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Negative convexity in municipal bonds: The new rate regime and active management

- A prolonged low interest rate environment in the 2010s led to the creation of a diverse coupon stack in the municipal bond market, including 2%, 3%, and 4% coupon bonds—a new phenomenon for a market that for years had issued predominantly 5% coupon bonds.
- In 2022—a year in which the Federal Reserve aggressively raised rates to combat inflation—many of these lower-coupon callable municipal bonds experienced price declines as the impact of negative convexity emerged.
- Active managers who are navigating this higher rate environment benefit from understanding how to prudently manage negative convexity risk. The diversity of the current coupon stack provides a historically unique lever for actively managing convexity risk.

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For roughly 10 years after the global financial crisis (GFC), negative convexity was of little practical concern to investors in the municipal bond market. The Federal Reserve's active yield curve control kept rates low, and investors sought ways to enhance low returns. In the muni (municipal bond) market, this manifested itself in a new willingness by investors to accept lower-coupon bonds in exchange for a better yield. The catch: These bonds would be more vulnerable to a hiking cycle of interest rates. And in 2022, when the Fed raised the federal funds rate by 425 basis points in response to inflationary pressures, these bonds did experience more significant price declines because of negative convexity. (A basis point is one-hundredth of a percentage point.)

In this paper, we review this period from the viewpoint of active muni investors. In doing so, we examine how the proliferation of the diverse coupon stack in the muni market paved the way for the current environment, in which the impact of negative convexity has moved front and center in active muni investing.

A short refresher on negative convexity

This section examines the mechanics of convexity in muni bonds. Experienced practitioners may skip to the next section, "Premium bonds in the muni market," without losing any context.

The price of a bond with respect to its yield is inherently nonlinear; convexity describes the extent and direction of this nonlinearity. Bonds with call provisions—an option that the issuer can use to call (pay off) the bond, if it is advantageous—exhibit negative convexity, where the nonlinearity works against the investor.[1] Specifically, with negative convexity, the duration of the bond lengthens as interest rates rise, amplifying losses, and shortens as interest rates fall, muting gains. In the muni market, most bonds are callable and therefore have embedded negative convexity.[2]

1 Mortgages are among the best-known debt instruments with negative convexity.

2 For additional context on the prevalence of callable bonds in the muni market, see the **Appendix**.

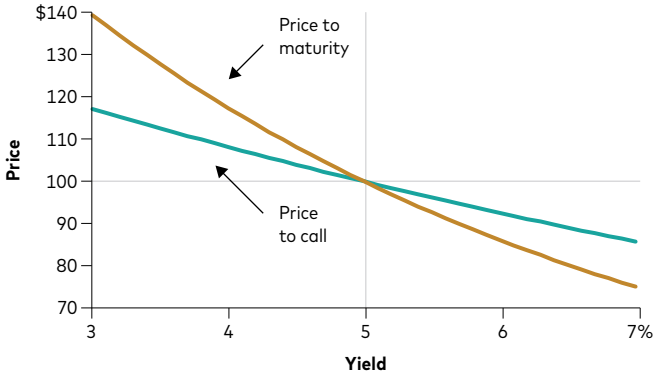
Negative convexity may be intuitively understood as a byproduct of the call option that, if exercised, changes the duration (usually dramatically). Consider a typical muni bond that has a 5% coupon and a 30-year final maturity and is callable at the 10-year mark—that is, the issuer has the right to purchase the bond at par 10 years after issuance. In muni parlance, this bond is said to be NC-10, or noncallable for the first 10 years.

First, let us assume that the issuer will exercise the option on the call date in every circumstance. This would give rise to the turquoise yield/price curve in **Figure 1**. The slope of this curve (i.e., duration) is relatively flat, because investors receive their payments sooner (by the end of the 10th year). In contrast, if we assume the issuer plans never to exercise the option and would rather service the debt until maturity, we obtain the yellow yield/price curve, which has a steeper slope.

