US Municipal Bond Risk Model

Arne Staal
+44 (0)20 31347602
arne.staal@barcap.com

www.barcap.com

As evidenced by recent events, the municipal bond market can experience substantial spread movements from month to month. Our new US Municipal Bond Risk Model is based on a duration-times-spread (DTS) approach that allows for improved risk estimation over a changing volatility environment. The extension of the DTS approach to municipal risk modeling is based on extensive empirical analysis that shows spread risk is well captured by conditioning on spread levels across fixed income markets. The model allows for risk decompositions relative to either the Treasury curve or the MMD (Municipal Market Data) curve. It accounts for shifts in the behavior of muni bonds due to special circumstances, e.g., trading de minimis, through additional risk factors. Our analysis shows that the predicted risk adapts quickly to changing volatility circumstances while maintaining appropriate levels of stability during periods of constant risk.

Anthony Lazanas, Antonio Silva, and Cevdet Aydemir contributed substantially to the development of the US Municipal Bond Risk Model and the writing of this paper.

1. Introduction

Until fairly recently, the municipal market was considered one of the safest, perhaps even somewhat staid, fixed income classes. Events during the recent credit crisis have forcefully reminded us that no financial market is immune to abrupt changes in the volatility environment. Aversion to credit risk and a renewed awareness of credit risk in the municipal market has led to significant spread movements, as well as steepening yield curves. While our POINT portfolio platform has included a muni risk model for several years, we continuously strive to ensure that our models are state of the art and provide suitable tools for portfolio managers and risk officers in any economic environment. With that in mind, we carried out extensive empirical analysis to determine how we can best forecast risk in the muni market in a dynamic fashion. Not surprisingly given our findings in other markets, we show that excess return risk is more adequately captured with a duration-times-spread (DTS) approach than with the more typical bucketing approach.[1]

The DTS approach is based on the empirical observation that spread volatility is linearly proportional to spread levels. By conditioning risk forecasts on spread levels, we are better able to predict future volatility. In particular, this approach accommodates rapid changes in the volatility environment while maintaining appropriate stability within a calm spread environment. Extensive empirical testing in the municipal and other markets confirms that the promised benefits are delivered consistently. Special circumstances that lead to additional systemic spread volatility differences are captured through additional risk factors. Examples are the de minimis, alternative minimum tax, and sector risk factors.

[1] See Ben Dor, A., L. Dynkin et al. (2007) for the original exposition of the DTS concept.

One interesting feature of the model is that we allow users to choose their yield curve benchmark. The first choice is the US Treasury yield curve; this allows for a consistent view of curve risk across asset classes and should appeal to multi-asset class investors. The second option is the MMD curve; this benchmark will appeal to pure municipal investors, as it captures the curve risk of the highest rated municipal bonds. In both cases, we consider spread risk relative to the MMD curve. When using the Treasury curve, we add the spreads between the Treasury curve and the MMD curve as additional risk factors. Finally we account for optionality in muni bonds through the inclusion of volatility risk factors.

This paper is organized as follows: section 2 provides an overview of the municipal bond market in the US. We discuss the features of the market and its relation to other markets. Section 3 examines the different sources of risk in the muni market. Section 4 details our risk modeling approach, highlighting the different return components of a muni investment and how to model each component through risk factors. Section 5 provides some examples of the performance and use of our risk model. It illustrates predicted risk for the Barclays Capital Municipal Index and briefly discusses customized risk reporting. Section 6 concludes.

2. The muni market

The municipal bond market is a decentralized one in which over two million bonds, issued by more than 50,000 state and local government units, are traded. The total market value of muni holdings is around $2trn. Until 2007, annual issue volume was around $300bn, divided among more than 10,000 separate issues of, on average, around $20mn dollars per issue. Issuance in 2008 was approximately $400bn, spurred partly by government stimulus measures. Munis are typically issued in series, and each issue is likely to consist of 10-30 bonds with different maturities. While derivatives on munis are traded in both primary and secondary markets, municipal bonds account for the vast majority of the principal amount of outstanding municipal securities. Our modeling efforts focus on the cash market.

Munis are traded in decentralized broker-dealer markets. There is no centralized exchange, and to obtain quotes, a buyer or seller must call multiple dealers or solicit bids from them. Approximately 2,700 muni brokers and dealers are registered with the Municipal Securities Rulemaking Board (MSRB), a self-regulatory organization that governs the conduct of dealers involved in underwriting, trading, and selling munis. Dealers must report all trades to the MSRB. Currently, information about all muni transactions is disseminated by the MSRB on a one-day (T+1) basis.

Compared with other bond markets, the muni market stands out because of its fragmentary nature and lack of transparency. The lack of a centralized exchange makes comparison shopping relatively costly. Because of local cost advantages and possibly for political reasons, smaller regional firms underwrite many municipal issues. The lack of a large intermediary with access to many different bonds may further increase the costs of efficiently matching buyers and sellers. Consequently, liquidity in the muni market is low, and the bid-ask spreads are high. Bonds ranked above the 99th percentile in trading activity trade on average less than six times per day. Effective spreads average about 2% of price for retail-size trades of $20,000 and about 1% of price for institutional-size trades of $200,000.

The tax advantages of munis, which we discuss later, make them more attractive to small investors. In fact, individual retail investors hold around 35% of the outstanding muni bonds in terms of market value. Insurance companies (10%) and banks and personal trusts (6.5%) are the other two major investor groups in the muni market.

There are three general types of muni bonds: general obligation (GO), revenue, and hybrid. GOs are unsecured municipal bonds, backed by the credit and taxing power of the state or municipality, that finance municipal operations. They have maturities of ten years or more. The creditworthiness of the issuing city or state is the only "guarantee" they provide. GO bonds finance projects that do not produce revenue. The issuer repays the bonds with funds raised by fees, property sales, and taxes collected. Generally, all individual bonds in a GO bond issue have the same maturity date.

