Research Institute

May 2024

Convexity and prepayment risk

How the price and yield relationship is impacted for issuer callable bonds

Jason Chen
Senior Research Analyst, DWS Research Institute

James Kole
Portfolio Manager-Fixed Income Solutions, Insurance

IN A NUTSHELL

- Bonds, particularly longer duration bonds, demonstrate non-linear sensitivity between prices and changes in yields. This change in duration or interest rate sensitivity is most commonly referred to as convexity.
- While traditional non-callable fixed income securities such as US Treasuries demonstrate positive convexity, where the price sensitivity increases and yields fall and vice versa, callable bonds demonstrate negative convexity where price sensitivity to rising yields can increase.
- For fixed income investors who allocate to asset classes with issuer or borrower callability, negative convexity can compound price risks, as duration can extend simultaneously with rising yields, resulting in a larger negative effect on prices and returns.
- Elevated levels of interest rate or credit spread volatility can also amplify price risks around negatively convex bonds, as the empirical or implied risk of a larger move in yields—and corresponding decline in prices—is increased.
- Selloffs in both short-term and longer-term bond yields has resulted in elevated convexity risks around mortgages and other callable bond asset classes, with higher base level yields, elevated rate and spread volatility, and the potential for rates and spreads to become more positively correlated relative to the previous decade.

Introduction

Following historically low interest rates reached during the COVID-19 crisis, upward price pressures forced global central banks to adopt more restrictive monetary policy in an effort to calm inflationary fears. Coordinated monetary policy that both increased short-term funding rates and gradually reduced central bank balance sheet sizes put pressure on the entire US sovereign yield curve, resulting in a historically fast repricing in medium-to-long-term US Treasury yields between 2021 and 2023. The magnitude and pace of these interest rate moves brought to light the significant impact of interest rate duration and convexity that can, in some cases, amplify the sensitivity of bond prices to moves in interest rates.

The move higher in US Treasury yields was a double-edged sword for fixed income investors. Longer duration portfolio holdings in particular experienced significant negative mark-to-market returns; however, this higher interest rate environment has been the first time since the Global Financial Crisis ("GFC")—and the introduction of Quantitative Easing ("QE")—that long-duration bond investors have been able to attain any meaningful yield in fixed income, either via reinvestment or through allocation of new capital. Mortgage bonds and other negatively convex fixed income asset classes were particularly problematic as they experienced duration extension that amplified the negative returns as a result of the back up in interest rates.

Going forward, investors may benefit from a more thoughtful approach to managing interest rate and credit spread duration particularly for callable bond holdings. Understanding the potential impact of negative convexity in a more normalized interest rate environment may serve as an important risk management component of fixed income portfolio risk management.

1 / What impacts the bond price?

1.1 Bond price sensitivity

For large segments of the core fixed income market, the relationship between the bond price and its yield is positively convex, meaning that as yields move lower—and bond prices move higher, the rate at which the price increases as a function of the yield declining also increases. This can be demonstrated by looking at the simple formula for pricing a bond (see Figure 1), which calculates the bond price as a function of three main components:

1. Time (the tenor or difference between settlement and maturity dates as well as the coupon payment frequency)
2. Bond Payments (the current coupon and current price of the bond)
3. Discount Rate (the current market yield)

