1_rec_fixedrt*), whether the underlying swap is fixed-fixed or fixed-floating (*c11_swp_NonFX_Pmnt_fix_float* and *c11_swp_NonFX_Rec_fix_float*), and whether the swaption was written or purchased (*osw_writtenorpur*).

3.5 IRD Duration

Using the duration of individual derivative positions, we construct our main measure of interest rate derivative exposure 'IRD Duration' at a fund-quarter level. We define IRD Duration for fund i in quarter t as the sum of the dollar durations (DV100) of interest rate derivative j held by the fund, divided by the fund's TNA:

$$\text{IRD Duration}_{i,t} = \frac{\sum_{j \in \text{IRD}} \text{DV100}_{i,j,t}}{\text{TNA}_{i,t}}, \tag{7}$$

where IRD includes government bond futures, interest rate swaps, and swaptions. Similarly, we define Bond Duration:

$$\text{Bond Duration}_{i,t} = \frac{\sum_{j \in \text{Bond}} \text{DV100}_{i,j,t}}{\text{TNA}_{i,t}}, \tag{8}$$

where Bond includes all non-derivative bonds such as fixed-rate bonds, floating-rate bonds, ABS, and MBS. We compute Total Duration as the sum of the two:

$$\text{Total Duration}_{i,t} = \text{IRD Duration}_{i,t} + \text{Bond Duration}_{i,t}. \tag{9}$$

3.6 IRD and Non-IRD Returns

We compute fund i's IRD return in quarter t as a percentage of TNA following Kaniel and Wang (2022):

$$\text{IRD Return}_{i,t} = \frac{\text{Realized Gain}_{i,t} + \text{Unrealized Appreciation}_{i,t} - \text{Unrealized Appreciation}_{i,t-1}}{\text{TNA}_{i,t-1}}. \tag{10}$$

where the realized gains and unrealized appreciation are for IRDs only. The residual non-derivative induced return (non-IRD) for fund i in quarter t is computed by subtracting the IRD return from the total fund return:

$$\text{Non-IRD Return}_{i,t} = \text{Fund Return}_{i,t} - \text{IRD Return}_{i,t}. \tag{11}$$

3.7 Treasury Bid-Ask Spreads

We collect daily data on U.S. Treasury bonds' Macaulay durations and bid-ask spreads from CRSP. We compute the mean half-spread each quarter for each security, which we match by CUSIP to funds' Treasuries holdings in N-PORT.

4 Stylized Facts on IRD Use by Fixed Income Mutual Funds

We establish some new stylized facts about fixed income mutual funds' use of IRDs: that (a) most funds use them, (b) their notionals constitute a sizeable proportion of their portfolios, (c) a substantial number of funds do not exploit them for hedging purposes, and (d) substantial variation in funds' portfolio duration changes are driven by IRD duration changes.

4.1 Funds' Aggregate IRD Holdings

Table 1 provides summary statistics on our sample funds' holdings of IRDs both in aggregate and across fund sectors. We find that IRDs are widely used and also used in large quantity. Among the fixed income mutual funds in our sample, 56% hold at least one derivative in at least one quarter in our sample period. Panel A shows that the aggregate notional amounts of fixed income funds' IRD holdings are very large, both in an absolute sense and relative to other derivative classes. Averaged across our sample period, the absolute notional of IRDs used is $404 billion, compared to $74 billion for credit derivatives and $183 billion for FX derivatives.[13] Panel B shows the averages of individual-fund level statistics calculated across the sectors. We find that IRDs constitute a sizeable proportion of funds' holdings also at the individual fund level. The absolute sum of notional amount of IRDs make up on average between 41.67% (HY corporate) and 79.62% (Global) of their total net assets.

Figure 3 shows how the aggregate sum of absolute notional amount in IRDs held by fixed income funds in our sample varies over time. Each is decomposed into the absolute notional amount of their long and short positions. Also plotted is their aggregate net notional amount, i.e. their long minus short positions. We present the amounts in billions of dollars in graph (a); and contextualize them by scaling them as a percentage of total net assets aggregated across all funds in graph (b). We see that funds' aggregate position, and each of the long and short components, are consistently large throughout our sample period. The gross holdings range from $294.06 billion to $481.37 billion in our sample period, and from 27.22% to 38.91% of aggregate TNA. Interestingly we also see that their net exposure to interest rate risk grew from +$37.6 billion at the start of our sample period in 2019Q3 to +$126.09 billion by the end of our sample period in 2023Q3, or from +4.97% to +9.95% of TNA. This positive exposure indicates that in aggregate fixed income mutual funds were using IRDs not to hedge their bonds' interest rate risk, but to amplify it, and were using them to take increasingly large bets that interest rates would go down, even as the Fed increased them rapidly in 2022 and 2023.

[13] The N-PORT data provides detailed security-level information for not just interest rate derivatives, but also five other derivative categories: credit, foreign exchange, commodity, equity, and other derivatives.

4.2 Cross-sectional and Time-series Variation in Funds' IRD and IRD Returns

Table 2 shows summary statistics of IRD holdings as well as other characteristics of funds in our sample, pooled across all funds and all quarters. Of particular interest are the standard deviations and low and high percentiles which show that there is substantial heterogeneity across funds in the cross-section and time-series in a number of key variables.

The results in Table 2 show that some funds hold an extremely large number of IRDs. For instance in 5% of the fund-quarter observations funds hold 67 or more IRDs, and the standard deviation of the number of IRDs held is over 26. Similarly there is substantial variation in funds' IRD notional as a percentage of net assets, with a standard deviation of 15.6% and 5th and 95th percentiles of -13.5% and 31.2%. In 47% of fund-quarter observations, funds are using IRDs to speculate on interest rate cuts, rather than hedge against them being hiked. IRD Duration as a percentation of TNA has a standard deviation of 2.23%, a substantial proportion of the mean (median) bond duration of 5.02 (4.66). Overall these summary statistics highlight that funds' IRD portfolio exposure to interest rate changes, in both directions, can be substantial.

We also find large variation in funds' IRD returns in the cross section, a combined result of large fluctuation in interest rates during our sample period and cross-sectional dispersion in funds' IRD portfolio exposure. The results in Table 2 that some funds had large negative IRD returns and some had large positive IRD returns in some quarters, with a standard deviation of 0.41%. The mean and median monthly non-IRD returns were 0.05% and 0.43%, respectively, so a one standard deviation change in IRD returns can affect funds' overall portfolio returns substantially, even changing their sign.

Subfigure (a) of Figure 4 plots the distribution of funds' IRD durations over time. The sample period is from July 2019 to August 2023. Again there is substantial cross-sectional variation in each quarter: further evidence that many funds were not just using derivatives to hedge the interest risk of their bond portfolios, but sometimes to amplify their bond returns.

Subfigure (b) of Figure 4 plots the distribution of funds' monthly IRD returns over time. The sample period is from July 2019 to August 2023.[14] We find that the spread of the distribution varies a lot over time, but in most months there is substantial cross-sectional variation. In particular in

[14] We exclude September 2023 due to incomplete data.

2022 the IRD return distribution widened. The distribution for fund duration is a lot less volatile than the distribution for fund returns, which is driven not just by variation in funds' duration but also by variation in yields. In the plot the gray vertical bars mark the dates when the Fed changed interest rates: lowering them in 2020 and raising them in 2022 and 2023. The width of the bars is proportional to the size of the interest rate change. In 2022 interest rates were raised rapidly: in March they were raised by 25 basis points, in May by 50 basis points, and in June, July, and September by 75 basis points in each month. So it is natural that there was greater variation in IRD returns as funds profited or lost larger amounts depending on whether they were short or long duration.

The distribution of IRD durations is much more stable over time than that of the IRD returns in Figure 4, where the return variation is driven not just by changes in IRD duration, but also by changes in interest rates. The cross-sectional dispersion suggests the need for regulators to monitor the whole cross-section of mutual funds, as there are an increasing number of funds which are susceptible to large losses if interest rates are hiked before they reduce the duration of their IRD portfolios, and fewer that will make large profits.

4.3 Are Funds only using IRDs for Hedging?

Having established that pooling across funds and time there is substantial variation across funds' exposure to interest rate risk through their IRD portfolios and IRD returns, we dig in more to examine the extend to which funds employ IRDs to hedge their non-IRD positions.

Figure 5 compares funds' IRD and non-IRD returns. Specifically each point represents the monthly return of a fund's IRD portfolio versus the monthly return on its non-IRD portfolio, in the same month, in a scatter plot. We see that IRD returns can be both positive and negative and large in magnitude. More importantly, we find no strong relationship between IRD and non-IRD returns: regressing the non-IRD returns on the IRD returns yields a an R^2 of only 18.8%, as there is tremendous variation both in the cross section and time series of funds' use of IRDs. These result show that funds' IRD returns do not tend to offset non-IRD returns, suggesting that funds speculate on interest rates as often as they hedge.

Figure 6 shows a histogram of the correlation between funds' monthly returns on their IRD portfolio and the rest of their portfolio. The correlation is one way to classify funds into hedgers (low/negative correlation) and speculators (high/positive correlation). For instance Kaniel and Wang (2022) use correlation terciles to examine equity mutual funds' use of all types of derivatives, and they find that the distribution is bimodal, with the most common correlations close to +1 and -1. We see that for fixed income funds' IRDs the distribution is very different: compared to equity funds it is much more common for the correlation to be smaller in magnitude, but there are a large number of instances when funds' IRD portfolios amplify their bond returns, rather than hedge them.

4.4 Contribution of IRD Duration to Portfolio Duration Changes

In Table 3 we decompose the cross-sectional variation in changes of total fund duration, measured as DV100/TNA, into the variance of changes in the IRD and bond components and their covariance:

$$\begin{aligned}\mathrm{Var}\left(\Delta\text{Total Duration}\right) &= \mathrm{Var}\left(\Delta\text{Bond Duration} + \Delta\text{IRD Duration}\right)\\ &= \mathrm{Var}\left(\Delta\text{Bond Duration}\right) + \mathrm{Var}\left(\Delta\text{IRD Duration}\right)\\ &\quad +2 \times \mathrm{Cov}\left(\Delta\text{Bond Duration}, \Delta\text{IRD Duration}\right). \end{aligned} \tag{12}$$

This decomposition analysis is particularly helpful in informing us of the relative contribution of duration changes due to IRDs to total changes in portfolio duration. The results in Table 3 show that 59.7% of the variation is due to changes in IRD duration, 47.8% to changes in bond duration, and their covariance contributes -7.5%.[15] So over half of the variation in changes in funds' duration can be attributed to IRDs, even more than for bonds. This is despite funds' IRD holdings being much smaller in market value than their bond holdings: funds' mean holding of bond is at least 78% of their portfolio, depending on the sector, while for IRD the highest sector average is 0.44% (see Table A1). This shows how disproportionately funds use IRD over bond when changing the duration of their portfolio.

[15] The negative covariance indicates that when funds change the duration of their portfolios using bonds, some of that is offset using IRD, but only a modest amount.

5 Why Do Funds use IRDs?

Having established substantial IRD use across fixed income funds in the previous section, often apparently not motivated by hedging interest rate risk, we investigate the economic forces that can instead explain their use of IRDs. We explore three such economic drivers: (a) risk taking and duration seeking, (b) liquidity management, and (c) transaction cost mitigation.

5.1 Risk Taking and Liquidity Management

We examine the extent to which variables that proxy for funds' incentives to engage in risk taking and liquidity management are associated with their IRD use. Derivatives allow implicit leverage for funds and can be used by fund managers as a tool to engage in risk taking. Funds can also employ derivatives to manage liquidity risk. As IRDs allow them to take duration exposure with lower capital, funds might find it more beneficial to take derivative positions to deal with fluctuations in investors' redemption needs. If funds instead take cash positions, they will either need to maintain liquidity cushions, which can adversely affect fund performance.