Of course, neither of these assumptions is realistic. If the issuer is rational, it will exercise the call, but only if it is in-the-money when the prevailing yield is lower than the 5% coupon (as it would enable the issuer to refinance the bond and save on interest expenses) at the 10-year mark. On the other hand, if the bond is valued at a discount after 10 years, the call option is out-of-the-money and the issuer will not exercise the option.[3] Accordingly, as shown in **Figure 2**, the bond is priced to call when it is trading at a premium (yield is less than coupon) and priced to maturity when it is trading at a discount (yield is greater than coupon). At par, when the call is at-the-money, the slope of the curve gets less steep as the yield falls (transitioning from out-of-the-money to in-the-money) and the duration shortens—this is the defining characteristic of negative convexity.

FIGURE 1

Yield/price curves for NC-10 30-year 5% coupon

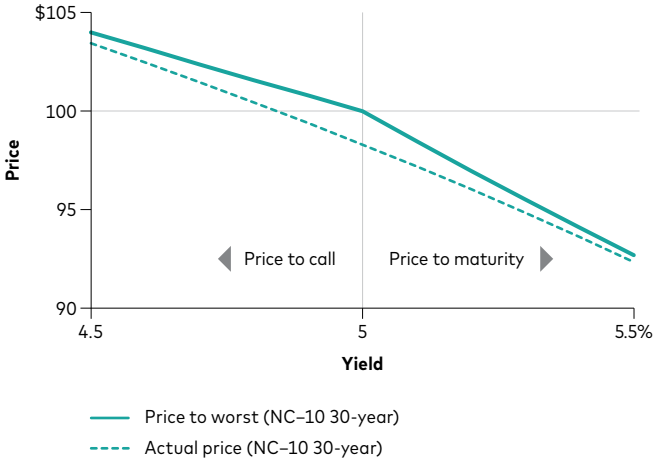


Notes: The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

FIGURE 2

Yield/price curve for NC-10 30-year 5% coupon with binary option



Notes: "Price to worst" represents the price of the bond assuming the bond is called by the issuer if it is in-the-money 10 years after issuance. The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

3 A bond with a par call is "in-the-money" when the prevailing yield is lower than the coupon; alternatively, it is "out-of-the-money" when the prevailing yield is higher than the coupon. A bond whose coupon matches the yield is referred to as "at-the-money."

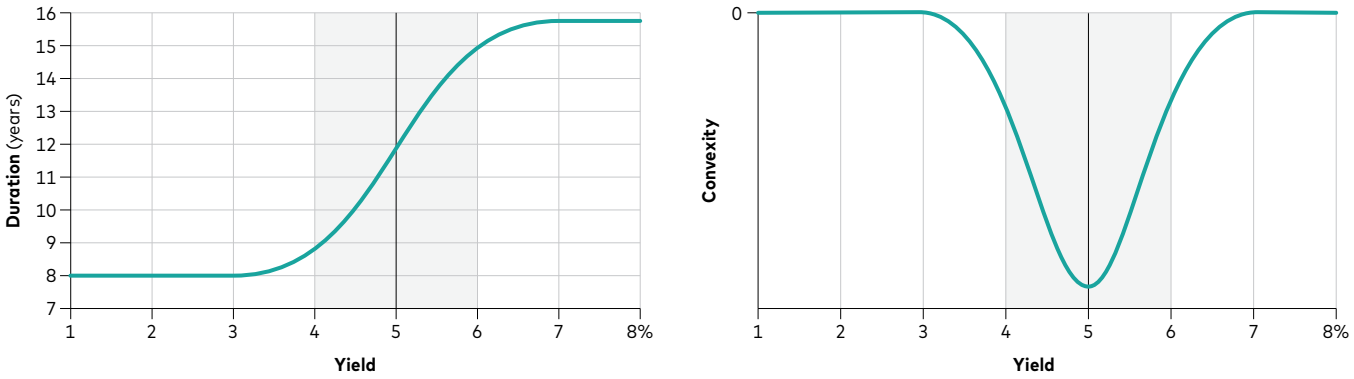
In practice, the actual market price would behave like the dotted curve in Figure 2, which is a smoothed version of the price-to-worst curve. The market tends to price in a greater probability of the call being exercised as the yield falls, causing the duration to shorten continuously (as opposed to shortening at the kink only).

