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Abstract

The significant growth in the investment fund sector coupled with recent increases in interest rates pose questions regarding the sector's vulnerability to shocks and its potential for amplifying systemic risk. In this *Note* we assess the sensitivity of cohorts of bond funds to a large one-off increase in interest rates by developing a tool to measure the impact on funds' net asset value (NAV). The results split by fund cohorts, show that losses increase with weighted average maturity of assets and with the proportion of fixed coupon bonds (Government and Emerging Market Bond Funds experiencing the largest losses). These losses have the potential to trigger larger than usual outflows, particularly for underperforming investment funds within cohorts. This *Note* highlights existing balance sheet and redemption vulnerabilities - such as relatively high leverage in Mixed Corporate Bond Funds – which may affect the resilience of cohorts beyond what is modelled in this *Note*. We also apply the ESMA stress test to assess the joint impact of an interest rate and a credit shock and find somewhat similar results. The tool developed here has been incorporated into our ongoing financial stability *Risk Assessments*, which inform both policy and supervision.

1. Introduction

Since the financial crisis in 2008, the global financial system has undergone significant structural change, with considerable growth of non-bank financial institutions (NBFI). Total assets of the global NBFI sector increased from €72 trillion in 2008 to €212 trillion in 2021, according to the FSB's latest annual monitoring report on non-bank financial intermediation (Financial Stability Board, 2022a). The shift from a traditional bank-centric model to an NBFI model reflects the use of alternative finance or investment sources and benefits the system by diversifying risk across investors and countries (Lane & Moloney, 2018). But with benefits can also come risks. In this Note we focus on potential sources of systemic risk from investment funds. These need to be monitored, understood, and in some instances mitigated: hence the need to understand the amplification and transmission mechanism of shocks and the interaction and propagation of risks from a system-wide perspective.[2]

Over the past decade, Ireland's NBFI sector has almost tripled in size. According to the Financial Stability Board (Financial Stability Board, 2022a) the sector in Ireland increased from €1,240 billion at end-2010 to €3,450 billion at end-2021, making it the fifth largest NBFI jurisdiction globally. [3,4]

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[2] These topics were the central theme of the FSB conference on the topic - *Understanding and addressing systemic risks in non-bank financial intermediation* - in June 2022 (Financial Stability Board, 2022b).

[3] The Irish NBFI sector is made up of investment funds (€2,092 bn), money market funds (€630 bn), entities engaged in securitisation (€443 bn) and non-securitisation purpose entities providing credit (€237 bn). For further details see Lai (2022).

[4] In the same decade the global NBFI sector more than doubled in size; the global NBFI narrow measure grew from 29.7 trillion USD in 2011 to 67.8 trillion USD in 2021 (Financial Stability Board, 2022b).

The composition of the sector in Ireland is dominated by investment funds and money market funds, which account for around two-thirds of total assets (Cima, Killeen, & Madouros, 2019). Within the investment fund sector, bond funds are the second largest fund cohort in Ireland accounting for €910 billion in 2022Q4, (the largest cohort being equity funds).

The COVID-19 crisis was a real-world example of exogenous distress affecting financial markets and challenging the resilience of investment funds (Central Bank of Ireland, 2023a). During that period, investor outflows increased notably, especially for illiquid funds. Falato, Goldstein & Hortaçsu (2021) present an empirical analysis of the fragility experienced by funds during the COVID-19 crisis. During the COVID-19 crisis, some investment funds suspended redemptions, particularly those that invested in illiquid assets with high leverage and low cash holdings, generating a spillover effect on to other funds (Grill , Vivar, & Wedow, 2022). Claessen and Lewrick (2021) draw similar conclusions and highlight the necessity of adding measures to address systemic risk (Claessens & Lewrick, 2021). Falato, Hortaçsu, & Shin (2022) study the spillover effect of *fire sales* induced by peer fund flows, finding that *fire sales* induced by investor redemptions have a significant impact on the performance and flows of other funds holding the same assets.

The interest sensitivity of bond funds is particularly important for financial stability (FS) at the moment due to the recent rise in interest rates in the last 18 months or so. The resulting fall in bond valuations (rise in yields) may lead investors to increase redemption requests in bond funds. This relationship is noted by the concave performance-flows relationship found for bond funds in Goldstein, Hao & Ng (2017). If the redemptions are large (say, larger than liquid assets) the fund may be *forced to sell* less liquid assets to meet these requests. Collective *forced selling* across a cohort of bond funds may lead to a reinforcing downward spiral in bond prices. This mechanism is further amplified due to the interconnectedness of NBFI. Other entities holding common assets with bond funds may also experience losses to their portfolios, with potential implications for the solvency of leveraged entities in particular. Thus, it is essential to assess whether bond funds are resilient to sharp interest rate rises, particularly in the current environment of tightening of monetary policy.

Scenario analysis and stress testing are tools that can be used to assess the impact of stress in investment funds, see Fiedor & Katsolis (2019) and Baranova et al (2017). One of the most straightforward assumption and calibration free ways to simulate stress dynamics for the bond market is to apply a parallel shift to the yield curve by a fixed amount. The system perturbation is an easy way to test the impact of interest rate shocks on valuations. Cetorelli, et al., (2016) explains how this method is useful for analysing vulnerabilities in the system and estimating funds' losses. This type of stress simulation, implemented by the European Central Bank (European Central Bank, 2017), presents the impact for European funds by fund sector and disentangles the effect due to price and volume. The European Systemic Risk Board applied a similar methodology to stress the portfolios of a sample of 200 bond funds domiciled in Ireland, Luxemburg, France, and Germany. The results, split by country, show that, faced with an interest rate shock of 100bps, the average fund loss is 4 per cent of the NAV (European Systemic Risk Board, 2022).

The main contribution of this *FS Note* is to implement a forward-looking exercise to evaluate the impact of *severe but plausible adverse scenarios* on the resilience of cohorts of bond funds (Bank of International Settlements, 2021). We apply a large interest rate shock to the bond portfolios of different cohorts of bond funds to see which cohorts are most vulnerable. It is essential to clarify that stress tests do not predict the likelihood of such events or scenarios. Thus, the exact magnitude of the stress that is applied is not critical to the analysis. They are tools to assess the overall resilience of a portion of the financial sector; that is, they allows us to compare the bond fund cohorts in terms of their relative impact and likelihood to amplify a shock.