We first investigate whether funds' IRD use is associated with greater risk taking. In Table 4, we test this hypothesis by running panel regressions of indicator variables of their IRD use and the size of their IRD exposure on lagged fund-level characteristics which could predict funds' risk taking. The regression equation for fund i's IRD use in quarter $t+1$ is given by:

$$\begin{aligned} \mathrm{Y}_{i,t+1} \quad = \quad & \delta_t + \gamma_{s(i)} + \beta_1 \cdot \text{Bond Yield}_{i,t} + \beta_2 \cdot \text{Expense Ratio}_{i,t} + \beta_3 \cdot \text{Size}_{i,t} + \\ & \beta_4 \cdot \text{Age}_{i,t} + \beta_5 \cdot 1\{\text{Bottom Rank: Fund return}_{i,t}\} + \boldsymbol{\kappa} \cdot \mathbf{C}_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{13}$$

where $Y_{i,t+1} = 1\{\#\text{IRD} \geq n\}_{i,t+1}$ is an indicator variable which takes the value 1 if fund i holds at least one or thirty IRDs in quarter $t+1$ for $n \in \{1, 30\}$ in Columns (1)-(2). In Columns (3)-(9) we use another proxy of funds' risk-taking, $Y_{i,t+1} = |\text{IRD Net Notional}_{i,t+1}|/\text{TNA}_{i,t+1}$. We include year-quarter fixed effects, δ_t, and fund sector fixed effects for sector s, $\gamma_{s(i)}$, to examine cross-sectional relationships.

We find that bond yield significantly increases both the probability that funds hold at least 30 IRDs, and the magnitude of their IRD net notional holdings as a percentage of TNA. Bond

Yield is the weighted average of yield of funds' non-derivative bond holdings, including ABS and MBS, using the market value as the weight. Bond yield is a proxy for funds' risk taking in their bond holdings, and the results suggest that funds which are reaching for yield in bond markets are also taking more interest rate risk in IRD markets. We find that this increased risk taking in IRD notional is concentrated in Phase 1 (when interest rates were cut), and in all fund sectors.

Funds with higher expense ratios have a greater incentive to take risk to justify their fees for active management and increase their compensation. We find that only high yield corporate bond funds with higher expense ratios take on interest rate risk exposure with their IRDs.

Large funds might suffer from diseconomies of scale, incurring large transaction costs when trading in large size and being out of good investment opportunities. That gives them an incentive to use IRD more.[16] They also have access to better pricing for derivatives, at least in over-the-counter markets. Consistent with this, we find that larger funds use more IRDs and have a bigger net notional. Size is computed as the log of fund TNA in millions of dollars.

Funds that are younger, which may also be associated with greater appetite for risk-taking, are more likely to hold at least thrity IRD contracts. These funds have relatively little reputation to lose while facing upside potential to draw large amounts of investor flows if risk taking is successful.

In tournaments where funds are competing for flows, funds which are lower ranked based on their current fund returns have an incentive to catch up to their peers by taking more risk. 1{Bottom Rank: Fund return$_t$} is an indicator variable which takes the value 1 if the fund return is below the 20th percentile of fund returns within CRSP category in that quarter. We find that low ranked funds took on larger IRD risk, particularly in Phase 3.

5.2 Transaction Costs

We further examine whether transaction costs explain why funds use IRDs. Funds have a choice of gaining exposure to interest rate risk through Treasury bonds or IRDs. Intuitively, if the transaction costs of attaining their desired level of duration using Treasury bonds are high, then funds may be better off using IRDs. For this, we estimate a hypothetical transaction cost that a fund would have incurred from trading Treasury bonds to replicate the IRD futures and interest rate swaps they hold. We focus on funds' new IRDs which the fund did not hold in the previous quarter to

[16] We test how transaction costs may explain funds' IRD use separately in the following section.

understand if the transaction costs explain funds' use of IRDs.

To estimate the transaction costs associated with replicating funds' IRD positions, we regress the daily bid-ask spreads of Treasuries on their durations and quarterly fixed effects. Then in N-PORT we estimate the transaction cost for the long and short replicating legs of each swap and futures position from the regression estimate for each leg's duration in that quarter. We denote this hypothetical transaction cost as 'IRD Bid-Ask Spread'. We also compute the market-value-weighted-average of half the bid-ask spread for funds' Treasury holdings, which we refer to as the 'Treasury Bid-Ask Spread'.

We run panel regressions of three different New IRD variables on IRD Bid-Ask Spread, Treasury Bid-Ask Spread, and other variables that may help predict funds' IRD use:

$$\begin{aligned} \mathrm{Y}_{i,t} &= \delta_t + \gamma_{s(i)} + \beta_1 \cdot \text{IRD Bid-Ask Spread}_{i,t} + \beta_2 \cdot \text{Treasury Bid-Ask Spread}_{i,t} \\ &\quad + \boldsymbol{\kappa} \cdot \mathbf{C}_{i,t} + \varepsilon_{i,t}. \end{aligned} \tag{14}$$

Specifically, in Table 5, we use as the dependent variable: (1) the number of new IRDs; (2) the sum of the absolute notional amount of the new IRDs over TNA; and (3) the percentage of new IRDs out of the total. We find that funds which would incur higher transaction costs from replicating their IRDs with Treasury bonds enter into new IRD contracts more, and increase their percentage of new IRDs as a fraction of total IRDs held.

Instead of using IRDs, either directly or indirectly by replicating them, funds could instead use Treasuries to attain their desired level of duration. Higher Treasury transaction costs could increase the attractiveness of substituting them with IRDs. We find evidence of this across our three measures of New IRD use. When Treasury transaction costs are higher, the number of new IRDs is significantly higher, both in absolute terms and relative to the total, and there is modest evidence that the size of the new IRD positions increases too.

5.3 Lengthening Duration Exposure with IRDs

When funds have a different level of duration to their peers, they may have an incentive to close the duration gap and return to the average duration level of the group against which they are benchmarked, to catch up their returns. We test whether they change their duration for IRDs and/or bonds when it's above or below that of their peer group.

We find supporting evidence that funds rebalance their IRD duration in response to the duration gap in the preceding quarters. Specifically, in Table 6 we run panel regressions of changes in duration from quarter t to $t+1$ on funds' duration gap from the peers in quarter t:

$$\begin{aligned} \Delta\text{Duration}_{i,t+1} &= \delta_t + \gamma_{s(i)} + \beta_1 \cdot \text{Duration Gap to Peers}_{i,t}(+) \\ &\quad + \beta_2 \cdot \text{Duration Gap to Peers}_{i,t}(-) + \boldsymbol{\kappa} \cdot \mathbf{C}_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{15}$$

where Duration Gap is defined as the fund's Total Duration minus the size-weighted average of Total Duration for its peers in the same Morningstar Category (excluding the fund itself) in that quarter. Duration Gap to Peers $(-)$ is the duration gap when the gap is negative, and Duration Gap to Peers $(+)$ when it is positive.

In Column (1) of Table 6, the further below its peers a fund's duration is, across both Phases 1 and 3, funds increase their duration, for both bonds and IRDs. The magnitude of the effect is even larger for IRDs than for bonds, despite IRDs constituting a much smaller proportion of funds' portfolios. The further above its peers a fund's duration is, the more it reduces its duration in total, but only by reducing its duration for bonds not IRDs, and the effect is insignificant in Phase 1.

So the duration gap to funds' peers matters, particularly when funds' interest rate risk is below that of their peers. This is consistent with funds competing with their peers' returns in a tournament, as funds which take lower interest rate risk might expect to earn lower yields, and so need to catch up to their peers. Most of the controls are insignificant, including the previous quarter's IRD and non-IRD returns when evaluating the sample as a whole. This suggests that funds' incentive to match their peers' risk taking in a relative sense dominates their concern about their own returns in an absolute sense.

6 IRDs' Contribution to Fund Returns

If fixed income funds are not necessarily employing IRDs for hedging, but instead for speculation, it is important to examine the extent to which this IRD use contributes to fund returns. Interest rate risk was unusually high during our sample period, with large interest rate cuts in Phase 1 and large hikes in Phase 3. So we have a particularly interesting laboratory in which to examine how much of funds' returns can be attributed to their IRDs.

6.1 IRD Duration and Fund Returns

To investigate the magnitude of fund returns associated with IRD, we run panel regressions of monthly returns on indicator variables, $1\{\text{Top (Bottom) IRD Duration}_{i,t}\}$, which take the value 1 if the IRD Duration is above (below) the 80th (20th) percentile for fund i in quarter t:

$$\begin{aligned}\text{Return}_{i,t+1} &= \delta_t + \gamma_{s(i)} + \beta_1 \cdot 1\{\text{Top IRD Duration}_{i,t}\} + \beta_2 \cdot 1\{\text{Bottom IRD Duration}_{i,t}\}, \\ &+ \boldsymbol{\kappa} \cdot \mathbf{C}_{i,t} + \varepsilon_{i,t}. \end{aligned} \tag{16}$$

where $\text{Return}_{i,t+1} = \{\text{IRD Return}_{i,t+1}, \text{Non-IRD Return}_{i,t+1}, \text{Fund Return}_{i,t+1}\}$ and the vector of controls $\mathbf{C}_{i,t}$ include bond duration, expense ratio, fund size, fund return, and flows, all in preceding quarter, that may affect returns in the subsequent quarter.

In Column (1) of Table 7, we find that in Phase 1, when interest rates were cut to zero, funds in the top IRD duration quintile had a higher average IRD return at 0.204% per quarter and the bottom quintile an average IRD return of -0.341% lower per quarter. Interestingly, we find that the non-IRD return for the top duration quintile is also significantly higher at 0.644% per quarter. That is, high IRD duration funds not only have higher IRD returns but also higher non-IRD returns. This is true even after controlling for the funds' bond duration, which motivates our tests in the next section in Table 8 on whether the higher fund returns are due to fund managers' skill and whether it persists over time.

Moreover, we show that IRD returns make up a large portion of fund returns in Phase 3, when interest rates were hiked. In Columns (7)-(9) of Panel A of Table 7, we show that funds in the top IRD duration quintile had a lower average IRD return at -0.323% per quarter, which constitutes the majority of the lower total fund return at -0.564% per quarter.

The granularity of our unique data also allows us to identify which IRDs are behind these performance results. In Panel B of Table 7, we further break down the IRD returns by derivative instrument, i.e., returns from futures, interest rate swaps, and other IRDs (e.g. options and swaptions). Across different phases, we find that government bond futures are the largest contributor to returns in both top and bottom quintiles of IRD duration. This is consistent with recent anecdotes that fund managers are increasingly engaging in basis trades using U.S. Treasury futures contracts.

6.2 Duration Ratio and Fund Returns

To measure funds' interest rate risk exposure using IRD relative to their bond duration, we employ the Duration Ratio of fund i's IRDs in quarter t, which is defined as the duration of IRDs (IRD Duration) divided by the duration of funds' non-derivative bond positions (Bond Duration):

$$\text{Duration Ratio}_{i,t} = \frac{\text{IRD Duration}_{i,t}}{\text{Bond Duration}_{i,t}}. \tag{17}$$

We show that Duration Ratio possesses significant explanatory power for the cross-section of fund returns. To investigate fund returns associated with Duration Ratio, we construct indicator variables, $1\{\text{Top (Bottom) IRD Duration Ratio}_{i,t}\}$, which take the value 1 if Duration Ratio is above (below) the 80th (20th) percentile for fund i in quarter t.

Using this relative measure of IRD duration, we find similar results that IRD returns significantly contribute to total fund returns, across three different phases in Table A3, highlighting the importance of considering their IRD use for fund-level performance. Again we find that amongst futures, swaps, and other IRDs, futures are the largest contributor to IRD returns in Table A4.

6.3 Skill: Persistence in Performance

We examine whether funds that employ IRDs tend to exhibit greater skill. To test this hypothesis, we condition on funds' IRD return performance in 2020.Q1—a period when interest rates were dramatically cut following the pandemic—and track their subsequent IRD return performance in the following periods, especially through Phase 3, during which interest rates were hiked substantially. This period provides a robust environment to test if fund managers are skilled. If so, we would likely observe them changing course and reducing the duration of their IRD positions. However, we find in Table 8 that funds' IRD durations tend to be sticky, and high IRD duration funds tend to maintain high IRD duration exposure. Additionally, funds that outperformed in their IRD positions up to 2020.Q1 perform particularly poorly in both their IRD and non-IRD positions in subsequent periods, resulting in 0.32% lower returns per quarter compared to funds whose IRDs underperformed during 2020.Q1.

In Figure 7, we plot the cumulative monthly IRD and total fund returns for funds which were in the highest and lowest quintile for IRD returns in January to March 2020, when interest rates were cut from 1.5% to zero. We break out the results into the four fund sectors. In each plot the grey and black dashed lines are the total fund returns in the top and bottom quintiles, respectively, and the red and green solid lines are the IRD returns in the top and bottom quintiles.