Figure 3 shows how duration and convexity change over a wide range of the yield vis-à-vis the 5% coupon. When the yield is sufficiently lower than the coupon (e.g., below 3%), the market effectively prices in a 100% probability of the call, resulting in the shortest possible duration, 8 years. By contrast, when the yield is in the high single digits (e.g., above 7%), the market prices in effectively 0% probability of the call, resulting in the longest possible duration, 16 years.

Figure 3 also plots the convexity of the curve. The bond is most negatively convex when it is near par because this is when the duration is changing the quickest, reflecting the roughly even chance that the bond will be called. When the bond is either deep in-the-money or deep out-of-the-money, convexity is muted, since changes in yields have smaller effects on the probability that the bond will be called.

FIGURE 3

Negative convexity for NC-10 30-year 5% coupon is most pronounced at 5% yield



Notes: The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

Premium bonds in the muni market

In the decade following the GFC, negative convexity was not a top concern for investors. In part because of the ultra-low-yield environment, most bonds (mostly with 5% coupons) were trading at substantial premiums and were largely priced to call. At the same time, this prevalence of premium bonds also reflected a more timeless, deep-seated preference for premium bonds on both sides of the muni market.

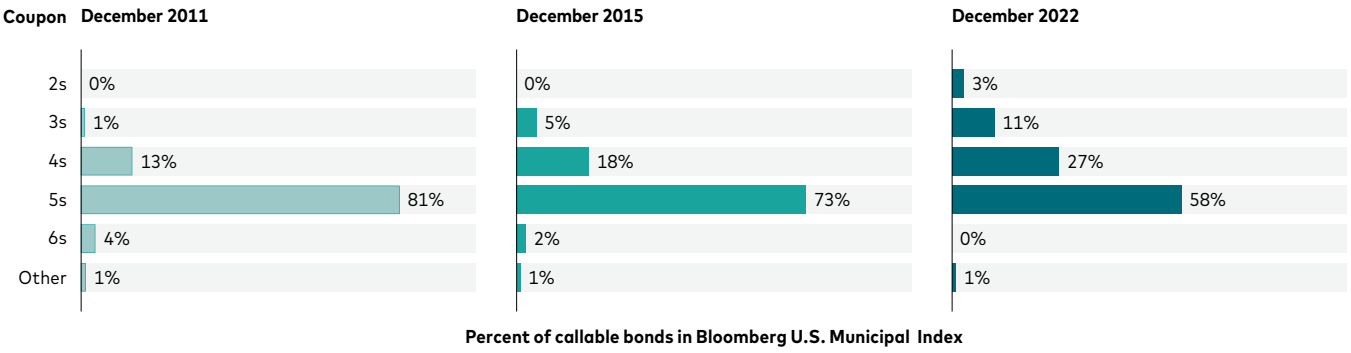
On the demand side, especially among institutional investors, there is a general aversion to owning discount bonds because they run a higher risk of triggering "de minimis" risk and adverse price impact because of the tax treatment peculiarity in the muni bond market.[4] On the supply side, issuers of muni bonds typically require voter approval to authorize a bond issuance—a process that may subject the face value of the bond to statutory limits.

This creates a dynamic where some municipal bond issuers come to the market with a higher coupon rate, pricing the bond at a premium and maximizing the proceeds from the issuance. The most common choice for the coupon rate is 5% ("5s"), which for most of the post-GFC period was in excess of prevailing yields. This practice of issuing premium bonds was so prevalent that the standard benchmark yield curves for the muni market are constructed using 5s.