Our stress test is part of the Central Bank of Ireland's risk identification and assessment framework and comes under the analytical tools and models used to inform judgements around the risk environment (Central Bank of Ireland, 2022). Given the increasing importance of the NBFI sector

within the global financial system, it is of utmost importance to consider how monetary policy is transmitted via the non-bank sector. Carstens (2021) notes how the NBFI sector can amplify market distress and affect monetary policy transmission, implementation and calibration. In particular, liquidity mismatch and leverage are the main vulnerabilities of the sector that can amplify the system-wide distress. In this regard, the Governor of the Central Bank of Ireland has highlighted the need for a macroprudential perspective in tackling systemic risks in investment funds that targets the collective action of fund cohorts, not idiosyncratic risk management issues at individual funds (Makhlouf, 2022). More generally, the Central Bank of Ireland outlines its position on the development of macroprudential policy for investment funds in a recent discussion paper (Central Bank of Ireland, 2023a).

The rest of this *FS Note* is organized as follows. Section 2 outlines the stress testing model we use. Section 3 describes the data used in the analysis. Section 4 reports the results of our study. Finally, Section 5 concludes by proposing some policy implications.

2 Model

This section describes the framework we implement to test the resilience of cohorts of bond funds when an interest rate shock perturbs financial markets. When the market is efficient, the bond price is the discounted expected value of its future cash flows. Therefore, an investment fund's sensitivity to interest rate risk depends on the features of its securities:

- The coupon type - Fixed, Floating, Zero Coupon, Inflation-linked, Interest-Rate linked, Stepped;
- The coupon rate (ceteris paribus, a bond with a lower coupon rate experiences a greater price decrease as the interest rate increases);
- The coupon frequency (ceteris paribus, a bond with a lower coupon frequency experiences a greater price decrease as the interest rate increases);
- The face value (ceteris paribus, a bond with a lower face value experiences a greater price decrease as the interest rate increases);
- The maturity (ceteris paribus, a bond with longer maturity experiences a greater price decrease as the interest rate increases); and
- Eventual callable features.

Bond prices usually have an inverse convex relationship with interest rates: if the market interest rate rises, the bond price declines. Modified Duration is an appropriate proxy to measure a bond price's sensitivity to interest rate risk.[5] The proxy captures the percentage change in a bond price due to a 100bps change in interest rates. Securities with a longer duration are more sensitive to interest rate risk. We define a fund level modified duration as the weighted average duration of the bonds composing its portfolio, with weights defined by the relative contribution of a security to the fund's assets. The impact of a change in the interest rate translates into a reduction in the NAV of a fund, which depends on the sensitivity of the fund to interest rate risk as estimated using the fund level modified duration. We complement the model by incorporating a measure of convexity to account for non-linear relationships and better proxy the degree of curvature. Convexity measures how much the duration changes when the interest rate moves, hence it is the second-order derivative of the price-yield function.[6] Similar to modified duration, weighted average convexity is

[5] For the basic principles of bond pricing and risk exposures, we refer to (Fabozzi, 1999).

[6] The fund convexity is computed with the same logic of fund duration, by weighted-averaging the securities' convexities and using their relative contribution to the fund's total assets as weights.

calculated for each fund. The fund loss is computed as a function of the change in the interest rate, duration and convexity.[7]

We apply an interest rate increase of 100bps to the bond portfolios of different cohorts of bond funds. This stress test is motivated by the scenario proposed by ESRB (European Systemic Risk Board, 2022) and aims to evaluate the sensitivity of funds' bond holdings to an exogenous parallel shock to the yield curve. We simulate an instantaneous shock of 100bps to the yield curve that generates a fall in bond prices for all securities in the fund's portfolio, using the fund-level estimates of modified duration and convexity and the relationship outlined in the Appendix. There have been some large changes in yield curves recently of a similar magnitude to the shock applied in this test.[8] However, as the shock in this test is applied instantaneously to all bonds regardless of currency, its impact at a fund cohort level will likely be more severe than from these recent market movements. This is because it does not allow for any benefits of diversification across currencies or allow for actions that may be taken by fund managers to mitigate against rising rates over a longer period e.g. by reducing the weighted average maturity of their portfolio.

We apply a second stress test by combining both interest rate and credit shocks to the individual securities in funds' portfolios using security level modified duration and convexity. The adverse scenarios for the stress test are outlined in the ESMA MMF stress-testing guidelines (European Securities and Markets Authority, 2022). The stress parameters and results of this stress test are provided in the Appendix.

3 Data

In this Section, we provide an overview of the composition of the bond fund sector in the fourth quarter of 2022 (2022Q4) and the data used to implement the stress tests described in the previous section. The total assets held by the bond funds in scope for this *FS Note* are approximately EUR 784 billion. We categorise the funds into cohorts using the following rules (see Figure A.**1** in the Appendix for the categorisation and order flow we use to assign funds to a particular cohort):

- **Government Bond Funds**: funds containing at least 70 per cent of government debt securities in their portfolios with respect to their total assets under management;
- **Emerging Market Bond Funds**: funds containing at least 70 per cent of non-advanced economies exposures;[9]
- **Corporate Bond Funds**: funds containing at least 70 per cent of corporate debt securities in their portfolios. Corporate Bond Funds are further split in:
    - ***Investment Grade Corporate Bond Funds***: corporate bond funds with at least 70 per cent of investment grade bonds;[10]
    - ***High Yield Corporate Bond Funds***: corporate bond funds with at least 70 per cent of high yield bonds;[11]
    - ***Mixed Corporate Bond Funds***: a residual cohort of corporate bond funds that do not reach the threshold to be included in one of the two ratings-based categories.

[7] See Appendix for details.

[8] US 10 Year Treasuries are up 100 basis points from July to October 2023 see here and UK 10 Year Gilts have also surged in 2023, for example rising 100 basis points in May see here.

[9] The list of non-advanced economies consists of countries not belonging to the advanced economies list compiled by the IMF. The following countries are classified as advanced economies: Australia, Austria, Belgium, Canada, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Macao, Malta, the Netherlands, New Zealand, Norway, Portugal, Puerto Rico, San Marino, Singapore, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, Province of China, the United Kingdom, and the United States.