Comparing the red to the green solid lines, funds which had the highest IRD returns in January to March 2020 accumulated lower IRD returns on average from July 2020 to September 2023 than those funds which had had the lowest IRD returns in January to March 2020, for high yield and investment grade corporate bond funds. Comparing the grey to the black dashed lines, funds which had the highest IRD returns in January to March 2020 accumulated lower total fund returns on average from July 2020 to September 2023 than those funds which had had the lowest IRD returns in January to March 2020. So we don't find evidence of persistent fund manager skill in timing interest rate moves across the interest rate cut and hike phases in our sample period. This is consistent with some persistence in funds' IRD duration strategy over time, as seen in the top left subfigure of Figure 8, and thus generating profits only in one direction of interest rate change and losses in the other.

7 Margin Calls

One of the key risks to bond funds from using IRDs is margin calls on their IRD positions. To this end, we further examine the extent to which bond funds face margin calls during periods of large interest rate changes in our sample.

Estimation of Margin Calls

We define a margin call as when a fund has insufficient cash holdings to finance a loss on their IRD positions due to changes in interest rates. Specifically, we compute Margin Call for fund i in quarter t as the beginning-of-period IRD duration multiplied by the change in the 10-year U.S.

Treasury yield in excess of their beginning-of-period cash holdings, as a percentage of their TNA:

$$\text{Margin Call}_{i,t} = \frac{\text{IRD Duration}_{i,t-1} \times \Delta\text{Interest Rates}_t - \text{Cash}_{i,t-1}}{\text{TNA}_{i,t-1}}. \tag{18}$$

We first show in Figure 9 that bond funds were subject to margin calls during periods of both interest rate cuts (Phase 1) and hikes (Phase 3). The share of funds facing margin calls in our sample spiked to 7.03% in 2020.Q1, representing 4.31% of funds' aggregate AUM, and to 6.25% in 2023.Q1, or 12.1% of AUM. More generally, we find that the share of funds facing margin calls based on AUM (blue solid line) differs from that based on the number of funds (red dotted line). The difference suggests that smaller funds were more susceptible to margin calls during the interest rate cuts in 2020, but larger funds, which typically hold more IRDs, were more susceptible to margin calls during the interest rate hikes in 2022 and 2023.

Determinants of Margin Calls

To further investigate which funds end up facing margin calls in our sample, we focus on the periods of large interest rate changes of more than 40 basis points in a quarter. This includes six quarters in our sample: 2020.Q1 (-1.22%), 2021.Q1 (0.81%), 2022.Q1 (0.80%), 2022.Q2 (0.66%), 2022.Q3 (0.85%), and 2023.Q3 (0.78%). We show in Panel A of Table 9 that the probability of a margin call in our pooled sample is around 1.6% and the magnitude of the margin call is on average 2.3 basis points of TNA. Conditional on a margin call, the magnitude of a margin call is substantial, making up 1.31% of TNA on average across all phases.

We examine the factors in bond funds that empirically contribute to margin calls. In Panel B of Table 9, we run panel regressions of an indicator of margin calls on the funds' lagged IRD returns and the components in the definition of margin calls, as in equation (18), along with other fund characteristics. The indicator of margin calls takes the value 1 if Margin Call in equation (18) is positive and 0 otherwise. We find that funds with lower IRD returns in the preceding quarter exhibit a higher probability of margin calls in Column 1, regardless of non-IRD returns. Among various types of IRDs, we show that futures returns drive the results, exhibiting significant explanatory power (Column 2), above and beyond what is explained by the IRD durations per se (Column 8) and after additionally including year-quarter fixed effects (Column 9). While IRD durations and the changes in interest rates, as the components of margin calls, are insignificant on average (Columns 3 and 4), we show that in Phase 3 they significantly explain the probability of margin calls (see Column 4 in Table A5 of the Appendix). In contrast, in Phase 1, IRD durations and cash holdings do not affect the probability of a margin call, only interest rate changes do.

Moreover, we find that funds which hold more IRDs are more likely to get margin calls. This suggests that the objective of using more IRDs among bond funds is not primarily to reduce margin call risk. Larger funds also exhibit a higher probability of margin calls, particularly in Phase 3, although it becomes statistically insignificant in more stringent specifications including all determinants and additional controls such as fund flows and fund age.

8 Conclusion

Using recently available data from the SEC, we have shown that interest rate derivatives are used widely by fixed income mutual funds, not just to hedge the interest rate risk that their bond portfolios face, but often instead to amplify that risk. Some funds hold an extremely large number of IRDs, and use them to change their interest rate exposure substantially. We find large variation in the duration of IRDs, both across funds and over time. Funds holding higher yielding bonds, those with higher expense ratios, larger funds, and funds which have recently underperformed relative to their peers tend to hold more IRDs and take on more IRD risk. Funds enter more new IRD positions when Treasury bond transaction costs are higher and when there would be higher transaction costs to replicate IRDs with Treasuries. Funds which have a duration gap to their peers use IRDs and bonds to close it, particularly when their portfolio is of shorter duration than their peers. They use IRDs disproportionately more, relative to the size of their IRD holdings.

When interest rates were cut in 2020, those fixed income mutual funds that increased the duration of their IRD portfolios outperformed their peers, not just with their IRDs but also the rest of their portfolios. But their IRD duration was somewhat persistent, and they subsequently underperformed when interest rates were hiked in 2022 and 2023. Futures are the largest contributor to IRD returns.

In our sample period even mutual funds with large exposure to interest rate risk through their derivative holdings could use market value weights to report their derivative exposures, which could dramatically understate the risk, given that market values can be very low. The SEC has recently standardized the weights to notional value, to more accurately and transparently reflect the risks that investors face, to allow those investors to allocate capital more efficiently by benchmarking returns to a more appropriately risk-adjusted index, and to allow regulators to better monitor the latent systemic risks to financial markets that funds' use of derivatives could cause. Based on the role we have shown IRDs can play in fixed income mutual funds' realized returns and interest rate risk exposure, this seems an important aspect of their portfolios to monitor.

Our sample period covers large interest rate cuts in 2020 and large interest rate hikes in 2022 and 2023, highlighting how substantial interest rate risk can be. In fact in 2023 interest rates continued to rise substantially. Funds' IRD duration has also been trending upwards. Recently we have already seen how interest rate risk and hidden leverage can lead to failures in the banking and pension sectors, for instance with Silicon Valley Bank in the U.S. and the LDI crisis in the UK. Regulators face a tradeoff between allowing mutual funds to use derivatives which can efficiently achieve their target level of risk exposure, while protecting investors and markets from the extra risks which derivatives bring. We hope that our analysis can inform policy discussions to help regulators get that delicate balance right.

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Figure 1: **Bond Yields.** This figure plots the lower bound of the range of the U.S. Federal funds rate (black solid line) and daily U.S. Treasury par bond yields for horizons of 1 month (red dashed line), 1 year (green dotted line), and 10 years (blue dot-dashed line) over time. The data is from the U.S. Treasury's website.

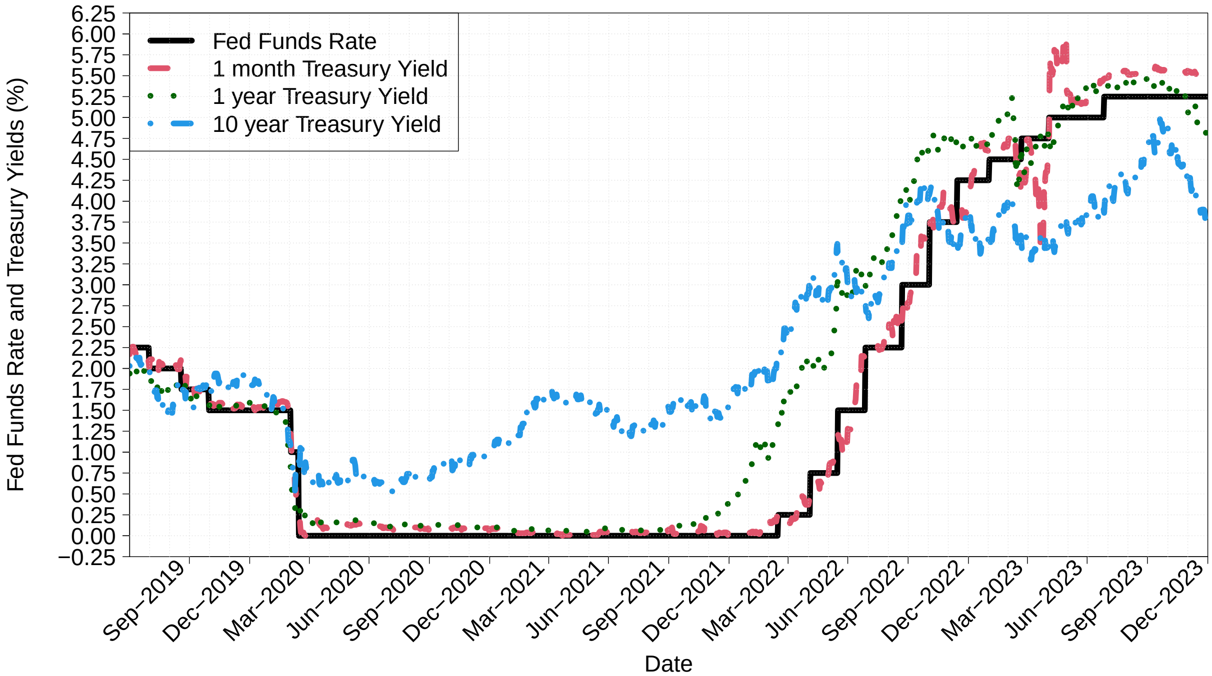


Figure 2: **Example of SEC Form N-PORT Filing.** This figure shows an example of an interest rate swap position in the SEC Form N-PORT filing for the PIMCO Total Return Fund reported on June 30th, 2022. The first column identifies the instrument, and shows the percentage it comprises of the fund's portfolio. The second and third columns provide more detail of its features, including its reset frequency and maturity date which we use to estimate its duration.

NPORT-P: Part C: Schedule of Portfolio Investments

For each investment held by the Fund and its consolidated subsidiaries, disclose the information requested in Part C. A Fund may report information for securities in an aggregate amount not exceeding five percent of its total assets as miscellaneous securities in Part D in lieu of reporting those securities in Part C, provided that the securities so listed are not restricted, have been held for not more than one year prior to the end of the reporting period covered by this report, and have not been previously reported by name to the shareholders of the Fund or to any exchange, or set forth in any registration statement, application, or report to shareholders or otherwise made available to the public.

Item C.1. Identification of investment.

a. Name of issuer (if any).	N/A
b. LEI (if any) of issuer. In the case of a holding in a fund that is a series of a series trust, report the LEI of the series.	N/A
c. Title of the issue or description of the investment.	IRS USD 2.80000 08/22/18-5Y CME
d. CUSIP (if any).	000000000

At least one of the following other identifiers:

Identifier.	Other unique identifier (if ticker and ISIN are not availa
Other unique identifier (if ticker and ISIN are not available). Indicate the type of identifier used	SWU00QL56
Description of other unique identifier.	Internal ID

Item C.2. Amount of each investment.

Balance. Indicate whether amount is expressed in number of shares, principal amount, or other units. For derivatives contracts, as applicable, provide the number of contracts.

Balance	1.000000
Units	Number of contracts
Description of other units.	
Currency. Indicate the currency in which the investment is denominated.	United States Dollar
Value. Report values in U.S. dollars. If currency of investment is not denominated in U.S. dollars, provide the exchange rate used to calculate value.	6312401.300000
Exchange rate.	
Percentage value compared to net assets of the Fund.	0.0104547

Item C.11. For derivatives, also provide:

a. Type of derivative instrument that most closely represents the investment, selected from among the following (forward, future, option, swaption, swap (including but not limited to total return swaps, credit default swaps, and interest rate swaps), warrant, other).	Swap

b. Counterparty.
i. Provide the name and LEI (if any) of counterparty (including a central counterparty).

Counterparty Record: 1

Name of counterparty.	Chicago Mercantile Exchange
LEI (if any) of counterparty.	SNZ2OJLFK8MNNCLQOF39

Index name.	USD-LIBOR-BBA-Bloomberg 3M
Index identifier, if any.	N/A

If the index's or custom basket's components are not publicly available in that manner, and the notional amount of the derivative represents 1% or less of the net asset value of the Fund, provide a narrative description of the index.