The primacy of 5s, however, waned as the post-GFC decade wore on. The Fed's accommodative stance set the tone for the decade following the GFC and ushered in an era of low interest rates. In low interest rate environments, investors tend to get creative to enhance their returns.[5] In the muni market, this manifested in more bonds being issued with coupons lower than 5%. **Figure 4** shows that, while more than 85% of muni bonds in the callable universe were 5s and above in 2011, this share shrank to 75% by 2015 and to 58% by 2022.

FIGURE 4

The coupon stack becomes increasingly diversified



Notes: Callable bonds in the Bloomberg U.S. Municipal Index on three dates—December 31, 2011, December 31, 2015, and December 31, 2022—are included. This excludes noncallable bonds, approximately 25%–40% of the index depending on the period.

Sources: Vanguard calculations, using data from Bloomberg.

4 In the muni market, when a bond reaches its de minimis threshold (meaning the discount on the bond is no longer de minimis), its price generally falls below the level implied by the yield/price curve. This is because the accretion on this discount bond is now taxable at the ordinary income tax rate—rather than the (lower) long-term capital gains tax rate that muni investors commonly use to compute a tax-equivalent yield on the muni bond—and this reduces investors' demand for the bond. See the Appendix for further details.

5 These investors include banks (Maddaloni and Peydró, 2011, Jiménez et al., 2014), pension funds (Lu et al., 2019), insurance companies (Ozdagli and Wang, 2019), endowments and sovereign wealth funds (Campbell and Sigalov, 2022), and individual investors (Lian, Ma, and Wang, 2019).

Importantly, investors moving down the coupon stack could harvest an additional return premium. For instance, in 2015, an investor in investment-grade munis could pick up 60 to 80 basis points of excess yield ("spread") by moving from 5s to 4s, and an additional 20 to 30 basis points by moving from 4s to 3s, without sacrificing credit quality.[6] Since the muni index yield to worst was just 2.1% at the time, the magnitude of these spreads was material. As a result, investors increased their demand for lower coupons, while issuers less concerned about maximizing proceeds were able to meet this demand and commit to lower coupon payments.[7] Lower coupons slowly became a larger and larger portion of the market, as Figure 4 shows.

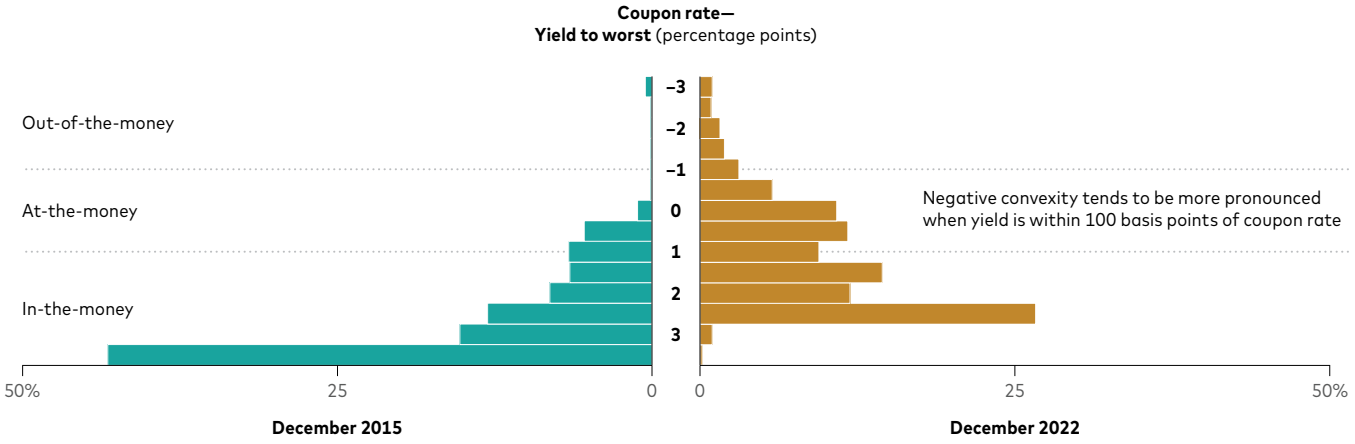
As long as interest rates remained low, this evolution of the coupon stack carried no immediate downside. While the embedded calls on these lower coupons were less in-the-money, all else equal,[8] they were not yet at-the-money given the sub-3% index yields. However, on the heels of the inflationary pressure in the early 2020s, the Fed began a series of interest rate hikes starting in early 2022. **Figure 5** compares the moneyness—the difference between the strike coupon rate and the current market yield (i.e., in-the-money or out-of-the-money)—of the muni bond universe of 2022 with that of 2015.