[10] We consider as investment grade the bonds with a rating AAA, AA, A, BBB and equivalent nomenclatures proposed by the credit rating agencies.

[11] We consider as high yield the bonds with a rating below BBB (BBB, BB, B, CCC, CC, C, D) and equivalent nomenclatures proposed by the credit rating agencies.

- **Mixed Bond Funds**: a residual cohort for the bond funds whose portfolios do not have a sufficiently large (70 per cent) portion of either government, emerging market or corporate debt securities.

70 per cent is chosen as the cut off as it is sufficiently high that the funds in the cohort are likely to be using an investment strategy that focuses specifically on the underlying assets of focus, i.e. *Government Bond Funds* describes a cohort of funds that focus specifically on investing in government bonds. This makes it more likely that the funds in the cohorts have similar investment strategies and mandates, and are more likely to act similarly. Table 1 reports the number of funds in each cohort, the total NAV (expressed in billions of euro), and the relative weight of each cohort as a percentage of the total NAV. The largest cohort is the Investment Grade Corporate Bond Fund cohort (EUR 235 bn), which, together with the other two corporate bond-based categories (Mixed Corporate Bond Funds (EUR 157 bn) and High Yield Corporate Bond Funds (EUR 79 bn)), make up over 60 per cent of the total NAV. Government Bond Funds (EUR 145 bn), Mixed Bond Funds (EUR 108 bn) and Emerging Market Bond Funds (EUR 61 bn) make up 18.4 per cent, 13.7 per cent and 7.8 per cent of total NAV respectively. These bond fund categories exclude liability driven investment funds (LDIs) for the purpose of this analysis due to their specific investment strategies (FSR H2 2022, Box C).

We use line-by-line securities holdings data for each of the funds to identify the characteristics of the bonds in their portfolio, obtained from the Money Market and Investment Fund Return collected by the Statistics Division of the Central Bank of Ireland. By combining the holdings information with third party debt securities data obtained from IHS Markit and the ECB Central Securities Data Base (CSDB) we are able to conduct in-depth analysis of fund composition and sensitivity to risks. We collect data on the bonds' maturity, coupon type (zero coupon bond, fixed, floating, inflation-linked, step-up), coupon rate, payment frequency, duration, convexity, issuer country, currency, and investment grade (credit rating).

Cohort	*Number of Funds*	*NAV (EUR bn)*	*NAV (per cent)*
Investment Grade Corporate Bond Funds	316	234.86	29.95
Mixed Corporate Bond Funds	158	156.67	19.98
Government Bond Funds	217	144.68	18.45
Mixed Bond Funds	148	107.65	13.73
High Yield Corporate Bond Funds	163	79.30	10.11
Emerging Markets Bond Funds	134	61.09	7.79
Total	1135	784.27	100

Table 1: Fund cohorts' size 2022Q4. The Table reports the number of funds populating each cohort and the total exposure in absolute (NAV (EUR bn)) and relative terms (NAV (per cent)).

From the IHS Markit and CSDB databases, we retrieve the security-specific data for 52,408 ISIN codes (out of 61,945 bonds composing the funds' portfolios). Data coverage on duration is high (92.6 per cent of exposures by total asset value), while the convexity coverage is more limited (71.4 per cent of exposures by total asset value).[12] For the securities with missing modified duration, we

[12] All the fund categories have a duration coverage greater than 93 per cent, except the Mixed Corporate Bond Funds that have a coverage of 79.5 per cent of their exposures (measured as a fraction of the total asset value of the cohort).

fill the missing values with the average modified duration of the corresponding fund cohort.[13] For the securities with missing convexity, we calibrate a model to estimate the values (see the Appendix). The convexity model offers a considerable contribution in broadening the data, estimating values for 13.2 per cent of the exposures by total asset value and expanding the data coverage for convexity to 84.6 per cent.

Figure 1 reports the composition of fund cohorts in terms of bond coupon type. Fixed coupon bonds (indicated by FIX) make up the largest share of bond holdings for all cohorts, but with considerable variation across different entity types. Government Bond Funds hold a non-negligible amount of inflation-linked (IDX) bonds. Finally, the three corporate bond cohorts hold a significant proportion of floating (FLO) and step-up (STE) bonds, making these cohorts somewhat less sensitive to the exogenous interest rate shocks.[14]

Fund cohorts present considerable variability in maturity (Figure 2). The market-value weighted-average maturity of the funds in each cohort ranges from 8.5 years for Government Bond Funds to 14.8 years for Mixed Corporate Bond Funds. In between, we have Investment Grade Corporate Bond Funds (9.1 years), Mixed Bond Funds (9.1 years), High Yield Corporate Bond Funds (9.4 years) and Emerging Market Bond Funds (10.3 years). Corporate Bond Fund categories, in particular Mixed and High Yield, tend to have more heterogeneous maturity profiles, with significant outliers in terms of longer maturity funds.

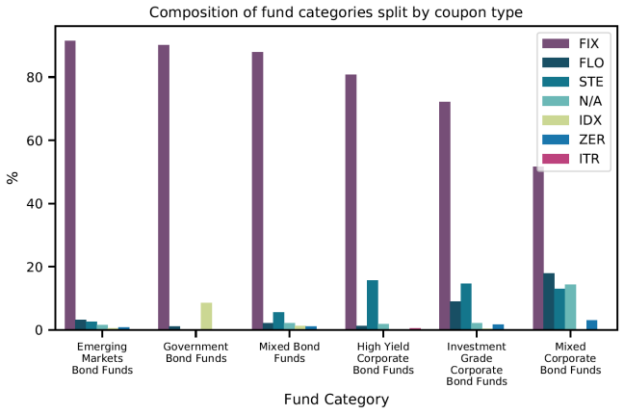
Figure 3 presents the composition of fund cohorts in terms of investment grade. The percentages are computed as the weight of each investment grade level with respect to the total NAV of each fund cohort. As expected, the Investment Grade Corporate Bond Fund cohort contains more than 96 per cent of investment-grade securities. In comparison, the High-Yield Corporate Bond Fund cohort contains more than 95 per cent of high yield bonds. Government Bond Funds are dominated by prime/high-grade securities. Mixed, Mixed Corporate and Emerging Market Bond Funds present heterogeneous investment grades, with a significant presence of highly speculative (<=CCC) securities.[15] While the investment grade composition does not directly affect the interest rate sensitivity of a bond, it will affect the level of stress applied in the combined ESMA interest rate and credit shock stress test reported in the Appendix.