Narrative description.	N/A
Custom swap Flag	◉ Yes ○ No

1. Description and terms of payments to be received from another party. Receipts: Reference Asset, Instrument or Index.

Receipts: fixed, floating or other.	◉ Fixed ○ Floating ○ Other
Receipts: Fixed rate.	2.800000
Receipts: Base currency.	United States Dollar

2. Description and terms of payments to be paid to another party. Payments: Reference Asset, Instrument or Index

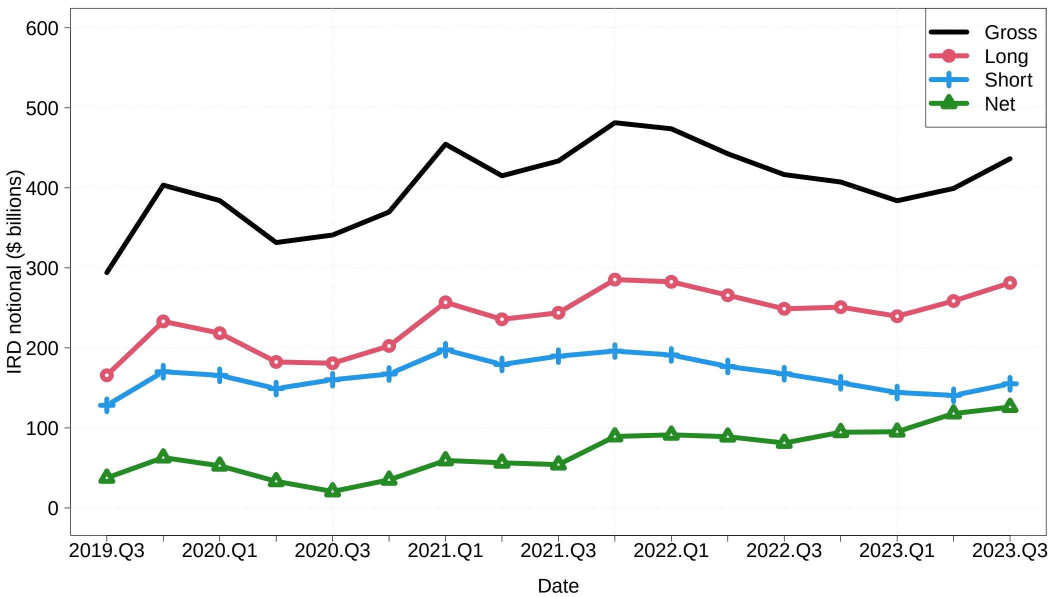
Payments: fixed, floating or other.	○ Fixed ◉ Floating ○ Other
Payments: fixed or floating	Floating
Payments: Floating rate Index.	USD-LIBOR-BBA-Bloomberg 3M
Payments: Floating rate Spread.	0.000000
Payment: Floating Rate Reset Dates.	Month
Payment: Floating Rate Reset Dates Unit.	3
Payment: Floating Rate Tenor.	Month
Payment: Floating Rate Tenor Unit.	3
Payments: Base currency	United States Dollar
Payments: Amount	0.000000
ii. Termination or maturity date.	2023-08-22

iii. Upfront payments or receipts

Upfront payments.	0.000000
ISO Currency Code.	United States Dollar
Upfront receipts.	-41117941.370000
ISO Currency Code.	United States Dollar
iv. Notional amount.	1819100000.000000
ISO Currency Code.	USD
v. Unrealized appreciation or depreciation. Depreciation shall be reported as a negative number.	47430342.670000

Figure 3: **Aggregate Interest Rate Derivative Holdings.** This figure plots the aggregate sum of absolute notional amount in interest rate derivatives ('Gross') held by fixed income funds in our sample over time, in billions of dollars in subfigure (a) and as a percentage of total net assets aggregated across all funds in subfigure (b). Each is decomposed into the absolute notional amount of their Long and Short positions. Also plotted is their aggregate net notional amount ('Net'), i.e. their Long minus Short positions. The notional amount is winsorized at the 1% and 99% level before taking the aggregate sum. All four lines in subfigure (b) are the same as graph (a), but scaled as a percentage of funds' total net assets aggregate across all funds.

(a) **Aggregate Interest Rate Derivative Holdings, in Dollars.**



(b) **Aggregate Interest Rate Derivative Holdings, as a Percentage of Total Net Assets.**

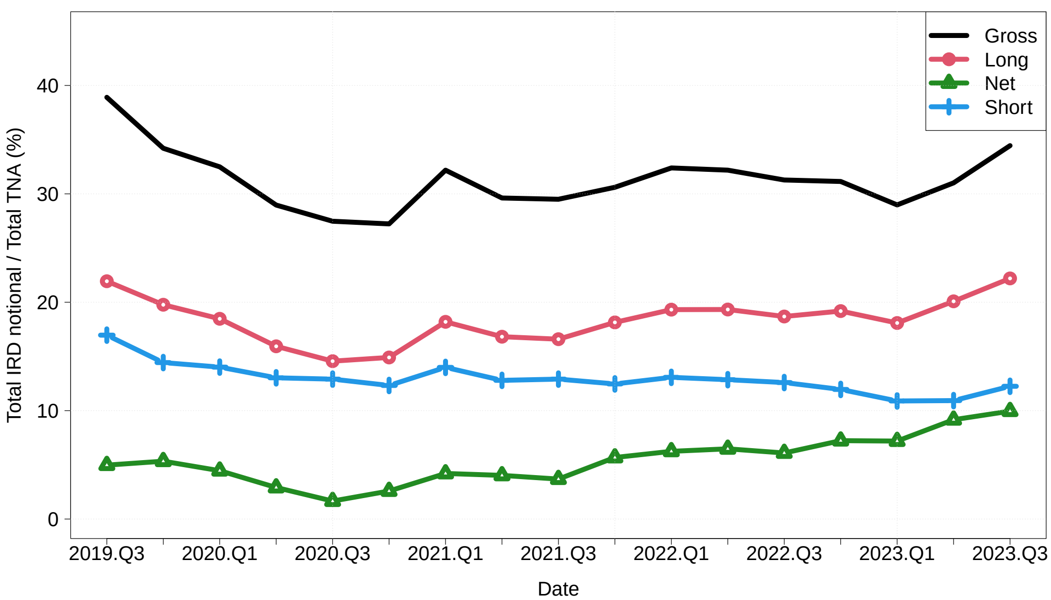
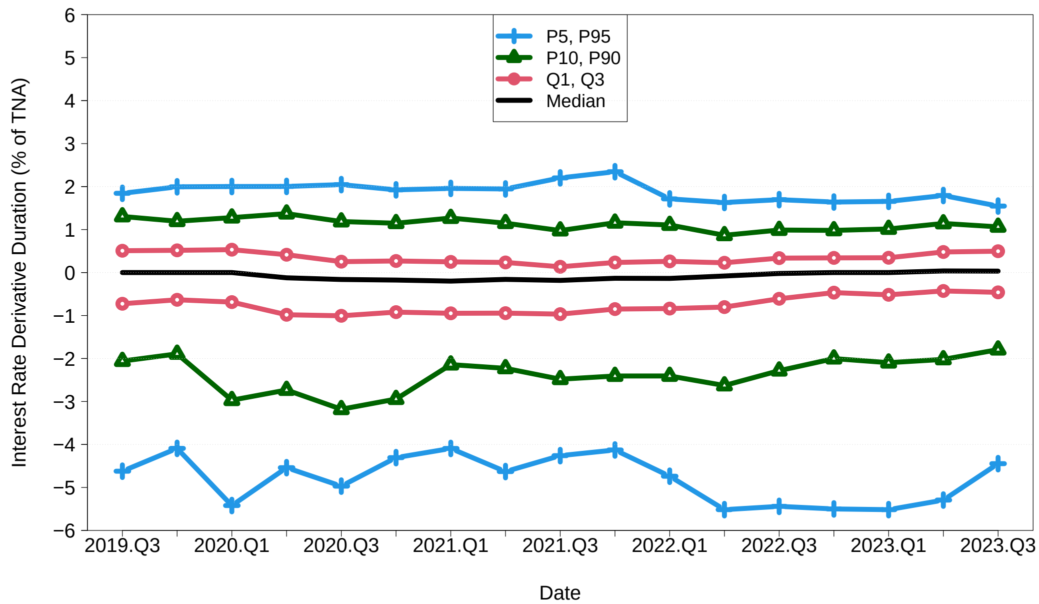


Figure 4: **Cross-sectional and Time-series Variation in Funds' IRD and IRD Returns.** Subfigure (a) plots the distribution of fixed income mutual funds' interest rate derivative durations over time, where duration is DV100 as a percentage of TNA. P5, P10, Q1, Median, Q3, P90, and P95 denote the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles, respectively. Subfigure (b) plots the distribution of fixed income mutual funds' monthly interest rate derivative returns over time. P5, P10, Q1, MEDIAN, Q3, P90, and P95 denote the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles, respectively. The gray vertical bars denote days when the Federal Reserve changed the Federal funds rate. The width of the bars are proportional to the size of the change. In July, September, and October 2019 there were interest rate decreases of 25 basis points. In March 2020, there were two interest rate decreases of 50 basis points then 100 basis points. In March 2022, there was an increase of 25 basis points. In May 2022, there was an increase of 50 basis points. In June, July, September, and November 2022 there were increases of 75 basis points. In December 2022 there was an increase of 50 basis points. In February, March, May, and July 2023 there increases of 25 basis points.

(a) **Distribution of Interest Rate Derivative Duration over Time.**



(b) **Distribution of Interest Rate Derivative Returns over Time.**

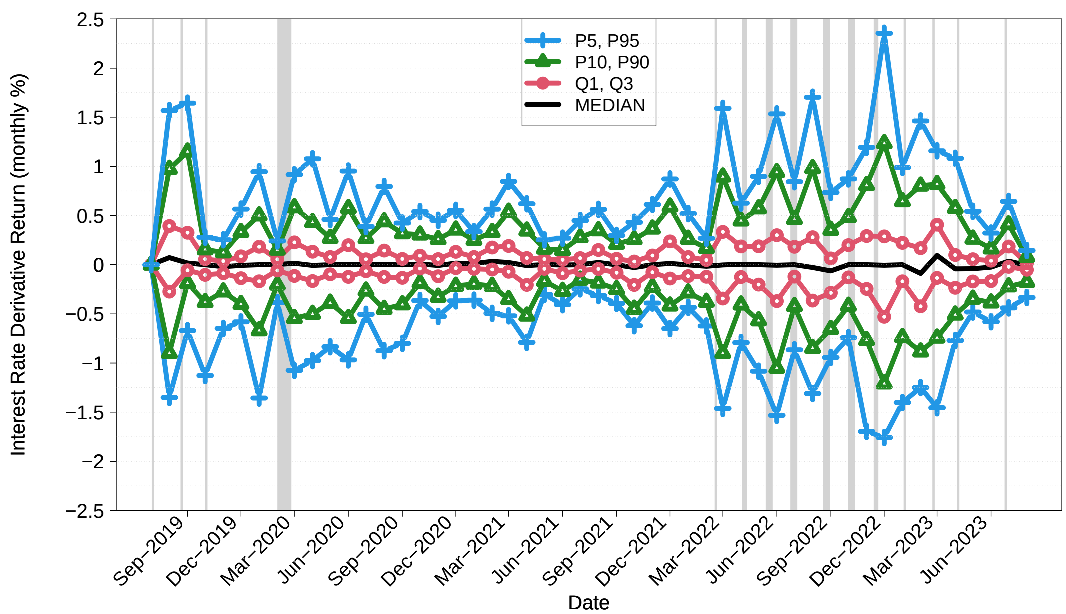


Figure 5: **Return Correlation: Interest Rate Derivatives vs Other Securities.** This figure plots the monthly returns of fixed income mutual funds' interest rate derivative (IRD) portfolios on the x-axis, versus the monthly returns on their non-IRD portfolios on the y-axis. Each point represents one fund's return in one month. The sample period is from July 2019 to August 2023. The negative 45 degree line shows how the points would line up if the IRD returns were a perfect hedge for non-IRD returns.