Revenue bonds are generally issued to finance specific revenue-generating projects, such as toll-generating roads and bridges, airports, water and sewage treatment facilities, healthcare facilities, and housing projects. Special authorities are often created to issue these bonds. Interest and principal are payable from the specific sources of revenues and are not backed by the full faith and credit of the issuer. Revenue bonds involve higher risk than GO bonds because of the possibility that the projects financed may not bring in enough revenue to pay bondholders. Double-barreled bonds are hybrids of general obligation bonds and revenue bonds, in which specific revenues of an enterprise are backed by a general obligation pledge.

Municipal bond maturities run from one to thirty years or more. Municipal notes are short-term obligations generally issued with maturities ranging from three months to three years. Muni coupon rates may be variable, fixed, or zero. Variable-rate bonds pay an interest rate that is periodically marked to a market index or based on a predetermined formula. Most variable-rate municipal bonds contain either daily or weekly reset frequencies. They almost always contain put provisions. As a result, variable-rate bonds usually trade at prices exactly equal to their face values.

Munis may contain one or many special features, such as call, put, sinking fund, and refunding provisions. Many municipal bond issues carry call provisions that allow retirement of the bond prior to the stated maturity. The call option usually becomes active only after ten years from the issue date of the bonds. In addition, a significant number of munis are pre-refunded. Pre-refunded municipal bonds are created when municipalities borrow money at lower interest rates to refinance municipal bonds issued when interest rates were higher. Once the refinancing is completed, the municipality uses the proceeds to buy a portfolio of U.S. Treasury securities, the interest and principal of which are used to retire the original issue to its call or maturity date.

Many munis are insured by outside agencies. These insurers guarantee that they will pay bondholders their interest and principal if the issuers default. Both individuals and issuers may carry insurance. Individuals must have at least $50,000 in three or more issues before they can buy insurance. Two well-known municipal bond insurers are the Municipal Bond Insurance Association (MBIA) and the American Municipal Bond Assurance Corporation (AMBAC). Large commercial banks also sometimes guarantee bonds. Currently, around 50% of issued bonds are insured. Of course, the distress among bond insurers during the recent credit crisis has led people to question the value of insurance. Not surprisingly, the fraction of insured issuance has been decreasing sharply during the credit crisis. To what extent this will fundamentally change market practices remains to be seen.

Most municipal bonds are free of federal income taxes on interest distributions. Also, most are free of state and local taxes in the state in which they are issued. These features make them popular among small investors. However, capital gains are not exempt from taxes. The Tax Reform Act of 1986 created classes of bonds that are subject to federal income tax. Still, most investors and issuers use the term "municipal bond" to refer to the tax-free variety. Tax-free municipal bonds are those that benefit the public sector. Taxable municipal bonds are used in the private sector.

The Barclays Capital Municipal Bond Index is a rules-based, market value-weighted index engineered for the long-term tax-exempt bond market. To be included in the Barclays Capital Municipal Bond Index, bonds must have a minimum credit rating of at least Baa3/BBB-. They must have an outstanding par value of at least $7mn and be issued as part of a transaction of at least $75mn. The bonds must have been issued after December 31, 1990, and have a remaining maturity of least one year. Taxable municipals, floating-rate bonds, and derivatives are excluded.

Barclays Capital also publishes a non-investment grade municipal bond index separate from the Barclays Capital Municipal Bond Index. To be included in the Barclays Capital Non-Investment Grade Municipal Bond Index, bonds must be non-rated or be rated Ba1 or below. They must have an outstanding par value of at least $3mn and be issued as part of a transaction of at least $20mn. The bonds must have been issued after December 31, 1990, and have a remaining maturity of least one year.

As of January 2009, the Barclays Capital Municipal Bond Index consists of 45,745 bonds, with a total market value close to $1.1bn. The muni index is dominated by AAA bonds, as well as NY and CA bonds. More than half of the munis in the index are insured, and 14% are pre-refunded.

3. Risk and return in the muni market

Until the recent credit crisis, munis were generally considered among the least risky fixed income securities. In fact, as we discuss later, muni yields tend to be less less volatile than Treasury yields, and default risk is perceived to be minimal for most munis. Nevertheless, a full spectrum of risk exists in the muni world. Not surprisingly, munis in the Barclays Capital municipal high yield index are more volatile than bonds in the investment grade index, especially in times of distress. Some potential factors that drive the volatility of munis:

i. **Curve risk:** Similar to all fixed income securities, munis are sensitive to changes in the base yield curve. Pricing in the muni cash market is generally done based on a reference curve composed of AAA rated general obligation bonds issued by high quality states. This reference curve is commonly referred to as the Municipal Market Data (MMD) curve and is provided by Thompson Financial. The correlation of the MMD curve with the Treasury curve is high. The POINT muni risk model allows for risk decomposition with either the Treasury or MMD curve as the benchmark.

ii. **Credit risk:** Historically, defaults have been rare in the muni market, and recovery rates have been high. For high grade munis, the cumulative default rate is less than 1% over a 15-year period. For A rated bonds and above, there is virtually no default risk over the one year horizon. For AAA and AA, there has been no default for the past 15 years. In addition, most munis are insured by outside agencies. The level of muni spreads is driven by perceived credit risk, as well as the precise characteristics of the underlying cash flows. It remains to be seen how the current credit crisis will affect actual and perceived default risk in the municipal market.

iii. **Issuer risk:** The credit risk of munis is obviously directly linked to the financial health of its issuer. A rare event, such as the flooding of Louisiana in 2005, can move the spreads of the munis issues by that state significantly. In addition, tax advantages provided by high-tax states to their residents potentially lead to an increased correlation between munis issued by the same state.