[13] This approach assumes that the missing securities in a cohort have similar characteristics to those for which data is available. We tested an alternate approach that reduced the sample to funds with >90% coverage and the results were similar. Applying the average duration approach providing more conservative results.

[14] Floating rate notes' duration lasts until the next coupon payment date, making them less sensitive to the exogenous interest rate shocks because they adapt to the latest market conditions.

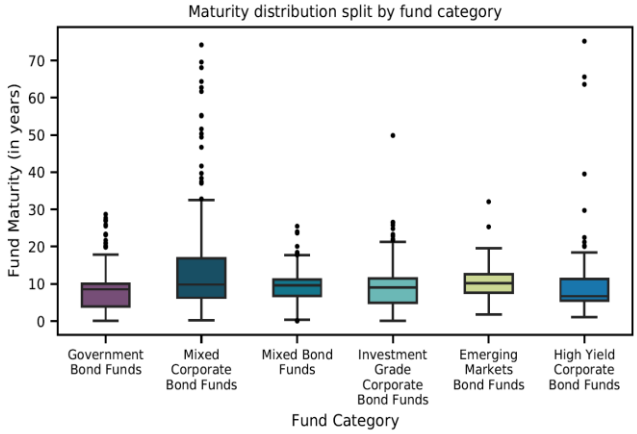
[15] The <=CCC category also includes securities for which no rating is available.

Figure 1: *Emerging and Government Bond Funds hold the highest percentage of fixed coupon bonds.*



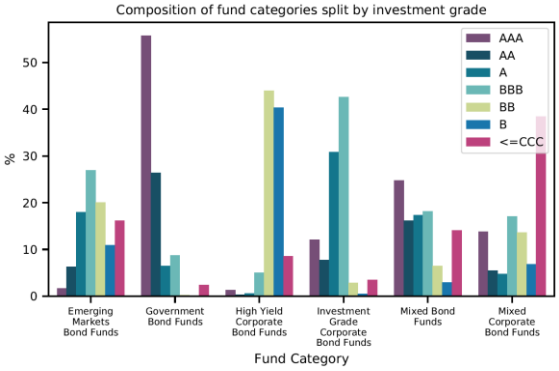
The abbreviations in the legend refer to the coupon types: FIX stands for Fixed coupon bonds, FLO for Floating, IDX for inflation-linked, ITR for interest rate-linked, STE for Stepped and ZER for Zero Coupon, N/A when not specified. Source: Money Market and Investment Fund Returns, IHS Markit and CSDB data

Figure 2: *Mixed Corporate Bond Funds have the longest average maturities.*



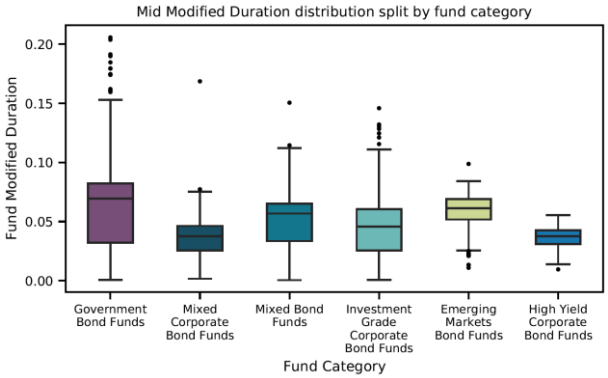
Fund maturity is the market-value-weighted average of the maturity of individual bonds composing the fund's portfolio. Source: Money Market and Investment Fund Return and authors' calculations.

Figure 3: *Securities' ratings breakdown differs substantially across the fund cohorts*



Securities categorized as AAA, AA, A and BBB are investment grade, the remaining ones (BB, B, <=CCC) and securities with unspecified rating are treated as speculative. Source: Money Market and Investment Fund Return , IHS Markit and CSDB data and authors' calculations

Figure 4: *Government, Mixed and Emerging Market Bond Funds are the most sensitive to interest rate shocks.*



Fund modified duration is the market-value-weighted-average of the modified duration of individual bonds composing the fund's portfolio. Source: Money Market and Investment Fund Return, IHS Markit and CSDB data and authors' calculations.

4 Results

4.1 Stress test result

This section reports the results of the stress test model with a parallel shock across the yield curve (see Figure 5). We simulate a 100bps parallel shock of the yield curve and assess the aggregate reduction in total NAV for each cohort. Each fund suffers a loss due to the shock with a specific sensitivity, proxied by the duration and convexity of the securities composing its portfolio. Government Bond Funds experience the biggest loss as percentage of the NAV (6.03 per cent), followed by Emerging Markets Bond Funds and Mixed Bond Funds with 5.34 per cent and 5.18 per cent respectively. The results for Investment Grade, Mixed and High Yield Corporate Bond Funds indicate lower interest rate sensitivity with reductions in total NAV of 4.36 per cent, 4.28 per cent and 3.47 per cent respectively. This is similar to the results of the stress test applied by the ESRB, where they found that a 100 bps shock led to an average loss of 4% of NAV across bond funds, while noting the impact varied across funds (European Systemic Risk Board, 2022). The ESRB note that the losses estimated in their exercise could trigger outflows in underperforming funds with the

potential for amplification of the initial shock. Our *Note* extends this analysis to look at relative losses across cohorts. We compare these losses to historical returns and note that the losses would be unusual (i.e. in the tails of the returns distribution) and thus may cause larger than normal outflows.[16]

The results described above can be explained by a number of factors. Two of prime importance are the maturity profile and the portion of fixed coupon bonds in the portfolio. While Corporate Bond Fund cohorts tend to have more heterogeneous maturity profiles, Mixed Corporate Bond Funds have the highest weighted average maturity but one of the lowest interest rate sensitivities. This is because they have a much higher portion of floating rate bonds (approximately 18 per cent of Mixed Corporate Bond Fund holdings). The importance of coupon type composition on interest rate sensitivity across fund cohorts can be seen in the modified duration distributions (see Figure 4). The fund duration is a proxy for the sensitivity to interest rate risk and strongly depends on the bonds' maturities and coupon types. Due to the high maturities and a high share of fixed coupon bonds, Government Bond Funds, Emerging Markets Bond Funds and Mixed Bond Funds are more sensitive to interest rate shocks.