Figure 1: Bond price as a function of yield

$$\text{Bond Price Formula} = \sum \frac{C_n}{(1+YTM)^n} + \frac{P}{(1+i)^n}$$

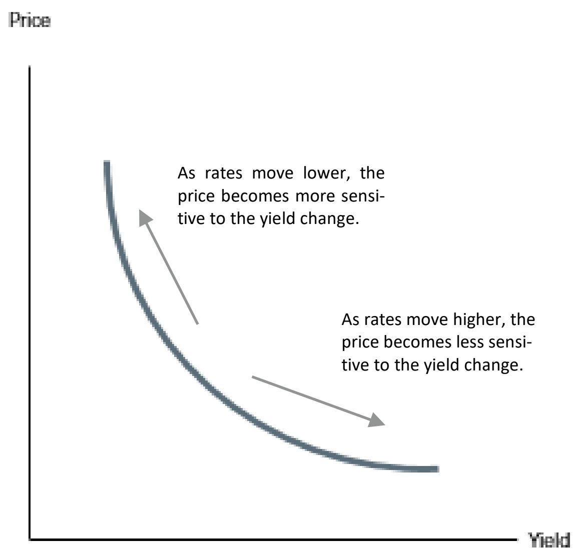
$$\text{Coupon Bond Price} = \frac{1-(1+r/n)^{-n*t}}{r/n} + \frac{F}{(1+r/n)^{-n*t}}$$

$$\text{Zero Coupon Bond Price} = \frac{F}{(1+r/n)^{-n*t}}$$

Source: EDUCBA.

Figure 2 illustrates how this formula translates changes in the yield to changes in the bond price all else equal. As the figure illustrates, the change in the price will increase as yields move lower and decrease as yields move higher, which creates an advantageous asymmetry for price returns as a function of changes in yields.

Figure 2: Positive convexity: the relationship between price and yield for non-callable bonds



Source: DWS Investment Management GmbH.

This information is subject to change at any time, based upon economic, market and other considerations and should not be construed as a recommendation. Forecasts are based on assumptions, estimates, opinions and hypothetical models that may prove to be incorrect. Source: DWS Investment Management GmbH.

The rate of change in the duration proportionate to the price paid for the bond is also a useful metric for bond investors when deciding between lower coupon, discounted bonds and higher coupon, higher priced bonds. At equivalent yields, discounted bonds can exhibit much steeper convexity of duration, which can be a desirable characteristic for investors with strong views on potential interest rate or yield rallies.

For a hypothetical non-callable fixed coupon bond issued at par, the present value of the future coupon and principal payments will depend on the changes in the variables:

1. More time (or longer tenor) will increase the sensitivity of the bond price to changes in the other variables.
2. The principal and interest payments, absent a default or restructuring, remain the same.
3. Increases in interest rates or market yields inversely affects the price in a non-linear way – the change in the denominator has a base effect.

We can demonstrate this in the below Table 1, which shows the change in the price of a bond for a given 1% move higher or lower in the interest rate, respectively, at different starting interest rate levels. As Table 1 illustrates, for rising yields, the rate of price decline proportionate to the change in the interest rate declines whereas for falling yields, the rate of price increase proportionate to the change in the interest rate increases. Additionally, this convex relationship between price and yield is more pronounced for longer tenor, longer duration bonds.

Table 1: **Price return as a function of change in yield and tenor**

	Tenor (years)					Tenor (years)			
Yield change (%)	30yr	20yr	10yr	5yr	Yield change (%)	30yr	20yr	10yr	5yr
from 1% to 2%	-17.7%	-13.4%	-7.9%	-4.4%	from 2% to 1%	21.5%	15.5%	8.6%	4.6%
from 2% to 3%	-16.8%	-13.0%	-7.8%	-4.4%	from 3% to 2%	20.1%	14.9%	8.4%	4.6%
from 3% to 4%	-15.8%	-12.5%	-7.7%	-4.3%	from 4% to 3%	18.7%	14.3%	8.3%	4.5%
from 4% to 5%	-14.8%	-12.0%	-7.6%	-4.3%	from 5% to 4%	17.4%	13.7%	8.2%	4.5%
from 5% to 6%	-13.8%	-11.6%	-7.4%	-4.3%	from 6% to 5%	16.1%	13.1%	8.0%	4.5%
from 6% to 7%	-12.9%	-11.1%	-7.3%	-4.2%	from 7% to 6%	14.8%	12.5%	7.9%	4.4%
from 7% to 8%	-12.0%	-10.6%	-7.2%	-4.2%	from 8% to 7%	13.6%	11.9%	7.8%	4.4%
from 8% to 9%	-11.1%	-10.1%	-7.1%	-4.2%	from 9% to 8%	12.5%	11.3%	7.6%	4.3%
from 9% to 10%	-10.3%	-9.6%	-6.9%	-4.1%	from 10% to 9%	11.5%	10.7%	7.5%	4.3%
from 10% to 11%	-9.5%	-9.2%	-6.8%	-4.1%	from 11% to 10%	10.5%	10.1%	7.3%	4.3%
from 11% to 12%	-8.8%	-8.7%	-6.7%	-4.1%	from 12% to 11%	9.7%	9.6%	7.2%	4.2%
from 12% to 13%	-8.2%	-8.3%	-6.6%	-4.0%	from 13% to 12%	8.9%	9.0%	7.0%	4.2%
from 13% to 14%	-7.6%	-7.9%	-6.4%	-4.0%	from 14% to 13%	8.3%	8.5%	6.9%	4.2%
from 14% to 15%	-7.1%	-7.4%	-6.3%	-4.0%	from 15% to 14%	7.7%	8.0%	6.7%	4.1%