iv. **Tax policy risk:** Interest payments of most munis are exempt from federal taxes, as well as the state taxes for local investors. The federal income taxation policy affects muni prices through the prevailing tax rates, as well as expectations of future tax rates. In fact, the spread between municipal and Treasury yields is, in general, comparable in magnitude with income tax rates for the highest brackets. Changes in federal income tax policy may lead to shifts in the clientele and, in turn, the tax rate of the marginal investor. Hence, the prospect of a future change in tax-exemption policy is a potential risk factor for munis.

v. **Liquidity risk:** Munis are traded in decentralized markets. Investors generally hold them until maturity because of the tax advantages, making the muni market very illiquid. Bid-ask spreads as high as 4-5% are not uncommon. Effective spreads are on average about 2% for trades of $20,000 and 1% for trades of $200,000. Liquidity has an effect on muni spreads, but it is hard to identify separately.

vi. **De minimis exposure:** Munis purchased at a market discount (difference between the secondary market purchase price and the issue price of the bond plus the accreted original issue discount) are subject to ordinary income tax. When the muni is sold, the accreted market discount is taxed at the ordinary income tax rate, while any excess gains are taxed at the capital gains rate. Since gains from munis purchased at a market discount are not fully exempt, these munis trade at a spread to fully tax-free munis. The "De Minimis Rule" states that if the muni is purchased with a small amount of market discount—an amount less than 0.25% of the face value times the number of complete years between the bond's acquisition date and its maturity date—the market discount is considered to be zero for ordinary income tax and taxed at the capital gains tax rate. Hence, as muni prices approach the de minimis threshold, investors require compensation for potential tax losses and the spread on munis increases.

vii. **Alternative Minimum Tax (AMT) considerations:** "Private activity" municipal bonds, i.e., those issued by airports and certain types of housing agencies, are subject to AMT. In 1986, the Tax Reform Act required that interest on private activity bonds (other than 501(c)(3) obligations) issued after August 7, 1986, be included in the calculation of AMT income for federal tax purposes. The yields on AMT bonds are higher, reflecting the risk that they could become taxable to some investors at some point.

viii. **Volatility risk:** Most munis become callable ten years after they are issued. This embedded optionality suggests that the dynamics of the volatility of muni yields are a potential risk factor. While most muni market participants do not view the volatility exposure as a major source of risk, based on theoretical reasoning and our experience with other callable securities, we empirically determine the importance of these risk factors.

ix. **Industry risk:** Revenue bonds issued for financing in different industries are potentially subject to a different set of risk factors driven by business conditions in their industries. Most defaults from 1986 to 2000 have occurred in the industrial development, housing, and healthcare sectors.

We carefully examined these sources of risk for their usefulness as factors in a statistical model. The next section discusses the results in more detail, but they can be summarized as follows: curve risk is captured through exposure to the Treasury curve and spreads to the MMD curve. Volatility risk is captured through short- and long-dated volatility factors. Credit risk, issuer risk, tax policy risk, liquidity risk, AMT risk, industry risk, and de minimis risk are captured through spread factors. To the extent possible, spread risk is captured though common DTS risk factors. However, de minimis risk, AMT risk, and industry risk require additional risk factors because of their effect on spread risk beyond what can be captured through conditioning on spread levels.

Before we discuss risk decomposition in more detail, we briefly consider the relationship between the muni market and other asset classes.

Figure 1 shows the correlation of the Barclays Capital Municipal Index monthly returns with returns on Treasuries, corporate credit, securitized products, commodities, and equities. Not surprisingly, returns in the muni market are fairly highly correlated with high grade fixed income instruments, while seemingly uncorrelated with commodities and equities over the past 10 years.

Figure 1: Correlations of monthly returns across asset classes

Correlation (1998-2008)	Barclays Municipal Index
Barclays US Treasury Index	0.4905
Barclays US Corporate IG Index	0.6815
Barclays US Securitized Index	0.6408
Barclays Corporate HY Index	0.3135
Barclays Commodities Index	0.0095
S&P 500	-0.0071

Source: Barclays Capital

4. Risk modeling in the muni market

Our Global Risk Model decomposes a security's total return into well-defined components. Based on the same framework, our US Municipal Bond Risk Model decomposes the total return on muni bonds into several components, identifies a set of factors driving each return component, and then combines the factors and return components in a linear factor model.

Return splitting

In order to decompose the total returns, we first write total return as the sum of coupon return and full price return:

$$R_{total} = R_{coupon} + R_{fp}$$

The full price of a muni can be expressed as

$$fp_t = P\left(t, YC_t, Vol_t, MMD\_spread_t, MMD\_OAS_t\right)$$

This leads to the following total return decomposition:

$$R_{total} = R_{carry} + R_{yc} + R_{vol} + R_{MMD\ spread} + R_{MMD\ OAS} + residual$$

The carry return, Rcarry, is deterministic and simply captures the effect of passage of time and coupons paid out to bondholders. The remaining components are random, and we discuss them in detail below.

Benchmark risk

We allow for two benchmarks in the muni risk model: the Treasury yield curve and the MMD yield curve. While the choice affects the risk decomposition, it does not alter the aggregate risk numbers. If the Treasury yield curve is chosen as the benchmark, we merely decompose the MMD curve into Treasury curve components and Treasury-to-MMD spread components:

$$MMD\ curve = TSY\ curve + MMD\ spread$$

In both cases, individual bond level spread risk is considered relative to the MMD curve.

Decomposing the MMD curve into the Treasury curve and spreads-to-MMD curve may seem counterintuitive. After all, muni market participants generally use the MMD curve for pricing purposes. However, there are potential benefits in using the Treasury yield curve for our muni risk model.