As discussed in Section 2, we also run a second stress test model with interest rate and credit specific shocks. The results of the interest rate shock component are similar to the results of the test described in this section, while the credit shock highlights that the fund cohorts containing a higher portion of lower rated/speculative bonds are more vulnerable. We report the detailed results in the Appendix.

4.2 Financial Stability Implications – Redemptions, Liquidity and Leverage

In this section, we extend the analysis by considering the financial stability implications of our main findings and, in particular, how the existing vulnerabilities of the bond cohorts (the leverage and liquidity levels) may interrelate with the fall in NAV from an interest rate shock. This gives us a sense of the resilience of the cohorts to an interest rate (and/or credit) shock and may point to the likelihood that fund cohorts would amplify a shock to the financial system. To interpret the consequent falls in NAV as a result of the shocks outlined in Section 4.1, we consider the liquidity, the leverage and the redemption histories of the cohorts of funds. Historical redemption levels give us a sense of what level of redemptions might be considered large for these fund cohorts and/or what levels they are currently managing. It also allows us to assess if redemptions have increased due to the change in monetary policy since July 2022. Liquidity and leverage levels reflect the funds' resilience to shocks.

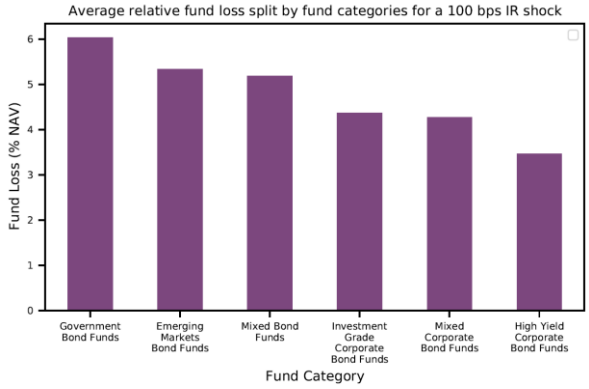
4.2.1 Redemptions

In considering the financial stability implications of the stress test results, we note that the majority of funds in each of the cohorts offer daily redemptions to investors (see Figure 6). This means that funds may be required to meet redemption calls on a daily basis. If the volume of redemption requests is large – larger than liquid assets – funds may be forced to sell less liquid assets at a price below their economic value, *i.e. a forced sale*. The financial stability risk is heightened if there are collective *forced sales* by the cohort of funds to such an extent that it impacts the functioning of the underlying markets and has real economy effects. If many funds are collectively *forced to sell* the same assets, this may lead to market dysfunction and also to spillovers to other entities holding the same assets. A recent example of this occurred in the UK gilt market in September 2022 following the announcement of the '*mini-budget*' by the then UK Government, see FSR 2022 Box C (Central Bank of Ireland, 2022). In general, Irish funds have access to a wide range of *Liquidity Management Tools* that may allow them mitigate the impact of large redemption requests. For example they may be able to gate or delay payment in relation to redemption requests, or incorporate the additional costs into the proceeds received by the investors (Daly & Moloney, 2017). Thus these tools can reduce *first mover advantage* (the advantage to investors of being the first to redeem their shares in

[16] The losses in NaV are greater than 2-3 monthly fund returns' standard deviation and 5 times 3 standard deviation of daily returns for the relevant bond indices. We do not have access to daily returns for the funds.

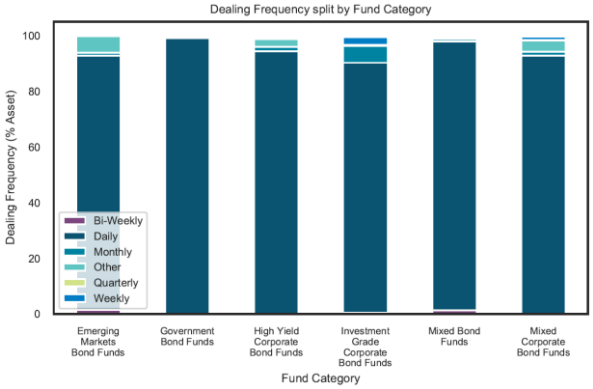
a fund, in essence to get access to the NAV price *before* the full effects of the *forced sales* are reflected). We do not take these tools into account in this *FS Note* and they may mitigate the potential vulnerability that we test in the *Note*.

Figure 5: *Government and Emerging Market Bond Funds have the largest losses from the shock.*



Source: Money Market and Investment Fund Return, IHS Markit and CSDB data and authors' calculations.

Figure 6: *The majority of all cohorts are accessible to investors through daily dealing.*



The Figure reports the dealing frequency for each fund cohort in the 2022Q4 (31/12/2022). Source: Money Market and Investment Fund Return and authors' calculations

While the stress test results are somewhat lower for High Yield Bond Funds (3.47 per cent reduction in NAV), when we consider the low level of liquid assets for the cohort in Figure 7 the results may be more concerning from a financial stability perspective. Poor performance and low liquidity buffers may increase *first mover incentives* for investors to redeem, leading to an increased risk of *fire sales*. An examination of monthly net flows (Subscriptions minus Redemptions) in Figure 8 highlights higher volatility of flows from Mixed Corporate, Emerging Market and High Yield Bond Funds in particular during the onset of COVID-19 but also more recently. Given the high share of speculative grade securities in each of these categories - which are typically less liquid in times of stressed market conditions - and the strategic complementarities previously set out (Goldstein, Hao, & Ng, 2017), investor flows in these fund types may be more sensitive to shocks to performance. We note that since monetary policy has moved into a tightening cycle, so far bond funds redemptions appear to be contained and well managed. The stress here relates to a sudden and more extreme event that funds may not have a chance to prepare for and highlights the vulnerabilities that exist within the sector.

4.2.2 Liquidity

Liquidity mismatches in fund cohorts means that they may not be able to meet large daily redemption requests if they are heavily invested in less liquid assets. Thus, *first mover incentives* exist if investors believe that liquid assets will be depleted by the first wave of redemptions following a market shock.