The contrast with 2015 is stark: Whereas effectively all callable bonds were in-the-money in 2015 (the coupon rate is greater than the yield to worst), by the end of 2022, only 75% were in-the-money. Of the remaining 25%, 14% of the callable bonds were out-of-the-money and 11% were at-the-money.

Negative convexity peaks when the bond is at-the-money and is generally more pronounced when the yield is within 100 basis points of the coupon rate (i.e., –1% to +1% of the vertical axis in Figure 5). This is another reason why negative convexity has moved front and center in the muni market in the current environment. Whereas only 13% of the muni bond universe was subject to material negative convexity in 2015 (all with varying degrees of being in-the-money), 41% of all muni bonds were subject to increased negative convexity at the end of 2022—reflecting a broad cross-section of out-of-the-money, at-the-money, and in-the-money bonds.

FIGURE 5

By the end of 2022, there was a greater diversity of moneyness in muni bonds



Notes: "Yield to worst" represents the yield the investor would receive assuming the bond is called by the issuer if it is in-the-money 10 years after issuance. Calculations are based on the Bloomberg U.S. Municipal Index, excluding noncallable bonds.

Sources: Vanguard calculations, using data from Bloomberg.

6 Based on Vanguard's calculations for callable bonds in the Bloomberg U.S. Municipal Index on December 31, 2015.

7 Some issuers tend to view their issuance "to worst" from their perspective, in which case lower-coupon bonds may be more attractive than 5s (even if they may be paying more in terms of higher yield).

8 Theoretically speaking, a lower coupon with better credit (and hence lower yield) could be equally in-the-money.

Negative convexity in a muni portfolio

In this section, we consider how negative convexity can affect a muni portfolio. **Figure 6** shows key attributes of a generic muni portfolio, which consists of longer-term bonds that were representative in the muni market as of late 2022. The portfolio has an average of 4.3% yield to worst and an average coupon rate of 4.5%. The portfolio is nearly at-the-money and has two years of negative convexity accompanying 10 years of duration (10-year callability weighing in heavily).

With two years of negative convexity, this portfolio faces an uphill battle in performance regardless of whether rates rise or fall. For instance, a 100 basis-point decline in rates would result in the portfolio's appreciating by only 9%—instead of 10% (10 x 100 basis points)—because the duration would shorten into the rally because of negative convexity. Similarly, a 100 basis-point increase in rates would cause the portfolio to depreciate by 11%—not 10%—because the duration extends with rising rates, again because of negative convexity.

FIGURE 6

Negative convexity now features prominently in a longer-term muni portfolio

Average maturity date	9/1/52
Average call date	9/1/32
Yield to worst (%)	4.3
Coupon rate (%)	4.5
Duration	10 years
Convexity	–2 years

Note: The numbers are *indicative* of current prices/model estimates and are for illustrative purposes only.