One advantage of using the Treasury yield curve is that is a well calibrated and widely accepted curve in the cash markets, while the MMD curve has several potential problems in practical use. The MMD curve is a yield curve, with bonds used to compute yields at each maturity selected to be within a certain coupon range, typically 4.0-5.5%. The short end of the curve (0-10 years) is constructed using non-callable bonds, whereas the long end of the curve (10-30 years) is constructed using yields of callable bonds, since most munis become callable after ten years. Consequently, the longer end of the MMD curve is not generally considered reliable, partly because the spread due to embedded calls that appears in the curve does not seem to match the implied spreads at which more liquid securities in the market trade. In addition, the MMD curve is proprietary; therefore, its construction details are unknown and, thus, cannot be used directly to construct a par curve that could be used as an input to pricing models.

More important, the Treasury curve is our benchmark curve for most other fixed income asset classes. Using the Treasury curve as the benchmark for muni risk decomposition makes it consistent with our treatment of other fixed income securities in the Global Risk Model and is especially useful for the analysis of mixed asset class portfolios.

We define the Treasury benchmark return for a muni as the portion of return that results solely from movements in the Treasury yield curve over the month. Analytically, the benchmark return can be computed by re-pricing the muni using the end-of-month Treasury curve while holding all other variables fixed. Alternatively, the benchmark return can be approximated fairly precisely by a linear combination of six key-rate durations (KRD) multiplied by the corresponding yield changes and a convexity factor that captures the second-order effects of a parallel shift in the yield curve. The six key rates we use in our Global Risk Model are 6m, 2y, 5y, 10y, 20y, and 30y key rates. The following equation formalizes this approximation:

$$R_{yc} = \sum_{i=1}^{6} KRD_i \times \Delta y_i + OAC \times \left(\overline{\Delta y}\right)^2 .$$

We have a similar approximation for the spread to the MMD curve

$$R_{MMD\ spread} = \sum_{i=1}^{6} KRD_i \times \Delta MMD\ spread_i + MMD\ OAC \times \left(\overline{\Delta MMD\ spread}\right)^2$$

where the key rate and convexity analytics are calculated with respect to the MMD spread to the Treasury curve. As discussed, to accommodate users that prefer to measure risk relative to the MMD curve, we provide the ability to choose either curve. The duration-convexity approximation remains unchanged, but the Treasury/MMD-spread decomposition will be aggregated in the factor representation when the MMD curve is chosen as the benchmark.

Of course, given that the highest quality muni bonds are largely free from credit risk, Treasury yields and MMD yields are likely to be strongly correlated. To illustrate, we explore the statistical properties of muni yields and compare them with Treasury yields. Figure 2 shows that for all key rate points, muni yields are around 30% less volatile than Treasury yields. Assuming an income tax rate of 30% for the marginal investor in the muni market, the difference in the level of volatilities can be largely explained by the tax advantage of munis. Notice that this implies that the spreads to MMD and the Treasury yield curve are negatively correlated.

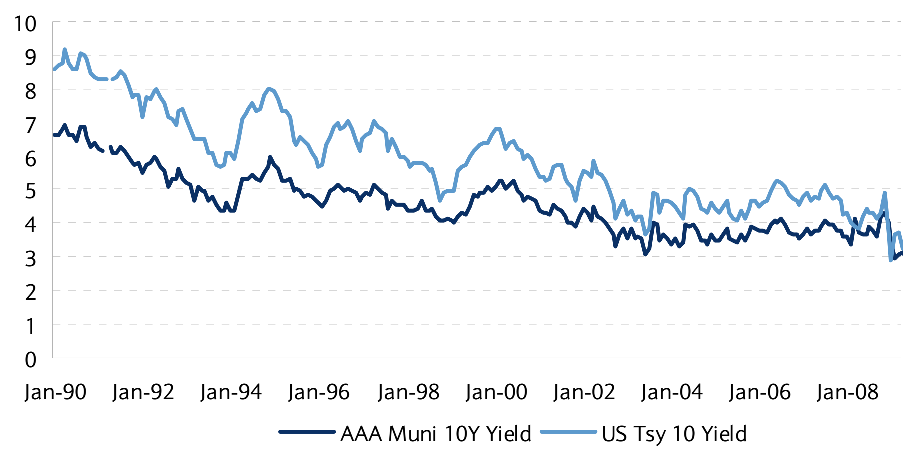
Figure 2: Volatility of monthly Treasury and MMD yield changes between 1998 and 2008

	0.5y	2y	5y	10y	20y	30y
TSY volatility	25.51%	28.93%	31.28%	27.41%	22.60%	21.43%
MMD volatility	17.10%	19.12%	21.82%	21.65%	16.23%	15.53%
Ratio	0.67	0.66	0.70	0.79	0.72	0.72

Source: Barclays Capital

The correlation between muni and Treasury yields is quite high. Figure 3 plots the time series of 10y MMD and Treasury yields. As evident from the figure, yield changes are highly correlated. The ratio of the two yields moves slowly over time, depending on market conditions, but both curves almost always move in the same direction.

Figure 3: Treasury and MMD 10y yields (%)



Source: Barclays Capital

We compute the correlation between six key rate changes from the Treasury and MMD curves in Figure 4. The results suggest that muni and Treasury yields are strongly correlated, especially for 2y and above. The lowest correlation is observed for the short end of the curve, where muni yields probably do not adjust to Fed actions as quickly as Treasury yields. This suggests that, to some extent, the choice of MMD curve or Treasury curve as the benchmark is merely one of convenience for risk purposes. It should be kept in mind, though, that during times of stress in the muni market, the two curves can behave more independently; correlations across the yield curve have been significantly lower (up to 40%) since the credit crisis erupted in 2007.