As highlighted in Figure 4, a significant number of funds would experience large drops in total NAV due to high modified duration of their bond portfolio. Due to the aforementioned flow-performance relationship, this could trigger outflows from funds that are particularly impacted by the shock. Goldstein, Hao, & Ng (2017) find that corporate bond funds tend to have greater sensitivity of outflows to bad performance when they have more illiquid assets. Thus, the liquidity of the underlying funds needs to be considered when discussing the potential financial stability implications of the stress test results. Speculative and emerging market bonds are typically less liquid than investment grade and advanced economy bonds. Thus, the finding of relatively high interest rate sensitivity of Emerging Market Bond Funds (5.34 per cent reduction in NAV) leads us to assess the share of less liquid assets for this cohort. We note that Emerging Market Bond Funds have relatively high levels of cash equivalents. This has increased in recent quarters to

approximately 10 per cent of total assets as of 2022Q4 (see Figure 7). This is the highest share of cash holdings across all fund cohorts analysed here.

The Government Bond cohort has high levels of liquidity buffers in the form of advanced economy, high and prime-rated sovereign bonds. In most states of the world, sovereign bonds are more liquid than other types of debt (e.g. corporate bonds). Whereas in certain tail events, such as during the US banking sector turmoil (which began in March 2023) and the disruption in UK gilt markets (September/October 2022), liquidity in (long dated) sovereign bonds has been reduced.[17] Thus in these specific circumstances, market liquidity conditions faced by the Government Bond Fund Cohort could be affected and, in the event of *forced sales*, funds may have to accept *fire sale* prices despite high liquidity buffers.

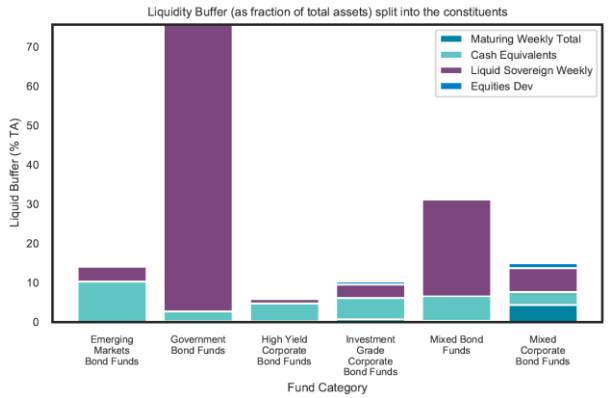
4.2.3 Leverage

The use of leverage by investment funds can amplify market shocks by triggering *fire sale* dynamics. An interest rate shock affects the performance of a fund's portfolio via the interest rate sensitivity of the individual bonds. However, the use of leverage amplifies gains/losses of a fund and therefore investors in leveraged funds will experience larger losses, ceteris paribus, than investors in unleveraged funds. The effect of leverage amplifying poor performance in investment funds may trigger large redemptions from these funds in the event of a large interest rate shock, leading to *fire sales* of bonds. Additional liquidity requirements may also arise via margin calls and additional collateral requirements to maintain positions in funds with exposure to derivatives contracts and repurchase agreements (repos). As above, this can lead to *forced selling* of less liquid assets. While our stress test does not explicitly model these dynamics, the presence of leverage from derivatives and repos is demonstrated in Figure 9. In the event of a large interest rate shock it is likely that bond funds gaining leverage from repos or derivatives will experience additional liquidity requirements as described. We note that Mixed Corporate Bond Funds have higher levels of leverage in comparison to the other cohorts and this may make them more vulnerable to shocks.[18]

[17] We note that since the disruption in UK gilt markets in September 2022 a number of actions have taken place by the Central Bank of Ireland, the Commission de Surveillance du Secteur Financier (CSSF) the Bank of England, the UK Pension Regulator, the UK Financial Conduct Authority and others to increase the resilience of GBP-denominated liability driven investments (LDI) funds (Central Bank of Ireland, 2023a).

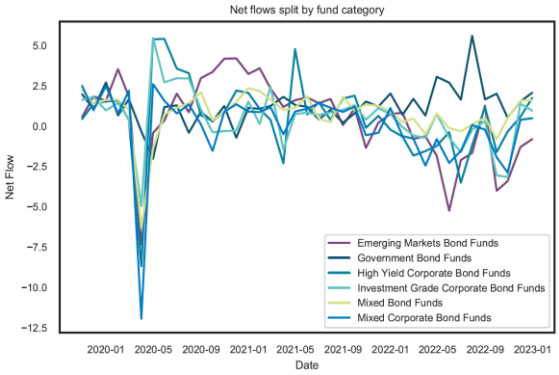
[18] Unsettled trade liabilities in the Mixed Corporate Bond Fund sector primarily relate to investments in the TBA ('To Be Announced') market for Agency Mortgage Backed Securities (MBS). A TBA transaction operates in a similar manner to a forwards contract where the buyer and seller agree upon general trade parameters such as agency, maturity, coupon, settlement date, par amount and price. The settlement date is generally one, two or three months forward and TBAs trade on a "cheapest-to-deliver" basis. 90 per cent of trading in agency MBS takes part in the TBA market. In 2020, due to poor liquidity conditions created by COVID-19, the Federal Reserve in the US intervened in the TBA market announcing that they would purchase at least $200bn in TBA securities (Mizrach and Neeley, 2020).

Figure 7: *Government Bond Funds have by far the most liquid assets.*



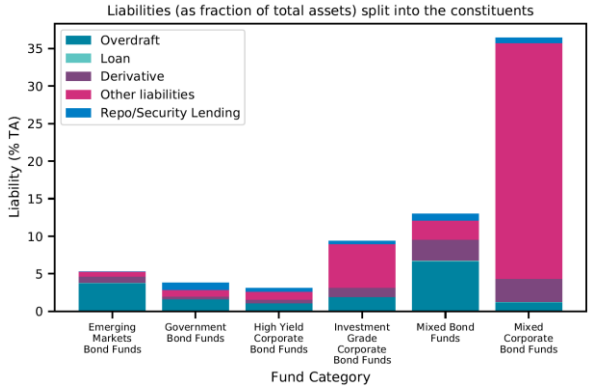
The percentage of liquid buffer (as a fraction of the total assets) is split into its constituents for each fund for 2022Q4 (31/12/2022). Source: Money Market and Investment Fund Return, IHS Markit and CSDB data and authors' calculations.