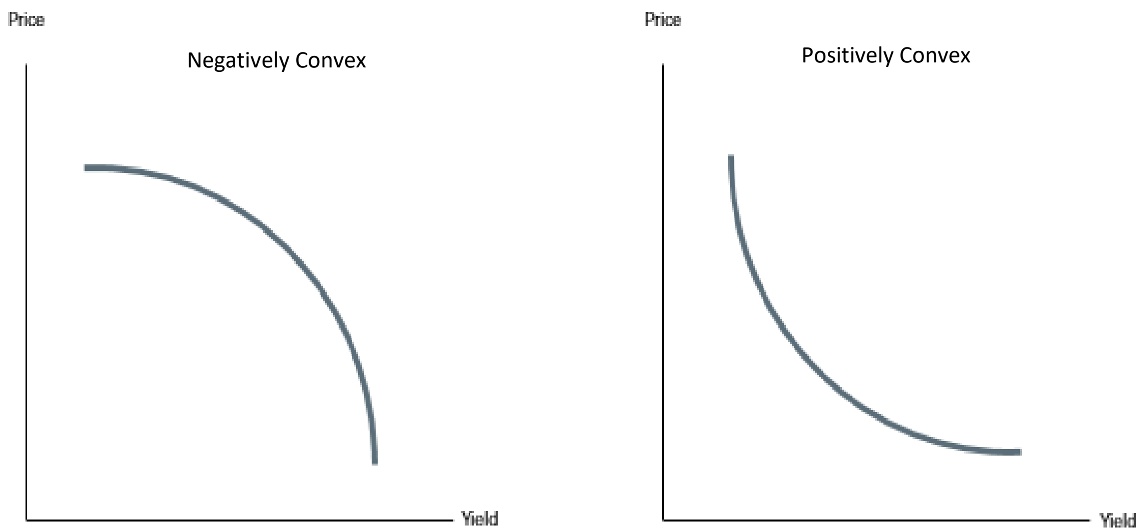
Source: DWS Investment Management GmbH calculations. For illustrative purposes only.
*Assumptions are semi-annual coupon payments, 5% annual coupon redeemable at par value $100.

2 / What impacts convexity?

2.1 Negative convexity and callability

Negative convexity, or concavity, refers to a bond with an inverse relationship between price and yield. As yields move lower, the rate of change (price appreciation) of the price relative to the yield will decrease and conversely, as yields move higher, the rate of change (price depreciation) of the price relative to the yield will increase. This is, all else equal, disadvantageous to an investor as their price participation for moves in the yield, especially more outsized moves in the yield, will be asymmetrically negative. Figure 3 illustrates the conceptual relationship between price and yield for negatively versus positively convex bonds.