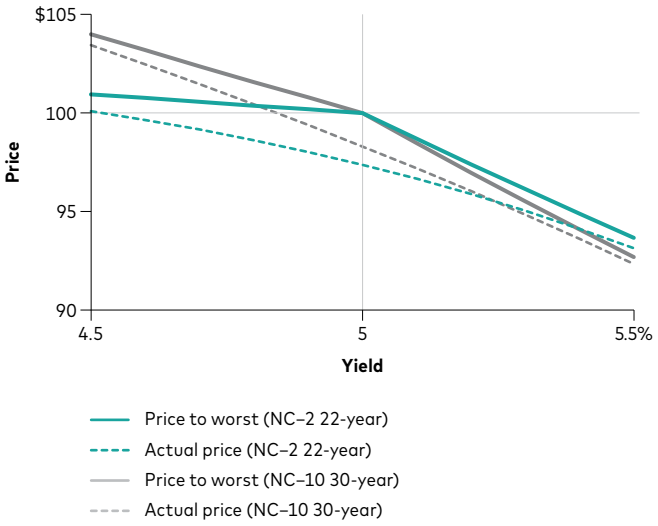
Source: Vanguard.

This example illustrates the importance of navigating negative convexity in managing any muni bond portfolio in the current environment. A common way to lessen the impact of negative convexity is to construct the portfolio with positive *active* convexity—less negative convexity relative to the benchmark.

Notably, there are two aspects to consider. The first is the age of the embedded call option. Consider a generic muni bond with a 22-year final maturity, which pays a 5% coupon and is callable in two years. Because the call option expires in two years, this bond would have significantly more negative convexity near par than a 10-year callable bond with the same coupon rate. **Figure 7** illustrates this comparison.

FIGURE 7

Shorter call date leads to more pronounced negative convexity: A yield/price curve for NC-2 22-year 5% coupon with binary option



Notes: "Price to worst" represents the price of the bond assuming the bond is called by the issuer if it is in-the-money at the time of expiration (i.e., two or 10 years after issuance). The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

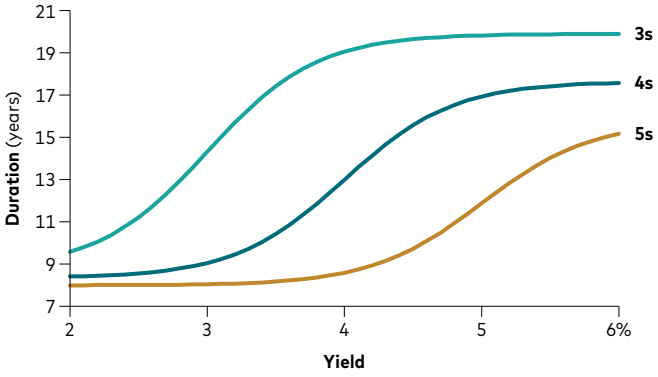
The greater convexity for the shorter call option reflects that the duration difference between 2- and 22-year bonds is greater than the duration difference between 10- and 30-year bonds. Relevant for the current environment, the muni investor would reduce negative convexity—have positive *active* convexity—with overweight positions in fresh calls (longer than seven years until call).

The second aspect of active convexity management comes from the dispersed coupon stack that now includes a significant number of 2s, 3s, and 4s—a "new normal" compared with the coupon stack that had centered predominantly on 5s. **Figure 8** shows the duration profiles of 3%, 4%, and 5% bonds with 30-year final maturities and 10-year calls.

The key observation is that lower coupons "kick out" earlier and to higher durations in a rising rate environment. For instance, when the prevailing yields are at 4%, 3s are already out-of-the-money, at which point they have considerable duration (but less negative convexity). In contrast, 5s are still in-the-money, with less duration (and similar negative convexity).

FIGURE 8

Durations for 3%, 4%, and 5% NC-10 30-year bonds



Notes: The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

Negative-convexity-aware active management

How might an active manager navigate the current environment of negative convexity? We illustrate how this may be done by leveraging the greater diversity of the coupon stack (the second aspect of active convexity) in three interest rate scenarios: 1) interest rates decline, 2) interest rates rise, and 3) interest rates stabilize around the current level. To fix the idea, we assume that the prevailing yields are currently at 4%; the 3s are trading at a discount, the 4s near par, and the 5s at a premium.