Figure 8: *Emerging Market Bond Funds are amongst the cohorts with the most volatile redemption flows.*



The net flows are computed as a fraction of the NAV in the period 31/12/2019 to 31/12/2022. Source: Monthly Net Asset Value Return and authors' calculations.

Figure 9: *Mixed Corporate Bond Funds have the highest on balance sheet liabilities.*



The percentage of liabilities (as a fraction of the total assets) is split into constituents for each fund cohort for 2022Q4 (31/12/2022). Source: Money Market and Investment Fund Return, IHS Markit and CSDB data and authors' calculations.

5 Final discussion and policy consideration

This *FS Note* describes the main findings of stress tests applied to certain cohorts of bond funds domiciled in Ireland. We test the resilience of these NBFI entities by generating exogenous shocks to interest rates (and in the appendix consider a shock to credit spreads). We note that the most affected cohorts for an interest rate shock are the ones holding long-maturity assets and those with a higher portion of fixed coupon bonds. These characteristics are key factors for greater sensitivity to interest rate shocks. Overall we find the two most affected cohorts are Government Bond Funds and Emerging Market Bond Funds. Due to the performance-flows relationship, the drops in NAV estimated in this *Note* could trigger outflows, particularly for underperforming investment funds within cohorts (with the potential for nonlinear and second-round effects to amplify the initial shock). The tool developed here - to assess fund cohorts' sensitivity to interest rate risk – has been incorporated into the Central Bank's ongoing financial stability *Risk Assessments*, which can inform policy and supervision (Central Bank of Ireland, 2023c).

We also study the redemption history and the resilience of the funds, comparing the funds' losses from the stress tests with their redemption histories, the proportion of liquid assets that they hold, and their leverage levels (Central Bank of Ireland, 2021). Historical volatility of redemption flows is much higher at the onset of COVID-19 and for Mixed Corporate, Emerging Market and High Yield

Bond Funds in particular. This volatility in flows may make these funds more vulnerable to shocks, as losses may lead to larger outflows and make *forced sales* more likely. An analysis of liquidity buffers shows Government Bond Funds have very high levels of liquid assets, although most of this is in government bonds themselves rather than in cash or other liquid holdings. In recent times, due to increased uncertainty following the changes in the macro economy (high inflation, rising interest rates etc. see Central Bank of Ireland 2023b) we have seen falls in liquidity in government bonds in the US and, in September 2022, the UK. If the shock was to occur at the same time as a fall in liquidity in government bond markets, these funds may have *forced sales*. When defining liquidity more tightly (relating only to cash equivalents), we see that Emerging Market Bond Funds have relative high liquidity levels whereas Government Bond Funds have lower levels.

Finally, Mixed Corporate Bond Funds performed relatively well in the stress tests but we note that during the onset of COVID-19, they experienced large outflows and also that they have the highest level of leverage out of all the cohorts. So in a shock, they may be more vulnerable due to rising redemption requests or solvency (or other liquidity calls) due to high leverage and other balance sheet liabilities.

The implemented analysis presents some limitations that we may look to overcome in future research. We consider only a one-off repricing of bonds; second–round dynamics are not included (e.g., fund managers may rebalance portfolios, use liquidity management tools or have reduced losses due to diversification across currencies). In addition, we do not reprice the derivatives used to cover interest rate changes; the EMIR dataset could be used to consider derivatives and to fine-tune the analysis. Also, the stress test framework treats investment funds independently, without considering the systemic risk due to common holdings.

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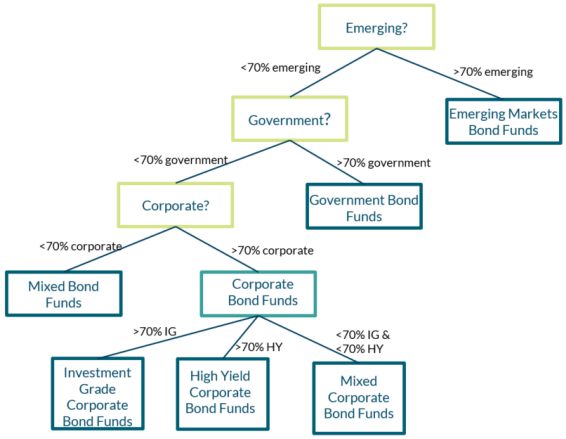
Appendix

Fund categorisation

We classify Irish bond funds following the flow described in the decision tree in Figure A.1.

Figure A.1: Decision tree for categorising bond funds.
The classification process starts by selecting the funds investing in emerging market bonds. Subsequently, we identify the funds containing a 70 per cent of assets of Government bonds, and we finally select the corporate bond funds by further splitting them according to their investment grade. Source: Money Market and Investment Fund Return and authors calculations.



Fund loss

The fund loss (L_f) as a function of the change in the interest rate (Δ_{IR}), duration (MD_f) and convexity (C_f) is computed as:

$$L_f = -\left(-\Delta_{IR} \cdot MD_f + \frac{(\Delta_{IR})^2}{2} \cdot C_f\right) \cdot CP_f \quad (1)$$

Where CP_f is the fund closing position.

Convexity estimation model

Duration is the weighted average of discounted bond's future cash flows: it tells the investors how many years it will take the bond cash flows to repay the initial investment. Usually, to compare the sensitivity to the interest rate risk of bonds (or funds), we use the modified duration, which measures the change in bond price when the interest rate fluctuates. Modified duration approximates the variation in the bond price when a slight variation in the interest rate level occurs, and it depends on the bond's features. The second-order adjustment of convexity catches the curvature that characterizes the price-yield curve. Based on our data availability, we calibrate the convexity model to estimate convexity where there are missing values in the database as follows (estimates in Table A.1):

$$C_i = \alpha + \beta_1 DTM_i + \beta_2 CR_i + \beta_3 MD_i + \epsilon_i \quad (2)$$

where the regression model is calibrated by exploiting data for which we have full coverage on the maturity expressed in days (DTM_i), the coupon rate (CR_i), and the modified duration (MD_i). Maturity positively impacts the convexity estimation, and the coupon rate is negative. The modified duration positively impacts the convexity value: bonds with high duration tend to have high convexity.