Figure 3: **Price and yield relationship for positively and negatively convex bonds**



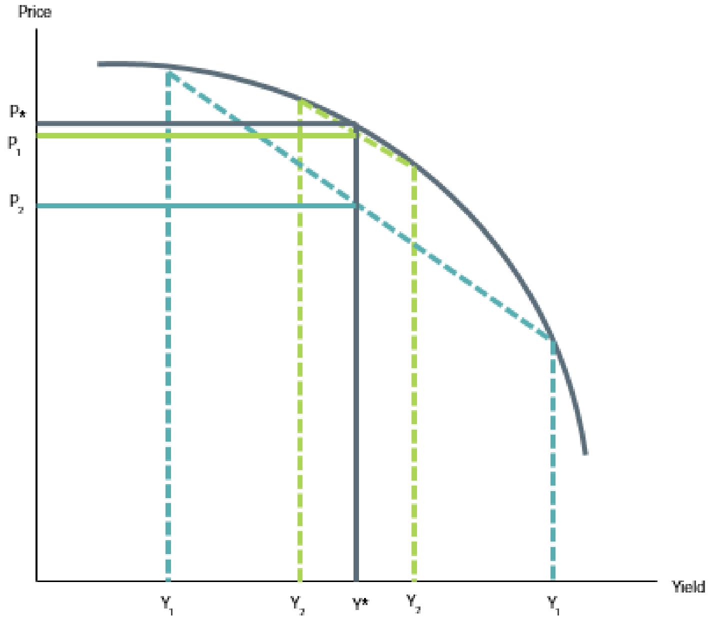
Source: DWS Investment Management GmbH.

The reason for this negative convexity is based on the probabilistic outcomes of the bond and are influenced by the optionality of the borrower to prepay the loan amount. Should yields fall, the borrower is likely to repay the loan and refinance to a lower market rate. Should yields rise, the likelihood of the borrower repaying the loan before the maturity date decreases significantly. In effect, by purchasing a bond where the borrower retains this optionality, an investor is short a call option and must therefore be compensated for the likelihood of a yield change influencing the price or duration of the bond.

2.2 Convexity and volatility

For investors in callable bond asset classes, one of the most important variables for the value of the issuer call optionality is the volatility around the yield or interest rate. As with any option, greater volatility in the price or yield will result in more uncertainty and a greater likelihood of a larger move. Parties who are long this optionality benefit from higher volatility whereas sellers of this optionality (in this case, the buyer of the callable bond) are implicitly short this optionality and must be compensated accordingly. Figure 4 shows how the fair market price of the bond will be lower for more volatile yields, with Y1 and P1 representing more volatility yield distributions and Y2 and P2 representing less volatility yield distributions. The fair price of the more volatile yield P2 is lower than the fair price of the less volatile yield P1 to reflect the greater prepayment uncertainty that the investors in P2 assumes. For a given level in yield, a higher volatility (shown as the teal lines labelled P2) would justify a lower fair bond price to compensate for the optionality that is afforded to the mortgage borrower.

Figure 4: **Impact of volatility/uncertainty on fair bond price for negatively convex bonds**



Source: DWS Investment Management GmbH.

As previously mentioned, bond asset classes that contain issuer callability provisions are subject to this inverted price/yield relationship. Table 2 shows a high-level overview of some of the major fixed income asset classes that exhibit negatively convex price behavior.

Table 2: **Bond asset classes with issuer callability**

Asset class	Description
Corporate Bonds	Since the global financial crisis, the share of callable bonds as a percentage of the corporate debt universe has steadily increased, with the share of callable bonds growing to nearly 90% of new corporate bond issuance as recently as 2020[1].
Asset-Backed Securities	Sectors of ABS such as credit cards and auto loans may differ in their prepayment experience. Where credit cards do not have prepayment options, auto loans that do possess prepayment optionality but are often not exercised as vehicle residual values decline relatively quickly and auto loans are typically shorter in duration[2].
Municipal Bonds	Municipal bonds are typically issued with an optional redemption date or "call date" approximately 10 years from the date of issuance. Bonds are commonly issued at higher coupons of 4, 5, or 6% to increase interest among investors for tax-advantaged cash flows. As a result, in lower interest rate environments, these higher coupon bonds are often issued at a premium, and the majority of municipal bonds can be called at par ahead of their maturity date.
Mortgage-Backed Securities	More than 95% of U.S. residential mortgage borrowers (or homeowners who finance through debt) borrow at fixed interest rates, and more than three-quarters of those mortgages are for 30-year terms[3], meaning that the MBS market tends to be very long tenor. In environments of falling interest rates, mortgage borrowers will often refinance at lower interest rates, prepaying their longer-duration mortgages. The refinancing rate will also depend on the economics of refinancing, depending on the size of the mortgage and the frictional costs associated with refinancing the loan.