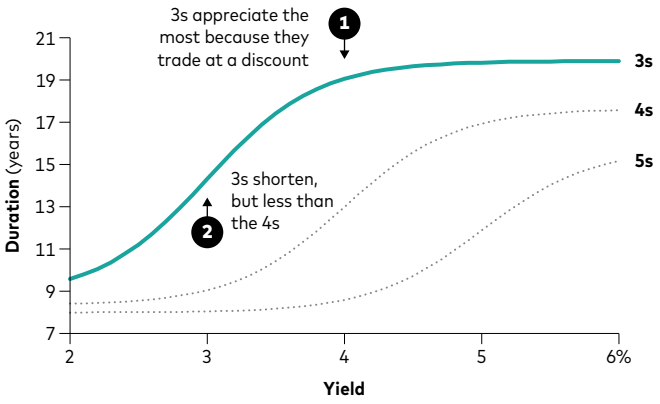
Scenario 1: Yields decline to 3%. The 3s are (all else equal) expected to outperform (**Figure 9**). Because of the material discounts, their durations have already extended. As the yields decline from 4% to 3%, the higher duration of 3s induces greater appreciation. Overweighting in 3s would also have positive active convexity *relative* to the market: Compared with the 4s, the duration would shorten *less* into the rally, providing continuous reward from the declining yields.

Scenario 2: Yields increase to 5%. The 5s are (all else equal) expected to outperform (**Figure 10**). They have the shortest duration, which would result in *less* depreciation for a given rise in yields. Relative to the 4s, 5s also have positive relative convexity: The duration would extend less into the sell-off, providing continuous *relative* protection from the rising interest rate.

Scenario 3: Yields stabilize at 4%. The 4s are (all else equal) expected to outperform. Because they are trading near par, they have more negative convexity. As a result, the market should price in the risk of adverse movements from changes in interest rates. Should interest rates remain stable, and thus the interest rate volatility is lower than the market expects, the investor can benefit from holding the bond at a higher yield, outperforming through excess carry.[9]

FIGURE 9

3s outperform 4s and 5s on the back of higher duration and positive active convexity

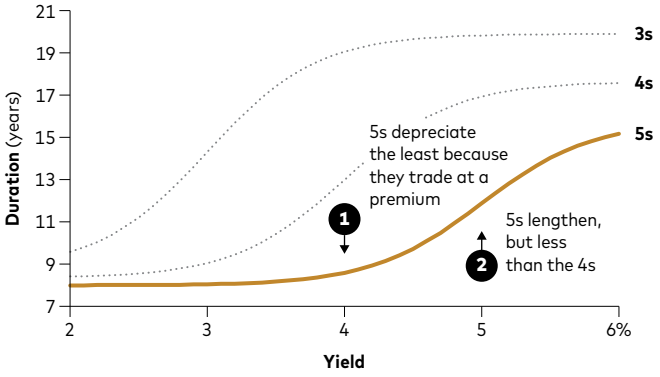


Notes: The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

FIGURE 10

5s outperform 3s and 4s thanks to low duration and positive active convexity



Notes: The chart is for illustrative purposes only. This hypothetical illustration does not represent the return on any particular investment and the rate is not guaranteed.

Source: Vanguard.

9 Assuming that the security is efficiently priced, holding 4s may be understood as "shorting volatility" wherein the investor benefits from lower volatility. When it comes to implementation of this idea, however, the portfolio manager may need to discern the extent to which the current pricing reflects the elevated volatility—retail investors have historically exhibited preference to hold par bonds.

Conclusion

In this paper, we explored the origin and current impact of negative convexity, which emerged in the muni market throughout 2022 and into the first half of 2023—a period with aggressive Fed rate hikes to combat inflation. Negative convexity, when activated, is an important driver of performance in the muni bond market regardless of the direction of interest rates. In a rising rate environment, negative convexity leads to extended duration and increased price impact for a bond. When the rate is falling, negative convexity shortens duration, which in turn dampens the magnitude of a bond's appreciation.