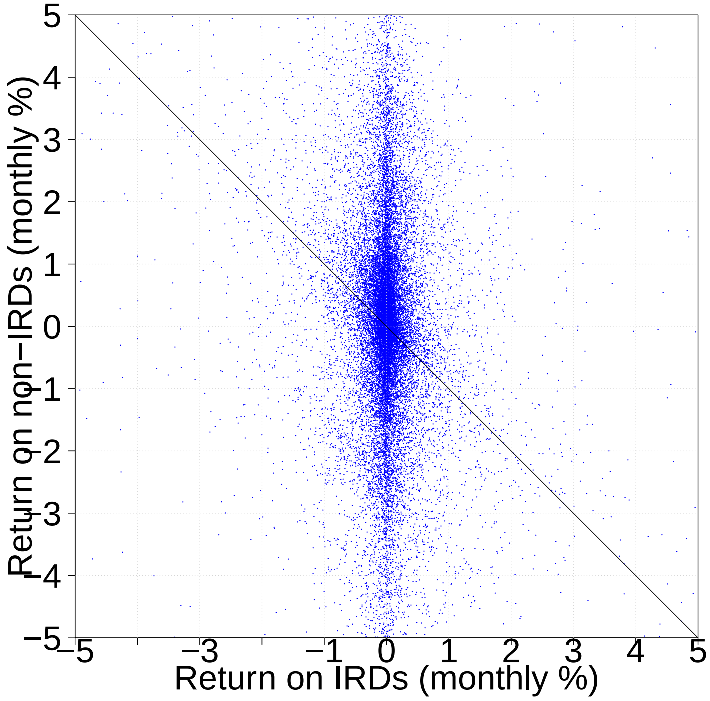


Figure 6: **Correlations between Funds' Returns on Interest Rate Derivatives and Other Securities.** This figure shows a histogram of the correlations between fixed income mutual funds' monthly returns on their interest rate derivatives portfolio and the rest of their portfolio. The correlations are computed using the maximum number of months available for each during our sample, with a minimum time-series of 3 months. The time period is from July 2019 to August 2023.

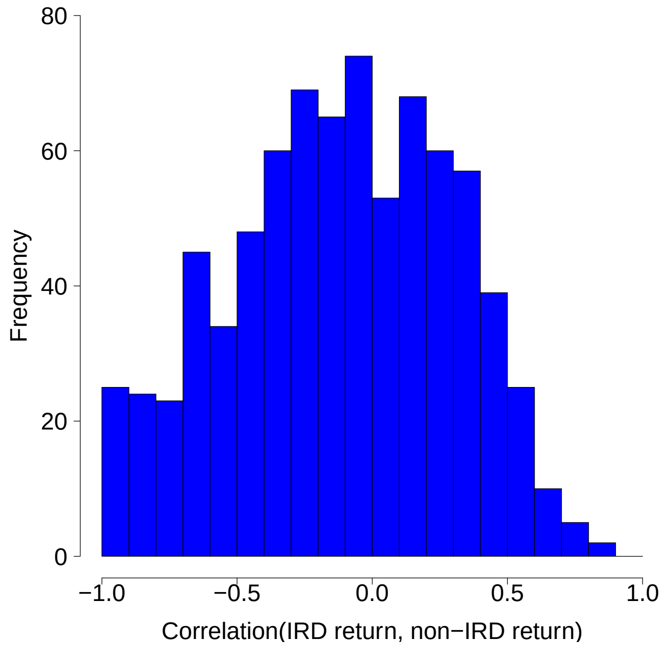


Figure 7: **Portfolio Sorts on IRD returns in January-March 2020.** This figure plots cumulative monthly IRD and total fund returns over the period 2020.Q3 to 2023.Q3. We sort funds into quintiles based on their IRD returns between January and March 2020, to see how the funds that had the highest and lowest IRD returns in that period went on to perform later in our sample. Government bond funds, global bond funds, investment grade corporate bond funds, and high yield corporate bond funds are plotted in the top left, top right, bottom left, and bottom right panels, respectively.

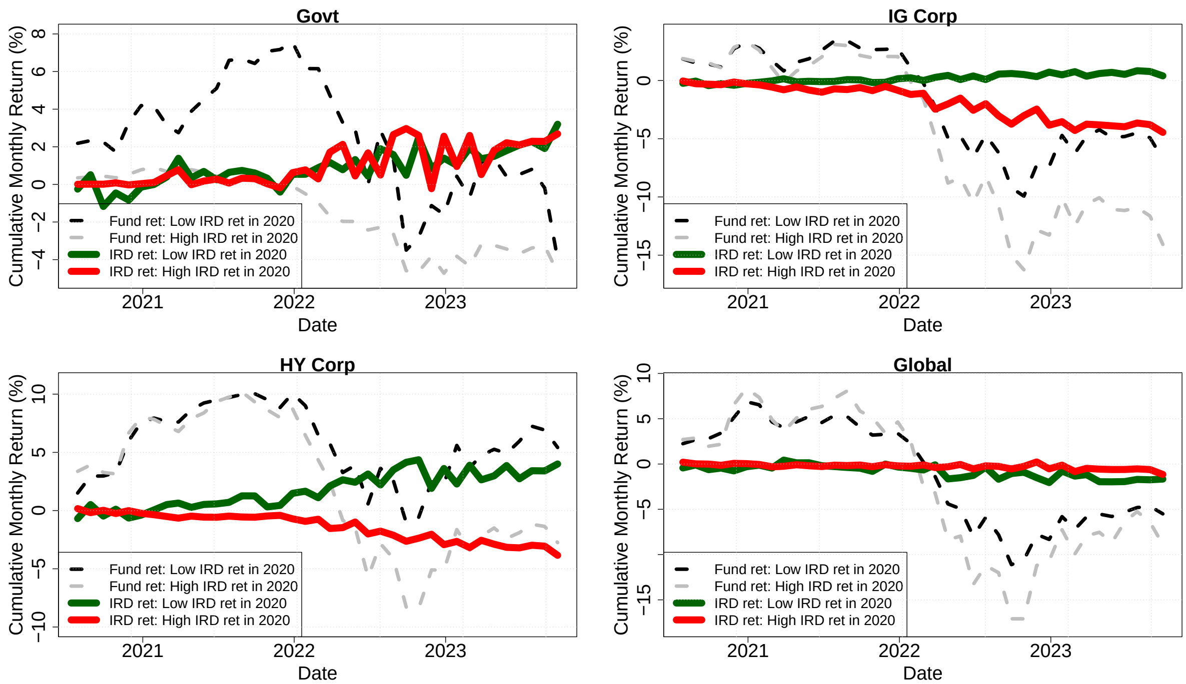


Figure 8: **Interest Rate Derivative Returns and Duration Ratios in Phases 1 and 3.** This figure shows the relationship between funds' mean monthly returns and mean quarterly duration ratios in Phase 1 (July 2019 - June 2020) on the x-axis and Phase 3 (October 2021 - September 2023) on the y-axis. Mean returns and mean duration ratios are winsorized at the 1% level. For each graph, the line-of-best-fit is also plotted.

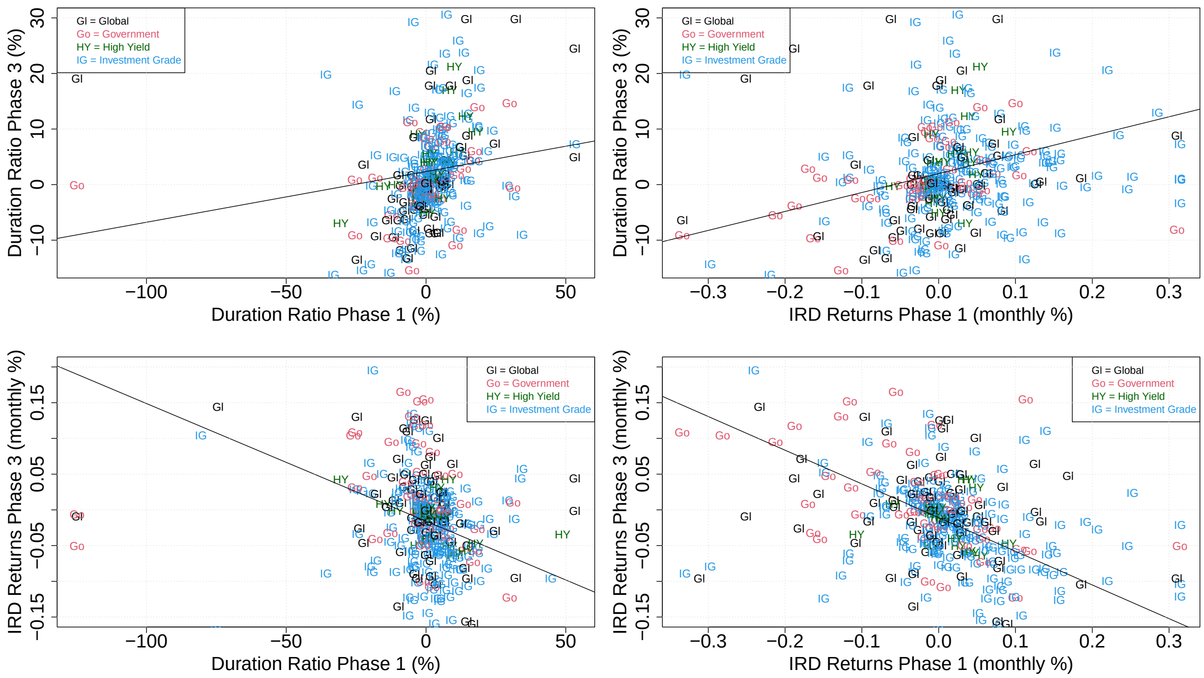


Figure 9: **Margin Calls on Interest Rate Derivatives.** This figure shows (a) the percentage of number of funds each quarter which faced a margin call on their interest rate derivatives (IRDs) from a change in the 10-year U.S. Treasury yield (red dashed line); and (b) the percentage of their AUM which faced the margin call (blue solid line). A margin call is defined as when a fund has insufficient cash holdings to finance a loss on their IRD holdings. The size of the margin call is computed as the lagged IRD DV100 multiplied by changes in the 10-year U.S. Treasury yield in excess of the fund's lagged cash holdings, scaled as a percentage of the funds' lagged total net assets. The time period is from 2019.Q3 to 2023.Q3.

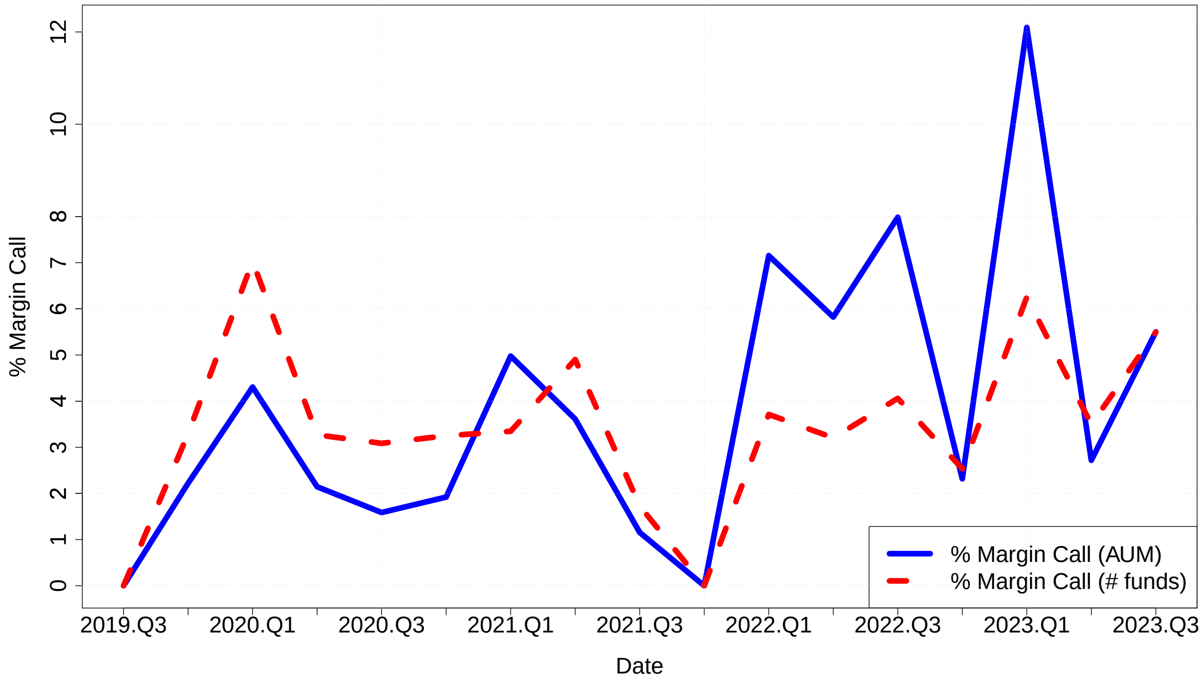


Table 1: **Use of Derivatives by Asset Class and Fund Sector**. This table shows the absolute notional amount of interest rate, credit, and foreign exchange (FX) derivatives held by fixed income funds in our sample. The sample period is 2019.Q3 to 2023.Q3. Panel A shows the amounts in billions of dollars. Panel B shows the mean and median amounts for different fund sectors (government, investment grade and high yield corporate, and global bond funds), scaled as a percentage of total net assets (TNA). Panel C shows interest rate derivative holdings by fixed income mutual funds for long and short positions, respectively, which are defined in Section 3. The numbers given show notional amounts as a percentage of total net assets. Mean, Std Dev, P25, Median, and P75 denote the mean, standard deviation, 25th percentile, 50th percentile (median), and 75th percentiles of the distributions pooled across all funds and quarters.