Figure 4: Correlation between Treasury and MMD yield changes, 1998-2008

	Tsy KR0.5	Tsy KR2	Tsy KR5	Tsy KR10	Tsy KR20	Tsy KR30
MMD KR0.5	0.66599	0.56167	0.40933	0.33386	0.28840	0.28844
MMD KR2	0.74265	0.77479	0.70188	0.62705	0.57412	0.55125
MMD KR5	0.64816	0.79189	0.83338	0.81051	0.77751	0.74669
MMD KR10	0.52845	0.73155	0.84546	0.87338	0.86592	0.84128
MMD KR20	0.43791	0.64221	0.77798	0.83720	0.85663	0.84333
MMD KR30	0.44815	0.65404	0.78910	0.85245	0.87680	0.86628

Source: Barclays Capital

Volatility risk

The majority of munis become callable ten years after they are issued. In addition, they commonly have embedded put or pre-refunding provisions. The embedded optionality, in turn, makes bonds sensitive to the changes in the term structure of volatility of interest rates.

Based on a pricing equation, a first-order approximation of the volatility return can be expressed as

$$R_{vol} = voldur \times F^{vol}$$

where the volatility duration is given by voldur=-100 * vega /(dirty price).

The single-factor model approximates the volatility returns with only the parallel shifts of the volatility surface. Hence, using partial vegas and several key points on the volatility surface, one can potentially improve the quality of the volatility return approximation. Our muni risk model uses a 2-factor model by approximating the partial vegas at 5y and 11y key points and estimating two latent factors that would capture the short- and long-term volatility changes. The volatility durations in the 2-factor model are approximated as

$$VolDur^{short} = wt \times VolDur$$
$$VolDur^{long} = (1 - wt) \times VolDur$$

where the variable wt is specified as MAX(MIN(1,(11-OAD)/(11-5)),0) and is equal to one if the OAD of the bond is less than 5, equal to zero if OAD is less than 11, and decreases linearly from one to zero if OAD is between 5 and 11. The cut-offs 5 and 11 are chosen based on the goodness of fit. Once the loadings are defined, the factor realizations can be estimated through monthly cross-sectional regressions:

$$R_{vol} = VolDur^{short} \times F_{short}^{vol} + VolDur^{long} \times F_{long}^{vol}$$

We find that the 2-factor volatility model performs better in accounting for the time-series variation of volatility returns of the bonds in our sample. Using the 17,815 bonds included in the analysis (bonds with less than 12 months of observations are excluded), the median time-series R-squared is computed as 62% for the 2-factor model and 53% for the 1-factor model.

Overall, our 2-factor model approximates the changes in the volatility structure of the benchmark interest rates and accounts for the volatility return of the munis reasonably well.

Spread risk: DTS

The portion of bond returns not explained by carry, the MMD yield curve (or, in the alternative representation, the Treasury yield curve and spread to MMD), or volatility returns is defined as the spread return. In the muni market, the most important factor driving spread returns is the tax-free nature of the interest income on munis. The prevailing marginal tax rates and the expectations about the future marginal tax rates create a wedge between the yields of munis and the yields of comparable Treasury securities. Spread returns will account for the spread between the muni bond and MMD curve.

A first-order approximation to spread returns is given by

$$\begin{aligned} R_{spread} &= -OASD \times \Delta OAS \\ &= (-OASD \times OAS) \times \left(\frac{\Delta OAS}{OAS} \right) \\ &= -DTS \times relative\ spread\ change \end{aligned}$$

where the OAS and OASD analytics are computed with reference to the MMD curve. In essence, the DTS concept is based on an examination of relative spread changes rather than absolute spread changes. The benefit lies in the empirical observation that relative spread changes are much better behaved from a statistical point of view than absolute spread chances (their distribution is much more likely to be time invariant). At the same time, the DTS approach is more reactive to expected risk changes because it conditions risk loadings on both duration and spread levels. In a rapidly changing environment, this removes the burden of forecasting changing volatility based on non-stationary factor time series (a problem of questionable feasibility) while capturing the risk changes by conditioning on observed signals of risk, i.e., spread levels. Our analysis shows that a model that incorporates DTS effects performs considerably better than one without spread conditionality.

The sample of bonds used in this study was chosen to fit certain characteristics. Each bond is a member of either the Barclays high grade or high yield municipal index and has an amount outstanding exceeding $10mn. To reduce the effect of outliers, we discard bonds in the highest and lowest 1% percentile of OAS levels. The sample period covers June 1999 to December 2008, with an average of around 20,000 bonds each month.

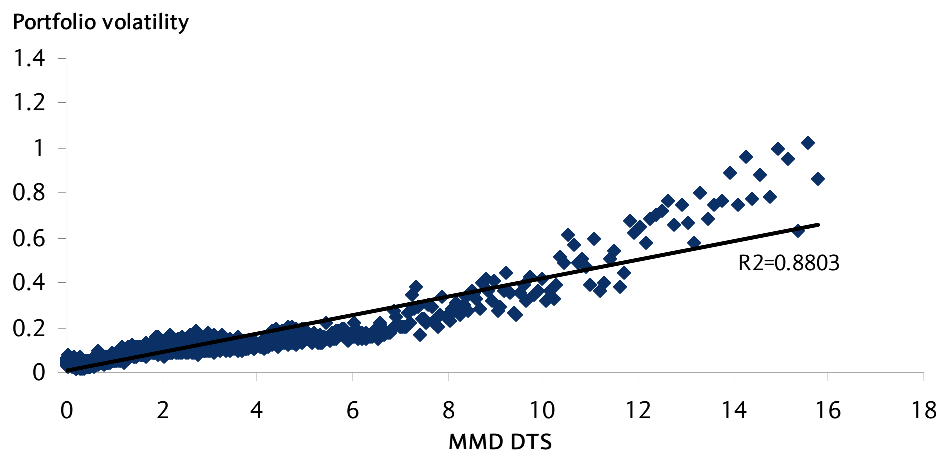
In order to find the factors that drive spread returns from month to month, we explore the factors that explain the monthly relative changes in OAS for munis. As discussed before, in the muni market, several factors may contribute to the OAS of a bond. First, the current marginal tax rate and expectation of future tax rates create a certain level of OAS for munis. Second, OAS decreases with the credit quality of the muni. Third, the type of muni, i.e., whether it is a general obligation or revenue bond, affects the spread level. Fourth, munis insured by outside agencies or pre-refunded and backed by riskless Treasury bonds trade at a lower spread. Fifth, munis whose payouts are subject to the AMT trade at higher spreads. Sixth, de minimis exposure requires investors to demand higher yields from bonds close or below the de minimis boundaries. In addition, investors are known to prefer different parts of the yield curve, certain coupon levels, geographical states, and types of industry backing revenue bonds.