Source: DWS Investment Management GmbH as of 3/31/2024.

[1] Becker, B., Campello, M., Thell, V. & Yan, D. Credit risk, debt overhang, and the life cycle of callable bonds. Review of Finance (2024).
[2] Johnson, J. Auto Asset-Backed Securities (Auto ABS) Primer. National Association of Insurance Commissions & The Center for Insurance Policy and Research (2018).
[3] Casselman, B. A 30-Year Trap: The Problem With America's Weird Mortgages. The New York Times (2023).

3 / Mortgage-backed securities

3.1 Negative convexity for mortgages

Negative convexity, or concavity, exists for all callable fixed income asset classes. However, negative convexity is most pronounced in mortgage-backed securities ("MBS"). Unlike non-callable bonds, MBS bonds will shorten their maturity date (get called) when interest rates fall as the borrower can refinance their mortgages at lower interest rates. Conversely, MBS bonds will extend their duration when interest rates rise as the borrower is incentivized to hold the below market mortgage interest rate as long as possible.

As yields and durations are estimated based on the probable path of principal and interest payments from the mortgage borrower, the sensitivity of the bond's duration to the change in interest rates will reflect an increasing likelihood of borrower prepayment (to refinance a mortgage or to sell their home) as interest rates fall. The likelihood of the loan being called by the issuer will impact the yield/price relationship, and the magnitude of negative convexity for an MBS bond depends on several factors, a few notable ones being:

- Interest volatility: as rate volatility rises the chances of the option being exercised over the life of the loan rises.
- Size of loan: the larger the loan the more sensitive the borrower will be to changes in interest rates. i.e. the more the borrower has to gain from refinancing into a lower rate mortgage and the more the borrower has to lose by calling the debt early.
- Frictional costs: the greater the upfront cost to refinance, the less likely the borrower is to do so. The-upfront costs associated with refinancing a mortgage vary depending on factors including the credit quality of the borrower, downpayment size/loan-to-value of the existing loan, purpose of the mortgage as well as taxes and fees which can vary widely based on geographical location. (e.g. NY borrowers can incur an additional 2-2.5% fee on their refinancing costs vs other states)
- Origination channel (retail, correspondent or broker)
- WACs (actual weighted average mortgage rate of a particular pool of mortgages) – GSE's allow up to 100 bps of room for securitizations of loans for specific coupons, i.e. a mortgage pool could have a WAC of 6.45% or 7% and still have a passthrough coupon of 6%. Obviously the pool with a 6.45 WAC would prepay slower than a pool with a 7% WAC.
- Seasoning (age of the loan). Borrowers that have been in their homes for a long time are more likely to move or be motivated to take cash out of their homes. Alternatively, borrowers that just moved into their homes are less likely to move and some states have restrictions on refinances if a borrower just did a cash out refinance (e.g. Texas doesn't allow GSE's to re-securitize loans of borrowers that have done a cash out refinance within the previous 12 months)
- Loan purpose (purchase, refinance, cash out)