Panel A: Absolute Notional Amount ($bil.)		
Interest Rate Derivative	Credit Derivative	FX Derivative
404.01	74.01	182.87

Panel B: Absolute Notional Amount / TNA (%)				
Asset	Government	IG Corporate	HY Corporate	Global
Mean				
Interest Rate	78.50	48.04	41.67	79.62
Credit	23.35	8.33	15.32	14.87
Foreign Exchange	37.18	12.43	19.8	67.41
Median				
Interest Rate	48.14	25.75	19.33	31.59
Credit	9.27	4.13	5.87	10.10
Foreign Exchange	19.10	5.18	4.31	47.66

Panel C: Notional Amount / TNA (%) by Instrument							
Long position							
Asset Class	Instrument	#Fund-Qtr	Mean	Std Dev	P25	Median	P75
Interest Rate	Future	7,827	19.62	22.94	5.33	13.44	25.17
Interest Rate	Swap	3,866	26.57	37.93	3.86	10.84	29.16
Interest Rate	Swaption	1,589	21.86	31.21	2.63	10.06	28.66
Short position							
Asset Class	Instrument	#Fund-Qtr	Mean	Std Dev	P25	Median	P75
Interest Rate	Future	8,973	15.91	22.55	3.10	8.17	18.76
Interest Rate	Swap	3,781	23.47	34.23	2.98	9.41	27.05
Interest Rate	Swaption	714	15.90	29.47	1.40	5.31	15.59

Table 2: **Summary Statistics**. This table shows summary statistics for the fixed income mutual funds in our sample period between 2019.Q3 and 2023.Q3. TNA is total net assets in millions of dollars. IRD notional / TNA is the ratio of interest rate derivative notional to total net assets in percentages. IRD Duration is dollar duration measured by DV100 as a percentage of TNA for interest rate derivatives. Bond Duration is dollar duration measured by DV100 as a percentage of TNA for government bond, corporate bonds, asset- and mortgage-backed securities (ABS and MBS). Total Duration is the sum of IRD Duration and Bond Duration. IRD return is the fund return induced from the IRD positions, as in equation (10), in percentages. Non-IRD return is quarterly fund return minus IRD return. Duration Gap is fund's Total Duration minus the size-weighted average of Total Duration for its peers in the same Morningstar Category (excluding the fund itself) in that quarter. Cash/TNA is the percentage of funds' TNA which is held in cash and other short-term liquid instruments. Bond yield is the market-vale-weighted-average of yield of funds' bond holdings. Fund flow is the dollar amount invested in or withdrawn from the fund relative to the lagged TNA, in percentages. All variables are winsorized at the 1% and 99% levels.

	Mean	SD	p5	p25	Median	p75	p95	N
TNA ($ millions)	1,413.51	3,420.95	7.81	68.42	277.59	1,051.90	6,583.63	20,571
Number of IRDs	9.50	26.19	0.00	0.00	0.00	5.00	67.00	20,571
IRD notional / TNA (%)	2.86	15.63	-13.46	0.00	0.00	0.74	31.21	20,571
IRD Duration (%)	-0.40	2.23	-2.73	-0.16	0.00	0.00	1.31	14,550
Bond Duration (%)	5.02	3.08	0.68	2.97	4.66	6.56	10.42	14418
Total Duration (%)	4.62	3.52	0.21	2.47	4.50	6.48	10.07	14418
IRD return (%)	-0.01	0.41	-0.60	0.00	0.00	0.00	0.53	20,571
Non-IRD return (%)	0.05	3.83	-7.09	-1.20	0.43	1.98	5.67	18,519
Duration Gap (%)	-0.02	21.83	-7.38	-1.20	0.06	1.43	8.07	14,549
Cash/TNA (%)	3.18	5.47	0.00	0.00	0.88	4.16	13.68	20,571
Bond yield (%)	3.84	2.89	0.14	1.96	3.36	5.17	8.89	14526
Expense ratio (%)	0.60	0.32	0.10	0.40	0.57	0.78	1.19	14,841
Fund flow (%)	1.24	14.09	-16.11	-4.40	-0.46	4.02	24.51	14,853

Table 3: **Variance Decomposition of Changes in Duration.** Panel A of this table shows the variance decomposition of changes in Total Duration, measured as the dollar duration (DV100) of a 100 basis point change in interest rates, as a proportion of the total net assets (TNA).

$$\begin{aligned}\text{Var}\left(\Delta\text{Total Duration}\right) &= \text{Var}\left(\Delta\text{Bond Duration} + \Delta\text{IRD Duration}\right)\\ &= \text{Var}\left(\Delta\text{Bond Duration}\right) + \text{Var}\left(\Delta\text{IRD Duration}\right)\\ &+ 2 \times \text{Cov}\left(\Delta\text{Bond Duration}, \Delta\text{IRD Duration}\right)\end{aligned}$$

In Panel A, the total variance is decomposed into the variance for changes in Bond Duration (i.e., DV100/TNA for bonds, including government bonds, corporate bonds, asset- and mortgage-backed securities (ABS and MBS) in the first row; and the variance for changes in IRD Duration (i.e., DV100/TNA for interest rate derivatives) in the second row; and twice their covariance in the third row. Panel B shows the correlation matrix of changes in DV100/TNA for their total, bond, and IRD. The correlation between debt and IRD is needed to compute the covariance term in Panel A.

Panel A: Variance decomposition of changes in duration	
	Δ DV100/TNA (% of total variance)
Var(Bond)	47.8
Var(IRD)	59.7
2 $\times$ Cov(Bond, IRD)	-7.5
Total	100

Panel B: Correlations of Δ DV100/TNA			
	Total	Bond	IRD
Total	1		
Bond	0.6365	1	
IRD	0.7250	-0.0698	1

Table 4: **Risk Taking and Liquidity Management**. This table shows results from panel regressions of funds' risk taking using interest rate derivatives (IRDs). Risk taking is measured by indicators for whether a fund uses at least one or at least 30 IRDs in a quarter, and by the absolute value of a fund's net notional amount of IRD as a percentage of its fund size of total net assets (TNA). We omit fund subscript i in the variable names for notational simplicity. Bond yield is the weighted average of yield of funds' non-derivative bond holdings using the market value as the weight. 1{Bottom Rank: Fund return$_t$} is an indicator variable which takes the value 1 if the fund return is below the 20th percentile of fund returns within Morningstar Category in quarter t. The control variables are lagged average fund flow and flow volatility: the mean fund flow in the previous four quarters, and the standard deviation of monthly fund flows in the previous 12 months. Phase 1 is July 2019 to June 2020. Phase 2 is July 2020 to September 2021. Phase 3 is October 2021 to September 2023. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

	$1\{\#\text{IRD} \geq n\}_{t+1}$		$\lvert\text{IRD Notional}_{t+1}\rvert$ / TNA_{t+1} (%)						
	$n = 1$	$n = 30$	All Phases	Phase 1	Phase 3	Govt	IG Corp	HY Corp	Global
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Bond yield (%)	-0.001	0.016***	0.461**	0.545**	0.221	2.471***	1.425***	-0.630***	0.523*
	(-0.16)	(3.25)	(2.45)	(2.45)	(1.04)	(2.80)	(2.67)	(-2.76)	(1.74)
Expense ratio (%)	-0.060	0.030	-0.981	0.221	-0.933	1.665	-0.109	-6.348**	-4.468
	(-0.91)	(0.81)	(-0.55)	(0.11)	(-0.45)	(0.26)	(-0.04)	(-2.22)	(-1.06)
Log (fund size)	0.046***	0.037***	1.316***	0.630**	1.783***	3.369***	1.153***	0.411	0.970
	(4.39)	(5.07)	(4.73)	(2.19)	(5.48)	(3.72)	(3.30)	(0.84)	(1.32)
Log (fund age)	0.053***	-0.020*	0.021	-0.353	-0.227	-9.557***	1.672**	-0.219	2.466
	(2.63)	(-1.79)	(0.04)	(-0.59)	(-0.34)	(-3.39)	(2.48)	(-0.29)	(1.42)
1{Bottom Rank: Fund return$_t$}	-0.037*	0.022	1.182*	-1.246	3.953***	0.357	2.479**	0.043	0.155
	(-1.83)	(1.50)	(1.70)	(-1.41)	(3.41)	(0.20)	(2.28)	(0.05)	(0.08)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.072	0.069	0.068	0.054	0.083	0.228	0.070	0.084	0.055
N	9,892	9,892	9,892	1,897	4,717	12,05	4435	2,452	1,800

Table 5: **Transaction Costs**. This table shows results from panel regressions of the number of new interest rate derivatives (IRDs) and IRD notional in each quarter on quarterly fund-level characteristics for fixed income mutual funds, including IRD and Treasury transaction costs, between 2019.Q3 and 2023.Q3. We omit fund subscript i in the variable names for notational simplicity. # New IRDs_t is the number of IRDS that funds did not hold in the preceding quarter $t-1$, but do hold in the current quarter t. $|\text{New IRD Notional}|/\text{TNA}_t$ is the sum of the absolute notional amount of the new IRDs. The mean IRD bid-ask spread is the hypothetical mean transaction cost of replicating the funds' Treasury futures and interest rate swaps, weighted by the IRD market value, by summing half the bid-ask spread for buying a long-short portfolio of Treasury bonds with the same duration as the long and short legs. The mean Treasury bid-ask spread is the mean transaction cost of trading the fund's Treasury bond holdings. The control variables are: bond yield (the weighted average of yield of funds' bond holdings using the market value as the weight); $1\{\text{Bottom Rank: Fund return}_t\}$ (an indicator variable which takes the value 1 if the fund return is below the 20th percentile of its Morningstar Category in that quarter); return volatility (the standard deviation of monthly fund returns in the previous 12 months); flow volatility (the standard deviation of monthly fund flows in the previous 12 months); and cash/TNA (the percentage of funds' TNA which is held in cash and other short-term liquid instruments). All regressions include year-quarter and fund sector fixed effects. Standard errors are double clustered at the fund and year-quarter levels. t-statistics are in parentheses.

	# New IRDs_t	$\frac{\lvert\text{New IRD Notional}_t\rvert}{\text{TNA}_t}$ (%)	$\frac{\#\text{New IRDs}_t}{\#\text{Total IRDs}_t}$ (%)
	(1)	(2)	(3)
Mean IRD Bid-Ask Spread_t (%)	698.872**	270.991	7.045**
	(2.57)	(0.81)	(2.74)
Mean Treasury Bid-Ask Spread_t (%)	444.939***	397.885*	4.113***
	(2.97)	(1.85)	(3.10)
Controls	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes
R^2	0.108	0.137	0.061
N	2,811	2,784	2,810

Table 6: **Lengthening Duration Exposure with IRDs.** This table shows the results of panel regressions of changes in fixed income funds' duration on duration gap, controlling for a number of variables. In Columns (1)-(3), the dependent variables are Total Duration, Bond Duration, and IRD Duration, respectively. Duration is the dollar duration (DV100) of a 100 basis point change in interest rates, as a percentage of total net assets (TNA). We omit fund subscript i in the variable names for notational simplicity. Duration Gap is computed as the fund's Total Duration minus the size-weighted average of Total Duration for its peers in the same Morningstar Category (excluding the fund itself) in that quarter. Duration Gap to Peers ($-$) is the duration gap when the gap is negative, and Duration Gap to Peers ($-$) when it is positive. The control variables are: fund flow, average fund flow, return volatility, flow volatility, and log(fund size). Phase 1 is July 2019 to June 2020. Phase 3 is October 2021 to September 2023. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