The results of regressions of spread returns on the OASD suggest that one common factor drives the OAS levels of all bonds over time; this factor can be interpreted as the tax effect on muni yields. It provides a minimum risk level for all muni bonds in proportion to its MMD spread duration. Reflecting its function as a minimum risk floor, we refer to this factor as Ultra-High-Grade:

$$R_{spread} = OASD \times F_{UHG} .$$

In the next step of the analysis, we consider other possible drivers of spread risk. As mentioned before, we aim to capture this spread risk through the DTS concept[2].

Figure 5: MMD DTS and monthly realized portfolio volatility (2005-2008)



Source: Barclays Capital

Figure 5 illustrates the relationship between duration-times-spread (DTS) and realized monthly volatility for randomly constructed portfolios of bonds in the Barclays Capital municipal indices. As evident from the graph, the relationship between DTS and risk is fairly linear, with a positive intercept (minimum risk level), which suggests a factor model of the type

$$R_{spread} = OASD \times F_{UHG} + DTS \times F_{DTS} \, .$$

To allow for independent behavior of the investment grade and high yield segments of the markets, we introduce separate risk factors

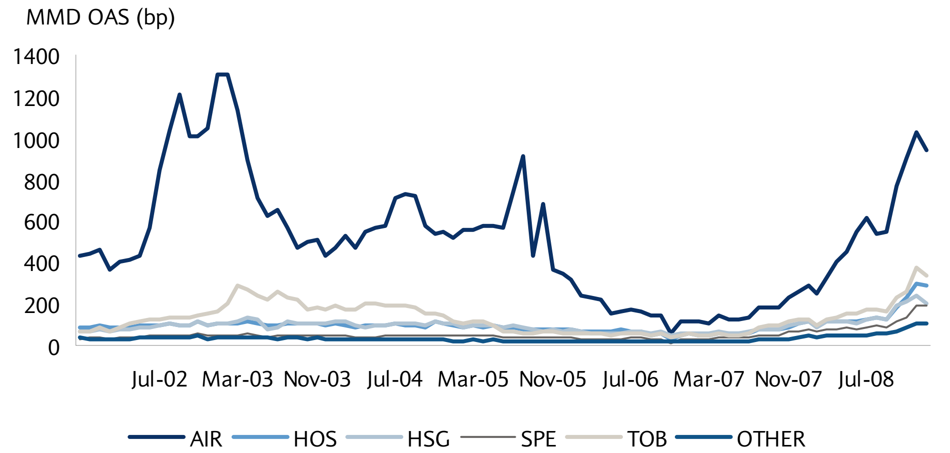
$$R_{spread} = OASD \times F_{UHG} + DTS^{IG} \times F_{DTS}^{IG} + DTS^{HY} \times F_{DTS}^{HY} \, .$$

This allows for smooth behavior of risk over the credit quality spectrum while recognizing that the investment grade and high yield markets can be subject to independent supply/demand pressures.

We need additional factors to capture nonstationary (regime-shift type) behavior due to events at the sector level, as well as a correction for the minimum level of risk of de minimis bonds and special tax circumstances (AMT). The sector factors that we found to be important are airlines, hospitals, housing, and tobacco. Figure 6 shows the average spread over the MMD curve by sector, as well as the average spread impact of the de minimis and the special tax effects.

[2] Throughout the paper DTS is expressed in units of percentage points times years, as spreads are expressed in percentage points and durations in years.

Figure 6: MMD OAS by sector (2001-2008)



Source: Barclays Capital

The sector and AMT risk factors have binary loadings, whereby the loading equals one if the particular circumstance applies and zero otherwise. In order to explore the effects of de minimis exposure on excess returns, we define a binary variable that is zero if price/cut-off is greater than 1.02 and one otherwise. Other candidates for causing systematic effects on spread volatility were not found to be statistically significant in explaining spread risk.

Based on these findings, we define our excess return model as follows:

$$R_{spread} = OASD \times \left[F_{UHG} + F_{de\min imus} + F_{\sec tor} + F_{AMT}\right] + DTS^{IG} \times F_{DTS}^{IG} + DTS^{HY} \times F_{DTS}^{HY}$$

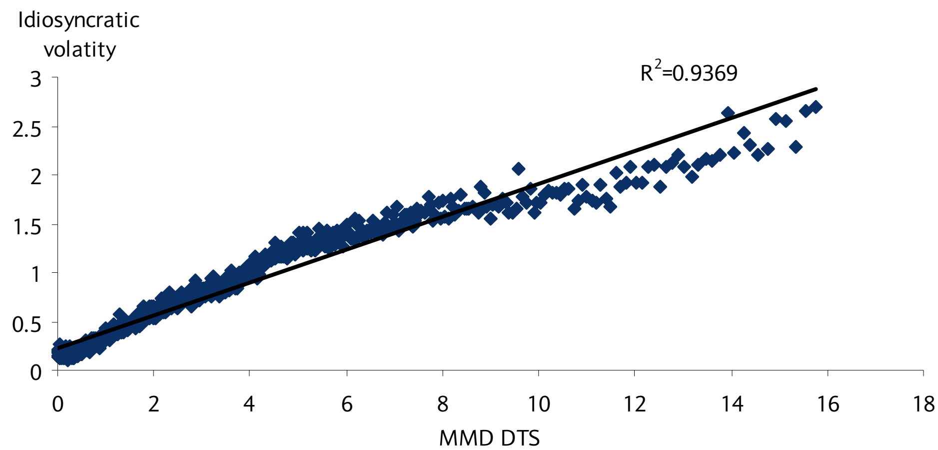
The first set of factors captures risk in proportion to spread duration. The Ultra-High-Grade (UHG) factor is the common intercept factor, which determines a minimum level of risk for all bonds. The de minimis, Alternative Minimum Tax, and sector factors capture adjustments to this minimum risk level due to special circumstances. The second set of factors includes DTS factors that capture risk in proportion to DTS. As explained earlier, we allow for separate DTS risk factors for investment grade and high yield bonds.