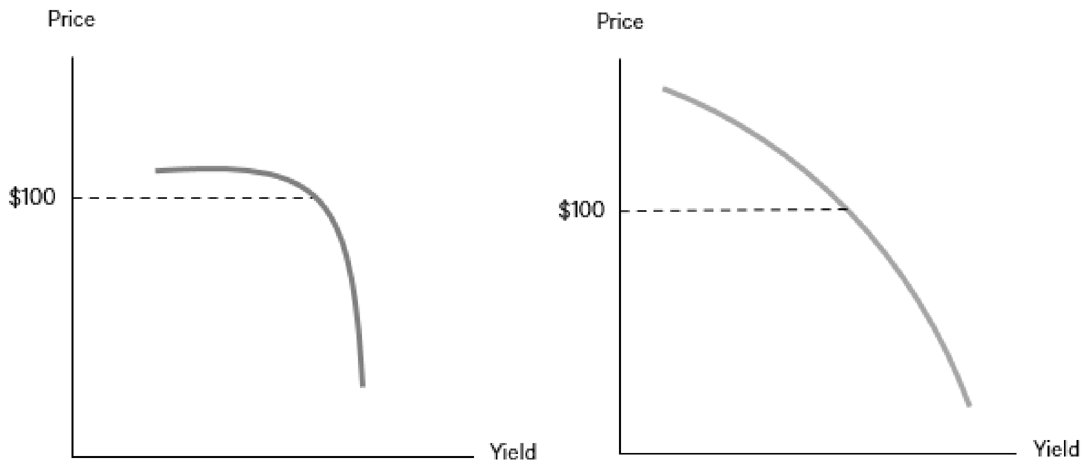
MBS investors are effectively short the prepayment optionality of the mortgage borrower and as a result demand compensation to take on this additional risk. This additional compensation is estimated as the option cost generated by mortgage prepayment models. MBS prepayment models will generate a nominal spread (z spread), option cost and option adjusted spread (OAS) for a given dollar price. The OAS is simply the nominal spread minus the option cost, which means that the higher the option cost (the more negatively convex a bond is), the more nominal spread (lower dollar price) the investor will demand from the seller to compensate for that risk. The OAS output is essentially what the model expects an investor would retain after hedging out all of the optionality of the bond. As a result of this methodology, MBS bonds are typically compared and valued based off of their OAS spreads.

3.2 Comparing convexity for mortgages with different terms

In our illustration in Figure 3, we demonstrated that higher volatility (and a wider implied range of outcomes) would justify a lower bond price, which we can express as a function of the volatility. In addition to interest rate volatility, the aforementioned factors may influence the convexity of a bond as well. For example, in the jumbo loan space, bonds will rarely trade above par value, as jumbo loan borrowers are far more likely to refinance their terms as the economics make sense even at modestly lower interest rate levels. Conversely, smaller loan amounts will exhibit much less prepayment sensitivity as the frictional costs of the loan may exceed the refinancing benefits at smaller amounts and smaller mortgages have empirically demonstrated less elasticity to changes in mortgage rates.

In Figure 5, we can illustrate conceptually how two bonds with different characteristics will exhibit different degrees of option value and therefore different degrees of negative convexity. The conditions for the first bond, which demonstrates significant negative convexity, would be associated with significant and immediate refinancing or call risk as yields fall below the mortgage rate and the bond price exceeds par value. The characteristics of this bond would likely lean toward larger mortgage sizes with relatively small frictional costs relative to savings associated with refinancing. Thus, the prepayment optionality and the associated steep negative convexity would require greater investor compensation as reflecting in the fair price. Conversely, in the right chart, a mortgage bond that is perhaps a smaller loan size and has much higher proportional frictional refinancing costs might demonstrate a far lower prepayment probability and correspondingly demonstrate much less extreme convexity.

Figure 5: Bonds with different characteristics will exhibit differ degrees of convexity



Source: DWS Investment Management GmbH.

Other complexities may also create dispersion among mortgages that demonstrate otherwise similar characteristics. While smaller loan sizes in general may require more outsized moves in mortgages rates to justify the economics of refinancing (call protection), those same mortgage borrowers typically experience higher natural turnover as they are more likely to upsize their homes or migrate to other locations. The forfeiture of their current low mortgage rate is less painful because the balance of their loans is sufficiently small that it won't prohibit natural turnover.