	$\Delta\,(\text{DV100/TNA})_{t+1}$ (%)								
	All periods			Phase 1			Phase 3		
	Total	Bond	IRD	Total	Bond	IRD	Total	Bond	IRD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Duration Gap to Peers$_t$ ($-$)	-0.057***	-0.011***	-0.031***	-0.082***	-0.031***	-0.031**	-0.068***	-0.016**	-0.032**
	(-5.24)	(-2.82)	(-4.28)	(-4.09)	(-4.15)	(-2.28)	(-3.14)	(-2.42)	(-2.38)
Duration Gap to Peers$_t$ ($+$)	-0.033***	-0.016***	-0.006	-0.013	-0.012	0.007	-0.039***	-0.017***	-0.008
	(-3.22)	(-5.26)	(-1.08)	(-0.39)	(-1.48)	(0.38)	(-3.09)	(-3.86)	(-1.20)
IRD return$_t$ (%)	0.003	-0.025	0.023	0.102	0.079	0.029	-0.069	-0.034	-0.002
	(0.06)	(-0.98)	(0.65)	(0.88)	(1.33)	(0.33)	(-1.02)	(-1.12)	(-0.04)
Non-IRD return$_t$ (%)	0.002	0.001	0.001	-0.004	-0.021***	0.013*	0.007	0.012***	-0.003
	(0.46)	(0.22)	(0.47)	(-0.33)	(-3.55)	(1.78)	(0.94)	(3.11)	(-0.66)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.038	0.031	0.021	0.046	0.059	0.027	0.053	0.047	0.023
N	9,765	9,641	9,765	1,872	1,853	1,872	4,659	4,599	4,659

Table 7: **IRD and Fund Returns**. This table shows results from predictive panel regressions of fixed income funds' quarterly returns on quarterly fund-level characteristics for fixed income mutual funds between 2019.Q3 and 2023.Q3. Panel A decomposes total returns into interest rate derivative (IRD) and non-IRD returns. Panel B further decomposes the IRD returns into those attributable to futures, swaps, and other IRDs. We omit fund subscript i in the variable names for notational simplicity. $1\{\text{Top (Bottom) IRD Duration}_t\}$ is an indicator variable which takes the value 1 if the dollar duration of a fund's interest rate derivative (IRD) holdings as a percentage of its total net assets (TNA) is above (below) the 80th (20th) percentile for funds in that quarter. The control variables are: bond duration, expense ratio, log(fund size), fund return, and fund flow. Bond Duration is dollar duration (DV100) of bonds, as a percentage of TNA. Phase 1 is July 2019 to June 2020. Phase 2 is July 2020 to September 2021. Phase 3 is October 2021 to September 2023. All the independent variables are winsorized at the 1% and 99% levels. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

Panel A: IRD vs Non-IRD

	Return$_{t+1}$ (%)								
	Phase 1			Phase 2			Phase 3		
	IRD	Non-IRD	Total	IRD	Non-IRD	Total	IRD	Non-IRD	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$1\{\text{Top IRD Duration}_t\}$	0.204***	0.644**	0.785***	-0.057***	-0.258***	-0.336***	-0.323***	-0.178**	-0.564***
	(3.18)	(2.38)	(2.79)	(-2.91)	(-2.68)	(-3.43)	(-10.04)	(-2.30)	(-6.60)
$1\{\text{Bottom IRD Duration}_t\}$	-0.341***	0.463	0.227	0.099***	-0.128	-0.037	0.231***	-0.287***	-0.077
	(-4.91)	(1.39)	(0.75)	(3.29)	(-0.95)	(-0.32)	(6.04)	(-2.63)	(-0.65)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.104	0.758	0.759	0.038	0.493	0.499	0.091	0.675	0.676
N	1560	1,560	1,560	3,311	3,308	3,308	5,381	5,373	5,373

Panel B: IRD Type

	IRD Return$_{t+1}$ (%)								
	Phase 1			Phase 2			Phase 3		
	Futures	Swaps	Other IRD	Futures	Swaps	Other IRD	Futures	Swaps	Other IRD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$1\{\text{Top IRD Duration}_t\}$	0.326***	-0.119***	0.008**	-0.028	-0.027***	0.006***	-0.275***	-0.008	0.009***
	(7.87)	(-3.25)	(2.20)	(-1.65)	(-2.64)	(2.72)	(-9.81)	(-0.67)	(3.41)
$1\{\text{Bottom IRD Duration}_t\}$	-0.175***	-0.136***	0.006*	0.111***	-0.033**	0.011***	0.224***	-0.027*	0.004*
	(-3.42)	(-3.99)	(1.73)	(6.18)	(-2.55)	(4.11)	(6.96)	(-1.92)	(1.66)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.158	0.086	0.049	0.048	0.025	0.045	0.116	0.011	0.037
N	1,560	1,560	1,560	3,311	3,311	3,311	5,381	5,381	5,381

Table 8: **Persistence in Performance.** This table shows results from predictive panel regressions of fixed income funds' quarterly returns on quarterly fund-level characteristics for fixed income mutual funds between 2020.Q2 and 2023.Q3. 1{Top (Bottom) 2020.Q1 IRD return$_t$} is an indicator variable which takes the value 1 if funds' IRD return was in the 80th (20th) percentile of funds in the first quarter of 2020. Bond duration is the dollar duration of a fund's interest rate derivative (IRD) holdings as a percentage of its total net assets (TNA). We omit fund subscript i in the variable names for notational simplicity. Phase 1 is July 2019 to June 2020. Phase 2 is July 2020 to September 2021. Phase 3 is October 2021 to September 2023. All the independent variables are winsorized at the 1% and 99% levels. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

	Return$_{t+1}$ (%)											
	All Phases			Phase 1			Phase 2			Phase 3		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	IRD	Non-IRD	Total	IRD	Non-IRD	Total	IRD	Non-IRD	Total	IRD	Non-IRD	Total
1{Top 2020.Q1 IRD return$_t$}	-0.156***	-0.237***	-0.429***	0.098	0.686**	1.011***	-0.105***	-0.280***	-0.393***	-0.220***	-0.226***	-0.484***
	(-6.68)	(-2.80)	(-4.57)	(1.18)	(2.47)	(3.44)	(-5.57)	(-2.66)	(-3.61)	(-5.96)	(-2.93)	(-5.24)
1{Bottom 2020.Q1 IRD return$_t$}	0.088***	-0.184*	-0.110	-0.034	0.335	-0.107	0.054**	-0.110	-0.094	0.133***	-0.263**	-0.132
	(3.74)	(-1.68)	(-1.00)	(-0.36)	(1.13)	(-0.41)	(2.15)	(-0.81)	(-0.78)	(3.69)	(-2.48)	(-1.27)
Bond duration$_t$ (%)	0.004*	-0.090***	-0.083***	-0.008	0.337***	0.331***	0.002	0.037***	0.040***	0.007**	-0.239***	-0.228***
	(1.81)	(-6.89)	(-6.53)	(-1.47)	(9.89)	(9.69)	(1.00)	(2.63)	(2.94)	(2.02)	(-22.64)	(-20.74)
Expense ratio$_t$ (%)	0.017	0.367***	0.409***	-0.041	-2.667***	-2.721***	-0.003	0.734***	0.729***	0.036	-0.200*	-0.116
	(0.84)	(3.47)	(3.70)	(-0.73)	(-7.66)	(-7.71)	(-0.14)	(4.94)	(4.91)	(1.10)	(-1.93)	(-0.96)
Log(fund size$_t$)	-0.008***	0.001	-0.007	-0.005	-0.078*	-0.088**	0.004*	0.016	0.020	-0.015***	-0.014	-0.030**
	(-2.60)	(0.05)	(-0.48)	(-0.44)	(-1.74)	(-1.98)	(1.79)	(0.87)	(1.14)	(-3.30)	(-1.11)	(-2.15)
Fund return$_t$ (%)	0.001	-0.005	-0.002	0.000	-0.639***	-0.644***	0.003	0.016	0.018	0.002	0.065**	0.071**
	(1.24)	(-0.75)	(-0.32)	(0.01)	(-31.31)	(-33.99)	(0.90)	(0.66)	(0.76)	(1.20)	(2.44)	(2.38)
Fund flow$_t$ (%)	-0.000	0.001	0.001	0.001	0.000	0.001	-0.000	-0.002	-0.002	-0.000	0.009***	0.009***
	(-0.14)	(0.50)	(0.54)	(0.94)	(0.03)	(0.19)	(-0.14)	(-0.66)	(-0.85)	(-0.86)	(3.25)	(3.36)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.031	0.671	0.675	0.021	0.758	0.760	0.038	0.493	0.500	0.042	0.675	0.676
N	9,334	9,323	9,323	642	1,560	1,560	3,311	3,308	3,308	5,381	5,373	5,373

Table 9: **Margin Calls**. Panel A shows the mean, median, and standard deviation summary statistics of variables related to margin calls on IRD positions, by Phase. 1{Margin Call > 0} is an indicator variable which takes the value 1 if the fund experienced a margin call and zero otherwise. Margin Call, Conditional is Margin Call as in equation (18) conditional on facing margin calls. % Margin Calls (#Funds) is the percentage of funds each quarter facing a margin call from interest rate changes larger than 40 basis points, and % Margin Calls (AUM) in terms of assets under management. Panel B shows results from regressions of the margin call indicator on fund-level characteristics and the change in interest rates. Standard errors are double clustered at the fund and year-quarter levels. t-statistics are in parentheses.

Panel A: Summary Statistics

	All				Phase 1				Phase 2				Phase 3			
	Mean	SD	Median	N	Mean	SD	Median	N	Mean	SD	Median	N	Mean	SD	Median	N
1{Margin Call > 0}	0.02	0.13	0.00	20,571	0.02	0.13	0.00	4,557	0.01	0.08	0.00	5,992	0.02	0.14	0.00	10,022
Margin Call (%)	0.02	0.40	0.00	20,571	0.06	0.82	0.00	4,557	0.00	0.08	0.00	5,992	0.01	0.11	0.00	10,022
Margin Call, Conditional (%)	1.31	2.86	0.48	330	3.50	4.98	1.32	84	0.72	0.75	0.44	40	0.53	0.57	0.36	206
% Margin Calls: #Funds (%)	1.58	2.36	0.00	17	1.76	3.51	0.00	4	0.67	1.50	0.00	5	2.06	2.29	1.60	8
% Margin Calls: AUM (%)	2.10	3.03	0.00	17	1.08	2.15	0.00	4	1.00	2.23	0.00	5	3.31	3.62	2.75	8

Panel B: Determinants of Margin Calls

	1{Margin Call$_t$ > 0}								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IRD return$_{t-1}$ (%)	-0.030**								
	(-2.42)								
Non-IRD return$_{t-1}$ (%)	-0.001	-0.001						-0.001	-0.000
	(-1.16)	(-1.20)						(-0.87)	(-0.43)
Futures return$_{t-1}$ (%)		-0.049**						-0.054**	-0.048**
		(-2.30)						(-2.30)	(-2.19)
Swaps return$_{t-1}$ (%)		-0.011						-0.012	-0.009
		(-1.07)						(-0.96)	(-0.87)
Other IRD return$_{t-1}$ (%)		0.084						0.052	0.098
		(1.15)						(0.55)	(1.22)
IRD Duration$_{t-1}$ (%)			0.002					0.005	0.004
			(0.44)					(0.99)	(0.94)
ΔUSD 10 year rate$_t$ (%)				0.008				0.009	
				(0.33)				(0.36)	
(Cash/TNA)$_{t-1}$ (%)					-0.002**			-0.003**	-0.002**
					(-2.73)			(-2.79)	(-2.76)
#IRDs						0.023*		0.033**	0.030**
						(1.80)		(2.70)	(2.59)
Log (fund size$_{t-1}$)							0.002*	0.002	0.002
							(1.77)	(1.42)	(1.50)
Controls	No	No	No	No	No	No	No	Yes	Yes
Time FE	No	No	No	No	No	No	No	No	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.011	0.016	0.003	0.003	0.009	0.004	0.002	0.037	0.071
N	15,345	15,345	13,372	15,762	15,377	16,668	16,668	10,323	10,323

Appendix

Data Cleaning for Notional Amounts for Options, Swaptions, and Warrants

For options, swaptions, and warrants, funds report in N-PORT principal amounts ('osw principalAmt'), the number of shares ('osw_shareNo'), and balances inconsistently, sometimes with different scaling, making it challenging to compute their notional values. For options, swaptions, and warrants, we apply the following in order:

1. For swaptions, we use the notional amount from the underlying swap where available, converting to US dollars if necessary.

2. If the balance's unit = 'PA' (principal amount) then we set the notional equal to the balance.

3. if the balance's unit = 'NC' (number of contracts)

    - if osw_principalAmt equals either 0.01, 1, 100, or 1000, and osw_principalAmt does not equal to balance, then we set the notional equal to osw_ principalAmt*balance.
    - if osw_shareNo equals either 0.01, 1, 2, 10, 20, 50, 100, 1000, 2500, 125000, 250000, 100000, 1000000, 200000 12500000, and osw_shareNo does not equal to balance then we set the notional equal to osw_shareNo*balance.
    - if osw_principalAmt = balance then we use this as the notional.
    - if osw_shareNo = balance then we use this as the notional.
    - if osw_principalAmt equals 100*balance (or 1000*balance), then we set the notional equal to osw_principalAmt.
    - if osw_shareNo equals 100*balance (or 1000*balance), then we set the notional equal to osw_shareNo.
    - if abs(balance) is less than 100, then we set the notional equal to osw_ principalAmt*balance.
    - if abs(balance) is less than 100, then we set the notional equal to osw_shareNo*balance.