Although negative convexity has been present before, the diversity of the coupon stack makes the current environment notable.[10] The current coupon stack includes 2s, 3s, and 4s—nearly unprecedented for the muni market, which has historically been dominated by a single coupon (5s).

This diversity of the coupon stack provides a historically unique opportunity for investors interested in taking *active* convexity risk from this point on. Specifically, assuming roughly 4% yield for par in the current environment, investors with a strong conviction that rates will decline may source 3s to express an overweight to discount callables. On the other hand, investors expecting rates to increase may source 5s to express an overweight to premium callables. In both scenarios, overweight positions have the effect of dampening negative convexity in the muni portfolio, contributing to potential outperformance relative to the broad market.

Of course, an awareness of the diversified coupon stack and its potential usefulness for navigating negative convexity is just the beginning. Implementing any of these ideas in a real-world portfolio management setting requires carefully weighing many additional considerations. For one thing, not all discount bonds may be easily available because of potential de minimis risk. The pricing of discount and premium callables also significantly figures into the decision-making. In addition, active convexity positions can require significant ongoing management, especially if interest rate volatility is elevated. Nevertheless, going forward, the ability of active managers to position themselves relative to the benchmark's negative convexity will be an important driver for successful active investing.

Negative convexity is no longer a theoretical concept buried in muni textbooks. Instead, it rejoins duration and credit as a central source of potential outperformance in active management of muni portfolios.

10 For example, in the 1990s (when rates were generally higher), muni bonds were generally 5s issued at par. The price impact of negative convexity then lay dormant for roughly two decades before it reemerged with the advent of the diversified coupon stack.

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Appendix

Why can call options be advantageous?

The call provision represents a sensible solution to one of the muni market's structural peculiarities. When an investor purchases a muni bond below a certain discount price—called the de minimis threshold—the accretion (up to the threshold) is treated as ordinary income instead of capital gains and is taxed at a higher rate.[11] This threshold is computed as follows:

$$\text{De minimis threshold} = \text{Lower of par or current original issue discount} - (0.25 \times \text{full years to maturity})$$

Once it is below the de minimis threshold, the bond's price reflects this additional tax liability. Many investors—especially those who are not certain they will hold the bond to maturity—therefore try to stay clear of this threshold, giving bonds with longer final maturities (and hence lower thresholds per the formula) a potential structural advantage. However, these bonds naturally come with higher durations, which may not be a commonly desired feature either.

With in-the-money call options in longer-dated bonds, this structure can assist investors with navigating two key market risks: They steer clear of the de minimis risk (especially with premium bonds) and they issue a debt with a shorter duration (assuming the bond remains in-the-money).

Figure 11 illustrates the de minimis and duration implications of embedded calls. The State of California recently issued a 5% bond (CUSIP: 13063DS82) that matures in September 2052. Because the bond is callable, it has a similar de minimis threshold to Stanford University's 30-year noncallable (CUSIP: 130179TN4) but has a duration comparable to its own 10-year bond (CUSIP: 13063DP85).

FIGURE 11

Duration/de minimis profiles of three California bonds

	Issuer		
	State of California	**Stanford University**	**State of California**
CUSIP	13063DP85	130179TN4	13063DS82
Callable	No	No	Yes (10-year call)
Coupon rate (%)	5	5	5
Yield to worst (%)	2.45	3.85	3.29
Maturity date	04/01/2033	04/01/2051	09/01/2052
Full years to maturity	9	27	29
De minimis threshold	97.75	93.25	92.75
Modified duration	8.04 years	16.08 years	7.54 years

Sources: Vanguard calculations, using data from Bloomberg.

11 As of this writing, the highest long-term capital gains rate is 23.8%, while the highest ordinary income rate is 40.8%.

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