In the current market environment where many mortgages trade at significant discounts (having been issued at much lower rates than we currently observe), the likelihood of refinancing is de minimis, so natural turnover is the principle driver of prepayment speeds (~95% of outstanding mortgages are at least 100 bps out of the money). Unlike low loan balance borrowers, jumbo borrowers are currently exhibiting historically low natural turnover as they are "locked-in" to their homes as many of their current mortgage rates are 350-450 basis points out of the money, and their outstanding mortgage balances are $400k-1.5mm. The forfeiture of these low mortgage rates would equate to adding hundreds of thousands of dollars in interest costs if they were to move and reset their mortgage at current interest rate levels. While mortgage models have always incorporated this reality into their projections, mortgage models perhaps don't yet fully reflect the historic lock-in that we are seeing today.

4 / Conclusion

After nearly a decade and a half of supportive monetary policy that kept interest rates low and interest volatility suppressed, markets have had to readjust to a new macroeconomic regime. Among other fixed income-related risks, the potential adverse impacts of negative convexity have again become front and center for fixed income investors. Unlike the extension trouble that we saw in the run up of rates that contributed to the demise of SVB and other regional banks, call risk is now becoming the predominate concern for callable bond investors.

Furthermore, negative convexity for mortgage-backed securities specifically has worsened considerably due to secular changes we've seen within the housing market over the last several years. As home prices, and consequently mortgage sizes, have increased in recent years, borrowers' sensitivity to mortgage rates has also increased dramatically. The weighted average loan size of a generic MBS pool has grown over $200,000 over the last five (from $320,000 to over $520,000). As a result of this massive increase, borrowers have a greater economic incentive to refinance their mortgage after even small movements in prevailing mortgages rates (25 bps today vs 50 bps in the past). In addition to home price appreciation, the mortgage lending landscape has also morphed dramatically over the last 5 years. Non-bank servicers now make up the majority of mortgage originations today, with over 40% being originated by Rocket, United and Penny Mac alone. The non-bank servicers are far more efficient at getting their borrowers to refinance vs the banks that used to dominate the space in the past. These combined changes have resulted in the generic new production pools or worst-to-deliver pools exhibiting the worst negative convexity in the history of our space.

While the most severe repricing in interest rates is likely behind us, structural shifts in the fixed income market has increased complexities within and across callable fixed income asset classes. In a post-QE liquidity environment, the directionality of interest rates as well as the elevated interest rate volatility environment introduce higher degrees of risk and uncertainty for callable bonds, and managing these risks in fixed income portfolios reinforces a need for a thoughtful approach to risk management. Nuanced shifts in the market structure for mortgage bonds has also necessitated deeper understanding of the risk exposures within mortgage pools and the more idiosyncratic issuer optionality risks that might be associated with those bonds. By understanding the macroeconomic implications of a less certain yield curve environment, the potential impact of interest rate volatility on bond convexity for callable (and non-callable) bonds, and the security or asset class-level optionality throughout their bond portfolios, investors can more precisely target the portfolio return and risk exposures that align with their investment views.

Important information – EMEA, APAC, LATAM & MENA

Important information – North America

The brand DWS represents DWS Group GmbH & Co. KGaA and any of its subsidiaries, such as DWS Distributors, Inc., which offers investment products, or DWS Investment Management Americas Inc. and RREEF America L.L.C., which offer advisory services.

The opinions and forecasts expressed are those of the speakers and may not come to pass.

Diversification does not eliminate the risk of experiencing investment losses.

All investments involve risks, including the potential loss of principal.

Investment products: No bank guarantee I Not FDIC insured I May lose value

DWS is the brand name of DWS Group GmbH & Co. KGaA and its subsidiaries under which they do business. The DWS legal entities offering products or services are specified in the relevant documentation. DWS, through DWS Group GmbH & Co. KGaA, its affiliated companies and its officers and employees (collectively "DWS") are communicating this document in good faith and on the following basis.