4. if the balance's unit = 'OU' (other units)

    - if osw_principalAmt = balance then we use this as the notional.

- if osw_shareNo = balance then we use this as the notional.
- if osw_shareNo=1 then osw_NotionalAmt = balance.

5. If none of the above applies, and if both osw_principalAmt and osw_shareNo are missing, we use balance as the notional amount.

Data Cleaning for Currencies of Notional Amounts

For notional amounts reported in non-USD in the N-PORT, we convert them to USD using the exchange rates provided in the N-PORT. We ensure that the exchange rates always represent the value of a foreign currency in USD so that multiplying the exchange rate to the corresponding non-USD notional always converts it to the notional in USD. When the exchange rate is missing, zero, or one (for non-USD notional), we change the notional as missing.

Data Cleaning for Exercise Price for Options, Swaptions, and Warrants

For Treasury bond options, 95% of the exercise prices are around 100. Among the other 5%, for any exercise price between 0.5 and 3, we multiply by 100 to make the scale consistent across positions.

Table A1: **Asset Composition of Portfolio Holdings, in Market Value**. This table shows summary statistics of the composition of portfolio holdings of different types of bond mutual funds, across different asset classes, in market value, as a percentage of total net assets. ABS denotes asset-backed securities, which are split into ABS-APCP (commercial paper), ABS-CBDO (collateralerized bond/debt obligations), ABS-MBS (mortgage-backed securities), and ABS-O (other). DBT denotes debt. Derivatives are split into DCR (credit), DE (equity), DFE (foreign exchange), DIR (interest rates), and DO (other). Equity is split into EC (common stock) and EP (preferred stock). RA denotes a repo agreement. RF denotes registered funds. STIV denotes short-term investment vehicles, such as a money market fund, liquidity pool, or other cash management vehicle.

Asset	Government	IG Corporate	HY Corporate	Global
ABS-APCP	0.19	0.17	0.04	0
ABS-CBDO	2.14	3.67	2.22	1.19
ABS-MBS	23.2	19.35	7.99	5.43
ABS-O	2.56	6.13	3.07	0.73
DBT	67.64	62.68	64.85	80.89
DCO	0.01	0	0	0
DCR	0	0	0.04	0.02
DE	0	0	0.01	0
DFE	0.04	0	0.02	0.67
DIR	0.44	0.4	0.18	0.4
DO	0.02	0.02	0.01	0.01
EC	0.23	0.81	1.7	0.27
EP	0.04	0.29	1.57	0.27
LON	0.5	0.74	5.42	1.1
RA	0.99	0.95	0.69	0.52
RE	0	0	0	0
RF	1.18	2.35	7.19	4.86
SN	0.67	0.54	0.13	0.23
STIV	5.16	5.17	5.6	4.54
Number of Fund-Quarters	2,015	6,874	4,679	2,574
Number of Funds	156	537	375	216

Table A2: **Frequency of Government Bond Futures Holdings by Country.** This table shows the frequency of fixed income funds' holdings of government bond futures contracts, across our all funds in our sample period July 2019 to September 2023, split into the top six most frequent country issuers: the United States, Germany, Australia, the United Kingdom, Canada, and Japan.

Futures			
Instrument	Underlying Security	Country	N
Future	U.S. Treasury bond	U.S.	23,583
Future	Non-U.S. government bond	Germany	4,734
Future	Non-U.S. government bond	Australia	808
Future	Non-U.S. government bond	U.K.	747
Future	Non-U.S. government bond	Canada	611
Future	Non-U.S. government bond	Japan	489

Table A3: **IRD and Fund Returns by Phase.** This table shows results from panel regressions of funds' quarterly returns on quarterly fund-level characteristics for fixed income mutual funds between 2019.Q3 and 2023.Q3. 1{Top (Bottom) IRD Duration Ratio$_t$} is an indicator variable which takes the value 1 if the dollar duration (DV100) of a fund's IRD holdings relative to the dollar duration (DV100) of its bond holdings is above (below) the 80th (20th) percentile for funds in that quarter. Bond Duration is dollar duration (DV100) of bonds, as a percentage of TNA. We omit fund subscript i in the variable names for notational simplicity. All the independent variables are winsorized at the 1% and 99% levels. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

	Return$_{t+1}$ (%)								
	Phase 1			Phase 2			Phase 3		
	IRD	Non-IRD	Fund	IRD	Non-IRD	Fund	IRD	Non-IRD	Fund
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1{Top IRD Duration Ratio$_t$}	0.115***	0.528**	0.603***	-0.051***	-0.116	-0.190***	-0.210***	-0.102	-0.350***
	(3.06)	(2.54)	(2.83)	(-3.97)	(-1.57)	(-2.65)	(-10.27)	(-1.57)	(-4.89)
1{Bottom IRD Duration Ratio$_t$}	-0.215***	0.563***	0.393**	0.050***	-0.050	-0.021	0.148***	-0.181**	-0.025
	(-5.62)	(2.73)	(1.98)	(3.04)	(-0.59)	(-0.27)	(6.19)	(-2.27)	(-0.30)
Bond Duration$_t$ (%)	-0.006	0.339***	0.333***	0.003	0.037**	0.041***	0.008**	-0.242***	-0.230***
	(-1.36)	(10.18)	(9.98)	(1.53)	(2.58)	(2.94)	(2.58)	(-22.27)	(-20.81)
Expense ratio$_t$ (%)	-0.050	-2.626***	-2.682***	-0.003	0.718***	0.711***	0.030	-0.222**	-0.147
	(-1.37)	(-7.70)	(-7.83)	(-0.17)	(4.87)	(4.83)	(1.04)	(-2.17)	(-1.25)
Log(Fund size$_t$)	-0.014*	-0.085*	-0.096**	0.005**	0.017	0.023	-0.010**	-0.015	-0.024*
	(-1.94)	(-1.89)	(-2.12)	(2.20)	(0.93)	(1.26)	(-2.36)	(-1.14)	(-1.68)
Fund return$_t$ (%)	-0.000	-0.639***	-0.643***	0.003	0.017	0.019	0.001	0.066**	0.071**
	(-0.10)	(-31.42)	(-34.28)	(0.86)	(0.70)	(0.79)	(0.83)	(2.44)	(2.38)
Fund flow$_t$ (%)	0.001	0.001	0.003	-0.000	-0.001	-0.002	-0.000	0.009***	0.009***
	(1.20)	(0.10)	(0.36)	(-0.12)	(-0.61)	(-0.78)	(-0.72)	(3.16)	(3.28)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.089	0.758	0.760	0.035	0.492	0.499	0.080	0.675	0.676
N	1,560	1,560	1,560	3,311	3,308	3,308	5,381	5,373	5,373

Table A4: **IRD and Fund Returns by Derivative Instrument.** This table shows results from panel regressions of funds' quarterly returns on quarterly fund-level characteristics for fixed income mutual funds between 2019.Q3 and 2023.Q3. $1\{\text{Top (Bottom) IRD Duration Ratio}_t\}$ is an indicator variable which takes the value 1 if the dollar duration (DV100) of a fund's IRD holdings relative to the dollar duration of its bond holdings is above (below) the 80th (20th) percentile for funds in that quarter. Bond Duration is dollar duration (DV100) of bonds, as a percentage of TNA. We omit fund subscript i in the variable names for notational simplicity. All the independent variables are winsorized at the 1% and 99% levels. All regressions include year-quarter and fund sector fixed effects. Standard errors are clustered at the fund level. t-statistics are in parentheses.

	IRD Return$_{t+1}$ (%)								
	Phase 1			Phase 2			Phase 3		
	Futures	Swaps	Other IRD	Futures	Swaps	Other IRD	Futures	Swaps	Other IRD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$1\{\text{Top IRD Duration Ratio}_t\}$	0.209***	-0.081***	0.006**	-0.029***	-0.020***	0.004***	-0.177***	-0.014**	0.004***
	(8.11)	(-3.55)	(2.37)	(-2.86)	(-2.91)	(3.50)	(-10.26)	(-2.05)	(3.03)
$1\{\text{Bottom IRD Duration Ratio}_t\}$	-0.109***	-0.085***	0.004*	0.058***	-0.020***	0.007***	0.144***	-0.020**	0.003*
	(-3.90)	(-4.53)	(1.81)	(5.00)	(-2.96)	(4.24)	(7.06)	(-2.32)	(1.87)
Bond duration$_t$ (%)	-0.007**	-0.003	0.001**	0.004***	-0.002***	0.000**	0.005**	0.001	0.000
	(-2.09)	(-1.14)	(2.12)	(2.90)	(-2.59)	(2.13)	(1.97)	(0.77)	(0.36)
Expense ratio$_t$ (%)	-0.022	-0.022	0.001	0.002	-0.003	-0.000	0.034	-0.007	-0.001
	(-0.89)	(-1.16)	(0.26)	(0.19)	(-0.48)	(-0.25)	(1.34)	(-0.74)	(-0.33)
Log(fund size$_t$)	-0.000	-0.013***	0.001***	0.004**	0.000	0.001***	-0.007*	-0.001	0.001***
	(-0.02)	(-2.95)	(2.80)	(2.30)	(0.08)	(2.62)	(-1.82)	(-0.60)	(2.59)
Fund return$_t$ (%)	-0.002	0.002	0.000**	-0.000	0.002	0.000	0.001	-0.000	-0.000*
	(-1.22)	(1.05)	(2.38)	(-0.24)	(1.15)	(1.10)	(1.29)	(-0.52)	(-1.65)
Fund flow$_t$ (%)	0.001	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000*
	(1.05)	(-0.17)	(-0.13)	(0.43)	(-0.86)	(0.26)	(-0.68)	(-0.57)	(1.76)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.130	0.071	0.045	0.041	0.023	0.034	0.102	0.011	0.032
N	1,560	1,560	1,560	3,311	3,311	3,311	5,381	5,381	5,381

Table A5: **Determinants of Margin Calls By Phase.** This table shows results from panel regressions of an indicator of margin calls on the lagged IRD returns, components of the definition of margin calls (i.e. lagged IRD durations, changes in interest rates, and lagged cash holdings), and fund-level characteristics, by Phase. 1{Margin Call$_t$ > 0} is an indicator variable which takes the value 1 if the fund experienced a margin call and 0 otherwise. Controls include fund flows and log of fund age in years. Standard errors are double clustered at the fund and year-quarter levels. t-statistics are in parentheses.

	$1\{\text{Margin Call}_t > 0\}$			
	All Phases	Phase 1	Phase 2	Phase 3
	(1)	(2)	(3)	(4)
Futures return$_{t-1}$ (%)	-0.054**	0.021	-0.007	-0.067*
	(-2.30)	(1.53)	(-0.49)	(-2.10)
Swaps return$_{t-1}$ (%)	-0.012	0.017	-0.004	0.002
	(-0.97)	(0.78)	(-0.50)	(0.23)
Other IRD return$_{t-1}$ (%)	0.053	-0.225	0.167	0.076
	(0.55)	(-1.47)	(0.91)	(0.83)
Non-IRD return$_{t-1}$ (%)	-0.001	-0.000	-0.000	-0.000
	(-0.87)	(-0.29)	(-0.54)	(-0.22)
IRD Duration$_{t-1}$ (%)	0.005	-0.031	0.006	0.009*
	(0.99)	(-0.95)	(1.02)	(2.22)
ΔUSD 10 year rate$_t$ (%)	0.009	-0.067**	0.045**	0.055***
	(0.36)	(-7.98)	(4.10)	(4.18)
Cash TNA$_{t-1}$	-0.003**	-0.003	-0.001	-0.003**
	(-2.79)	(-0.98)	(-0.97)	(-2.39)
#IRDs$_{t-1}$	0.033**	0.055	0.006	0.034*
	(2.70)	(1.06)	(1.27)	(2.29)
Log (fund size$_{t-1}$)	0.002	-0.002	0.000	0.004
	(1.42)	(-0.94)	(0.72)	(1.89)
Controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
R^2	0.037	0.148	0.047	0.084
N	10,339	1,568	3,335	5,436