As a final comment, many investors would likely expect state factors to play a part in our risk decomposition. While intuitive, we find that state-specific effects are captured through the DTS factors. Estimating separate state factors leads to factors that are near perfectly correlated with each other, as well as the common intercept factor.

Idiosyncratic risk

The residual bond level return component that is unexplained by our systemic risk model is defined as the idiosyncratic component of returns. We have found that the idiosyncratic risk of munis scales in line with the DTS approach; idiosyncratic volatility is linearly proportional to the spread of the bond over the corresponding MMD yield. We construct a single duration-times-spread (DTS) factor through a robust estimation procedure. The standard deviation of the common DTS factor is then used to approximate the idiosyncratic risk of the muni based on the spread level of the bond. Figure 7 illustrates the relationship between DTS and idiosyncratic risk of individual municipal bonds.

Figure 7: MMD DTS and monthly realized idiosyncratic volatility (2005-2008)



Source:Barclays Capital

5. Risk predictions

We tested the performance of our municipal risk model extensively. In general, the results validate the use of the DTS approach. This section illustrates the behavior of the risk model by focusing on the risk and return behavior of the Barclays Capital Municipal and Municipal High Yield indices over the past three years. While we illustrate the behavior of predicted (tracking error) volatility, POINT provides a complete risk measurement platform and includes tail risk measures such as VaR and expected shortfall.

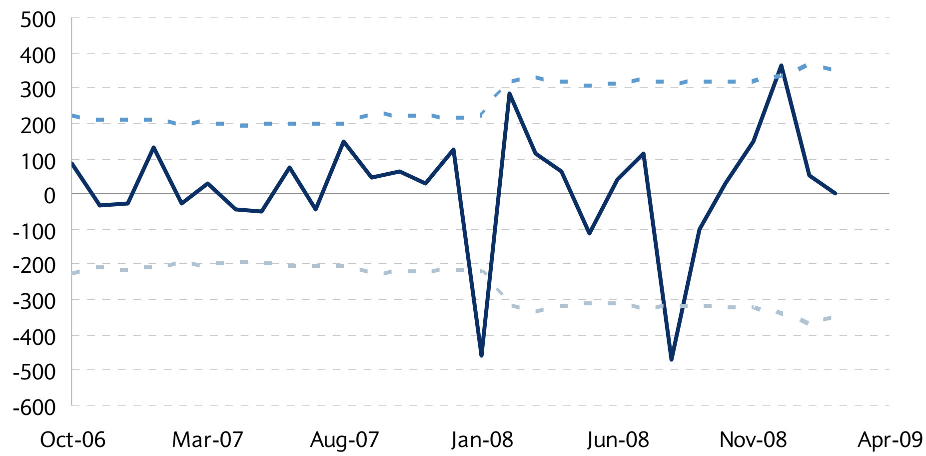
We test our risk models in many ways. Graphical analysis and formal testing both have a place in the process. One simple and intuitive way to assess the quality of the risk predictions is through a volatility bias statistic:

$$Stdev\left(\frac{\text{monthly return}}{\text{predicted monthly volatility}}\right)$$

If the predicted volatility accurately forecasts the actual subsequently realized volatility, this statistic will be close to 1. A confidence level for this statistic can be constructed through a bootstrap exercise.

Figure 8 illustrates monthly predicted risk and returns for the Municipal Index over the past three years. Results for longer or different periods are comparable. The upper and lower bounds denote 1.96x the monthly predicted volatility of the index while simultaneously plotting the total monthly index return. The volatility bounds illustrate a 95% confidence interval based on a simplifying normality assumption. The bias statistic equals 1.19, which is statistically not significantly different from 1 at the 5% confidence level. Removing the worst return over the past three years leads to a bias statistic of 1.05.

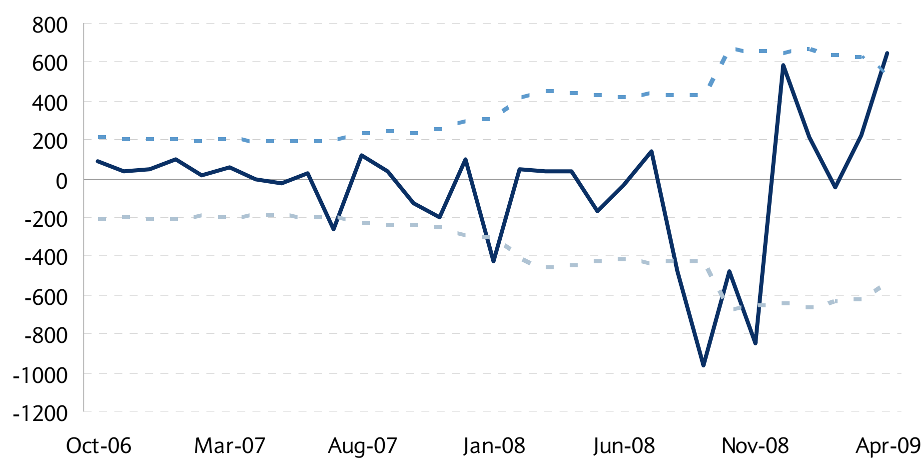
Figure 8: Municipal Index monthly return and predicted volatility (bp)



Source: Barclays Capital

Figure 9 contains the same information for the Municipal High Yield Index. The bias statistic is 1.28, which is statistically not significantly different from 1 at the 10% confidence level. Removing the worst return over the past three years leads to a bias statistic of 0.98.