This document is for information/discussion purposes only and does not constitute an offer, recommendation or solicitation to conclude a transaction and should not be treated as investment advice.

This document is intended to be a marketing communication, not a financial analysis. Accordingly, it may not comply with legal obligations requiring the impartiality of financial analysis or prohibiting trading prior to the publication of a financial analysis.

This document contains forward looking statements. Forward looking statements include, but are not limited to assumptions, estimates, projections, opinions, models and hypothetical performance analysis. No representation or warranty is made by DWS as to the reasonableness or completeness of such forward looking statements.

Past performance is no guarantee of future results.

The information contained in this document is obtained from sources believed to be reliable. DWS does not guarantee the accuracy, completeness or fairness of such information. All third party data is copyrighted by and proprietary to the provider. DWS has no obligation to update, modify or amend this document or to otherwise notify he recipient in the event that any matter stated herein, or any opinion, projection, forecast or estimate set forth herein, changes or subsequently becomes inaccurate.

Investments are subject to various risks. Detailed information on risks is contained in the relevant offering document.

No liability for any error or omission is accepted by DWS. Opinions and estimates may be changed without notice and involve a number of assumptions which may not prove valid.

DWS does not give taxation or legal advice. This document may not be reproduced or circulated without DWS's written authority.

This document is not directed to, or intended for distribution to or use by, any person or entity who is a citizen or resident of or located in any locality, state, country or other jurisdiction, including the United States, where such distribution, publication, availability or use would be contrary to law or regulation or which would subject DWS to any registration or licensing requirement within such jurisdiction not currently met within such jurisdiction. Persons into whose possession this document may come are required to inform themselves of, and to observe, such restrictions.

War, terrorism, sanctions, economic uncertainty, trade disputes, public health crises and related geopolitical events have led, and, in the future, may lead to significant disruptions in US and world economies and markets, which may lead to increased market volatility and may have significant adverse effects on the fund and its investments.

For investors in Bermuda:
This is not an offering of securities or interests in any product. Such securities may be offered or sold in Bermuda only in compliance with the provisions of the Investment Business Act of 2003 of Bermuda which regulates the sale of securities in Bermuda. Additionally, non-Bermudian persons (including companies) may not carry on or engage in any trade or business in Bermuda unless such persons are permitted to do so under applicable Bermuda legislation.

For Investors in Canada. **No securities commission or similar authority in Canada has reviewed or in any way passed upon this document or the merits of the securities described herein and any representation to the contrary is an offence.** This document is intended for discussion purposes only and does not create any legally binding obligations on the part of DWS Group. Without limitation, this document does not constitute an offer, an invitation to offer or a recommendation to enter into any transaction. When making an investment decision, you should rely solely on the final documentation relating to the transaction and not the summary contained herein. DWS Group is not acting as your financial adviser or in any other fiduciary capacity with respect to this proposed transaction. The transaction(s) or products(s) mentioned herein may not be appropriate for all investors and before entering into any transaction you should take steps to ensure that you fully understand the transaction and have made an independent assessment of the appropriateness of the transaction in the light of your own objectives and circumstances, including the possible risks and benefits of entering into such transaction. You should also consider seeking advice from your own advisers in making this assessment. If you decide to enter into a transaction with DWS Group you do so in reliance on your own judgment. The information contained in this document is based on material we believe to be reliable; however, we do not represent that it is accurate, current, complete, or error free. Assumptions, estimates and opinions contained in this document constitute our judgment as of the date of the document and are subject to change without notice. Any projections are based on a number of assumptions as to market conditions and there can be no guarantee that any projected results will be achieved. Past performance is not a guarantee of future results. The distribution of this document and availability of these products and services in certain jurisdictions may be restricted by law. You may not distribute this document, in whole or in part, without our express written permission. For Institutional Use and Registered Rep Use Only. Not for Public Viewing or Distribution.