	Convexity (C)
Const (α)	-55.59***
	(0.72)
DTM	0.0019***
	(6.98e-05)
CR	-0.44***
	(0.14)
MD	21.72***
	(0.08)
R-squared	0.77

Table A.1: A regression model is used to estimate convexity where there are missing values. The Table reports the estimated coefficients (standard errors in parenthesis) of the model on convexity (Eq.(2)). The convexity model is calibrated on 26,685 observations.

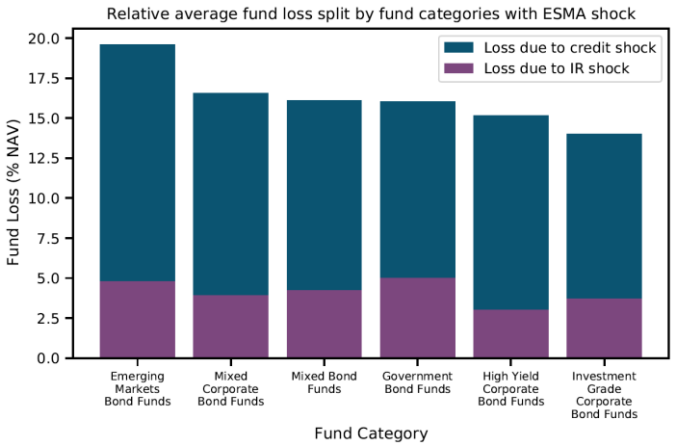
Results of the ESMA stress test, incorporating an interest rate and credit shock

This section reports the results (see Figure A.2) of the stress test model with interest rate and credit specific shocks. For each security we simulate the ESMA scenario which is composed of a country-specific interest rate shock and an investment grade-dependent credit shock. Hence, each security is perturbed by a specific shock depending on its origin and creditworthiness. This approach allows us to tailor the shock for each security according to the risks to which it is exposed. For example, the interest rate shock varies across countries with Japan having the lowest shock at 19 bps to Turkey with a shock of 191 bps. Across the credit shock, the size of the shock increases as the rating is reduced, ranging from 176 bps to 507 bps. We report the shock details in Tables A.2 and A.3 below. The credit shock is most impactful on the fund cohorts containing a higher portion of lower rated/speculative bonds, but this is somewhat offset for some cohorts by a lower interest rate result. [19] For example, High Yield Corporate Bond Funds hold more than 95 per cent of their portfolio in speculative bonds but is the second least affected cohort due to a lower interest shock. Mixed, Mixed Corporate and Emerging Market Bond Funds hold significant shares of their

[19] The effect of the credit shock may be underestimated for cohorts with a higher share of floating rate securities as the modified duration for a floating rate note resets at the coupon payment date, while the credit risk persists.

portfolios in lower rated bonds and as such are the cohorts with the largest reductions in NAV. The credit shock has less of an effect on Government and Investment Grade Corporate Bond Funds, as they hold higher rated bonds in their portfolios. However, Government Bond Funds are still very affected due to high modified duration with a resulting higher interest rate shock. Although the scenario itself is a simplification of what may happen in the markets, this analysis highlights the relative vulnerability of various fund cohorts due to the assets held in their portfolios.

Figure A.2: Emerging Market and Mixed Corporate Bond Funds are the biggest losers due to larger holdings of more speculative bonds in the ESMA stress test.



The interest rate shock ranges from 45 to 191, reflecting the geopolitical risk level. The size of the shock increases as the rating is reduced, ranging from 176 bps to 507 bps. Source: Money Market and Investment Fund Return, IHS Markit and CSDB data and authors' calculations. Note: we fill the NaN values of modified duration of the securities with the average modified duration of each fund cohort.

ESMA Shocks

Every year the European Systemic Risk Board (ESRB) in collaboration with the European Supervisory Authorities calibrate some adverse scenarios for the Money Market Fund (MMF) sector, European Securities and Markets Authority (2022). The scenarios aim to assess the resilience of financial institutions to adverse market conditions. Table A.2 reports the ESMA calibrated interest rate shocks (in basis points) to stress test the MMF sector. These shocks vary by country or region of the portfolio securities. Table A.3 reports the shocks to credit spread (in basis points). These shocks vary with the credit rating of the securities. The shock is imposed on the portfolios securities and reflects the interest rate and credit risk as a function of market risk and creditworthiness, respectively.

Geographic Area	Country	IR Shock
EU	Euro Area	68
EU	Bulgaria	68
EU	Croatia	68
EU	Czech Republic	68
EU	Denmark	68
EU	Hungary	85
EU	Poland	70
EU	Romania	88
EU	Sweden	49
Rest of Europe	United Kingdom	85
Rest of Europe	Iceland	
Rest of Europe	Norway	52
Rest of Europe	Russia	
Rest of Europe	Switzerland	45
Rest of Europe	Turkey	191
North America	Canada	74

North America	United States	97
Australia and Pacific	Australia	75
Australia and Pacific	New Zealand	
South and Central America	Brazil	
South and Central America	Chile	117
South and Central America	Colombia	115
South and Central America	Mexico	114
Asia	China	26
Asia	Hong Kong	92
Asia	India	
Asia	Japan	19
Asia	Korea	
Asia	Malaysia	60
Asia	Singapore	78
Asia	Thailand	
Africa	South Africa	68
EU	All countries	70
Other Adv Economies	All countries	62
Emerging Mkts	All countries	96

Table A.2: Interest rate shocks vary by country or region. Shocks to interest rate swap rates in basis point as proposed by the ESRB in collaboration with ESMA to conduct stress tests to assess the resilience of financial institutions. The shocks depend on the security's country or geographical area to represent various interest rate risk levels.

Investment Grade	Credit Shock
AAA	176
AA	201
A	231
BBB	302
BB	349
B	428
<=CCC	507

Table A.3: Credit shocks vary with rating Shocks to credit yields in basis point proposed by the ESRB in collaboration with ESMA to conduct stress tests to assess the resilience of financial institutions. The shocks depend on the security creditworthiness and they are split by the investment grade categories considered by the ESRB.

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