Figure 9: Municipal High Yield Index monthly return and predicted volatility (bp)



Source: Barclays Capital

It is worth noting that POINT allows for risk decompositions of aggregate risk over user-defined partitions. The US Municipal Bond Risk Model was constructed to parsimoniously capture risk as well as possible; however, many portfolio managers would prefer to see risk attributed to particular buckets. POINT will allow these managers to define their buckets and see predicted risk attributed to each bucket. One often-encountered example is a risk partition by state. Figure 10 illustrates the ability of POINT to provide flexible views of risk. This example decomposes the total predicted volatility (TEV) of the Municipal Index into contributions (CTEV) by states. Partitions across many other dimensions are readily available and easily customizable. Please refer to additional documentation for a more detailed explanation of the available functionality in POINT (Joneja, D., L. Dynkin et al. [2005]).

Figure 10: Risk contributions to the total TEV of the Municipal Index by state (partial list)

Security Partition Bucket	Net Market Weight (%)	CTEV
Total	100.00	174.85
ALABAMA-AL	0.67	0.99
ALASKA-AK	0.31	0.54
ARIZONA-AZ	2.08	3.82
ARKANSAS-AR	0.11	0.18
CALIFORNIA-CA	16.43	30.33
COLORADO-CO	1.49	2.56
CONNECTICUT-CT	1.40	2.05
DELAWARE-DE	0.21	0.31
DIST OF COLUMBIA-DC	0.94	1.96

Source: Barclays Capital

Finally, as with all risk models in POINT, the US Municipal Bond Risk Model is fully integrated with other asset classes. The risk and return relationships of all asset classes are modeled coherently in the POINT global risk model through common dependencies on risk factors, as well as the relationships between asset class-specific risk factors. A consistent view of mixed portfolio risk is readily available.

6. Conclusion

The revised Barclays Capital POINT US Municipal Bond Risk Model allows for risk decompositions relative to both the Treasury curve and the MMD curve. Optionality risk for munis with option provisions is captured through short- and long-term volatility factors. Spread risk is captured through a duration-times-spread (DTS) approach that markedly improves the dynamic accuracy of risk predictions. The model allows for events in industry sectors, and incorporates the special tax and de minimis effects through additional factors.

The model has been tested extensively and performed well through the recent credit crisis. The DTS approach assures that predicted risk responds more dynamically and accurately to the level of distress in the market as signaled through credit spreads. At the same time, it allows predicted spread volatility to decrease quickly once spread levels enter a lower volatility regime.

Portfolio managers and risk analysts can use Barclays Capital's POINT platform to manage mixed portfolios in an integrated fashion. The risk reports in POINT provide a comprehensive analysis of risk in terms of volatility and tail risk. These are also highly customizable, allowing for risk decompositions along dimensions that are relevant to the user's particular goals. The introduction of our new US Municipal Bond Risk Model is in line with our continued effort to improve and expand the risk-modeling capabilities available to our clients.

References

Ben Dor, A., L. Dynkin et al. (2007). "DTS (Duration Times Spread)," *Journal of Portfolio Management*, Vol. 33, No. 2.

Joneja, D., L. Dynkin et al. (2005). *The Lehman Brothers Global Risk Model: A Portfolio Manager's Guide*, Fixed Income Research, Lehman Brothers, April 2005.

Analyst Certification(s)

To the extent that any of the views expressed in this research report are based on the firm's quantitative research model, Barclays Capital Inc. hereby certifies that the views expressed in this research report accurately reflect the firm's quantitative research model and that no part of its analysts compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed herein.

I, Arne D. Staal, hereby certify (1) that the views expressed in this research report accurately reflect my personal views about any or all of the subject securities or issuers referred to in this research report and (2) no part of my compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed in this research report.

Important Disclosures

On September 20, 2008, Barclays Capital Inc. acquired Lehman Brothers' North American investment banking, capital markets, and private investment management businesses. Historical and current disclosure information is provided via the two sources listed below.

https://ecommerce.barcap.com/research/cgi-bin/all/disclosuresSearch.pl or call 1-212-526-1072; http://www.lehman.com/USFIdisclosures/

Clients can access Barclays Capital research produced after the acquisition date either through Barclays Capital's research website or through LehmanLive. Barclays Capital does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that Barclays Capital may have a conflict of interest that could affect the objectivity of this report. Any reference to Barclays Capital includes its affiliates. Barclays Capital and/or an affiliate thereof (the "firm") regularly trades, generally deals as principal and generally provides liquidity (as market maker or otherwise) in the debt securities that are the subject of this research report (and related derivatives thereof). The firm's proprietary trading accounts may have either a long and / or short position in such securities and / or derivative instruments, which may pose a conflict with the interests of investing customers. Where permitted and subject to appropriate information barrier restrictions, the firm's fixed income research analysts regularly interact with its trading desk personnel to determine current prices of fixed income securities. The firm's fixed income research analyst(s) receive compensation based on various factors including, but not limited to, the quality of their work, the overall performance of the firm (including the profitability of the investment banking department), the profitability and revenues of the Fixed Income Division and the outstanding principal amount and trading value of, the profitability of, and the potential interest of the firms investing clients in research with respect to, the asset class covered by the analyst. To the extent that any historical pricing information was obtained from Barclays Capital trading desks, the firm makes no representation that it is accurate or complete. All levels, prices and spreads are historical and do not represent current market levels, prices or spreads, some or all of which may have changed since the publication of this document. Barclays Capital produces a variety of different types of fixed income research, including fundamental credit analysis, quantitative credit analysis and trade ideas. Recommendations contained in one type of research may differ from recommendations contained in other types, whether as a result of differing time horizons, methodologies, or otherwise.