Creating a Live Yield Curve
In the Illiquid Muni Market
- Andrew Kalotay -
# Real-Time US Treasury Yields

**Source:** Bloomberg

<table>
<thead>
<tr>
<th>Tenor</th>
<th>Description</th>
<th>Price</th>
<th>Yield</th>
<th>Source</th>
<th>Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>1M</td>
<td>B 0 07/20/17 Govt</td>
<td>0.832</td>
<td>0.845</td>
<td>BGN</td>
<td>15:32</td>
</tr>
<tr>
<td>3M</td>
<td>B 0 09/21/17 Govt</td>
<td>0.973</td>
<td>0.988</td>
<td>BGN</td>
<td>15:32</td>
</tr>
<tr>
<td>6M</td>
<td>B 0 12/21/17 Govt</td>
<td>1.103</td>
<td>1.124</td>
<td>BGN</td>
<td>15:32</td>
</tr>
<tr>
<td>1Y</td>
<td>B 0 06/21/18 Govt</td>
<td>1.190</td>
<td>1.218</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>2Y</td>
<td>T 1 3/4 05/31/19 Govt</td>
<td>99-25/8</td>
<td>1.350</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>3Y</td>
<td>T 1 3/2 06/15/20 Govt</td>
<td>100-00 3/8</td>
<td>1.499</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>4Y</td>
<td>T 1 3/8 05/31/21 Govt</td>
<td>98-27 3/4</td>
<td>1.673</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>5Y</td>
<td>T 1 3/4 05/31/22 Govt</td>
<td>99-28 3/8</td>
<td>1.771</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>6Y</td>
<td>T 1 5/8 05/31/23 Govt</td>
<td>98-14</td>
<td>1.904</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>7Y</td>
<td>T 2 0 05/31/24 Govt</td>
<td>100-02 3/4</td>
<td>1.987</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>8Y</td>
<td>T 2 3/8 05/15/25 Govt</td>
<td>100-13</td>
<td>2.069</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>9Y</td>
<td>T 1 5/8 05/15/26 Govt</td>
<td>95-28+</td>
<td>2.135</td>
<td>BGN</td>
<td>15:33</td>
</tr>
<tr>
<td>10Y</td>
<td>T 2 3/8 05/15/27 Govt</td>
<td>101-29 1/4</td>
<td>2.159</td>
<td>BGN</td>
<td>15:33</td>
</tr>
</tbody>
</table>

**Source:** Bloomberg
Real-Time UST Yield Curve

Source: Bloomberg
How About the Muni Market?

Large but illiquid
   Small issue sizes, little trading after issuance
   Trades reported within 15 minutes to regulator MSRB/EMMA

Common structure: Serial issue of 5% bonds, callable at par after 10 years (5% NC-10)
   Issued at a significant premium

No live yield curve
   Although needed for a wide range of purposes
Typical Recent Municipal Issue

<table>
<thead>
<tr>
<th>Maturity Date (October 1)</th>
<th>Principal Amount</th>
<th>Interest Rates</th>
<th>Yield-to-Worst Price</th>
<th>CUSIP†</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td>$1,155,000</td>
<td>5.000</td>
<td>2.280%</td>
<td>119.503</td>
</tr>
<tr>
<td>2025</td>
<td>1,440,000</td>
<td>5.000</td>
<td>2.560</td>
<td>119.258</td>
</tr>
<tr>
<td>2026</td>
<td>3,580,000</td>
<td>5.000</td>
<td>2.720</td>
<td>119.625</td>
</tr>
<tr>
<td>2027</td>
<td>3,775,000</td>
<td>5.000</td>
<td>2.870</td>
<td>118.199*</td>
</tr>
<tr>
<td>2028</td>
<td>3,965,000</td>
<td>5.000</td>
<td>2.970</td>
<td>118.199*</td>
</tr>
<tr>
<td>2029</td>
<td>1,885,000</td>
<td>5.000</td>
<td>3.050</td>
<td>116.515*</td>
</tr>
<tr>
<td>2030</td>
<td>1,975,000</td>
<td>5.000</td>
<td>3.130</td>
<td>115.776*</td>
</tr>
<tr>
<td>2031</td>
<td>7,430,000</td>
<td>5.000</td>
<td>3.200</td>
<td>115.133*</td>
</tr>
<tr>
<td>2032</td>
<td>7,970,000</td>
<td>5.000</td>
<td>3.260</td>
<td>114.586*</td>
</tr>
<tr>
<td>2036</td>
<td>1,095,000</td>
<td>5.000</td>
<td>3.390</td>
<td>113.411*</td>
</tr>
</tbody>
</table>

$19,685,000, 5.000% Term Bonds due October 1, 2035, Yield 3.380%, Price 113.501*, CUSIP 68608JWF4
$7,800,000, 5.000% Term Bonds due October 1, 2041, Yield 3.500%, Price 112.428*, CUSIP 68608JWH0
$16,510,000, 5.000% Term Bonds due October 1, 2046, Yield 3.530%, Price 112.162*, CUSIP 68608JWJ6

* Priced to the first optional call date of October 1, 2026.
Why 5% NC-10?

Issuers: Show large savings from refunding
  Call option at issuance is deep in the money
  Bonds are usually eligible for advance refunding

Institutional investors: Avoid undesirable mark-to-market treatment if rates rise
  Prices of bonds selling at a discount are further depressed by tax payable at maturity by marginal buyer
    Bonds issued at a high premium are unlikely to fall below par
Benchmark Curves Represent Yields of 5% NC-10 Bonds

Because 5% NC-10 is the standard structure
Used to be par NC-10

Curves distributed by several vendors, once or twice daily
MMA and MMD are best known
Bloomberg curve represents yields of 5% *optionless* bonds

Yields obtained by surveying major market participants and using trade data from EMMA
Process not transparent
Typical 5% NC-10 Yield Curve And Corresponding Prices
Problems with Callable Benchmark Curves

Fail to be arbitrage free: *Prices of 5% callable bonds should decline with maturity*

Increasing yields do not assure declining prices

Implied optionless (NCL) curve not credible: Smooth callable curve implies *kink in optionless curve*

Usage: Analysts fail to ‘strip out’ call option

Should use optionless curve

Results based on callable benchmark are misleading

*Examples follow*
Smooth Callable Curve Implies Kink in Optionless Curve
Smooth Optionless Curve Implies Kink In Callable Curve

![Diagram showing yield vs maturity for different scenarios.](image-url)
Spreads of Benchmark Bonds to Callable Curve Are Nonsensical
The AP/MBIS Yield Curves

Benchmark curve derived from ‘ask’ prices posted by several dealers for roughly 4,000 investment-grade bonds

- Bonds updated monthly
- Selection, prices, and curve construction fully documented
- Rigorous, automated process; uses CurviLinear™ methodology

Credit-specific and optionless curves also reported

Calculated and disseminated hourly

- Plans call for greater frequency

Distributed to financial institutions, the press, and to the public (by AP, via third party tools)
CurviLinear™ Methodology

1. Solve for *optionless par yield* curve that prices bonds as closely as possible to the input prices
   Multidimensional nonlinear regression using Google’s open source Ceres Solver

2. Derive 5% NC10 curve from optionless par curve
   YTW’s of fairly priced 5% NC10 bonds

All prices, including call option values, computed using standard bond analytics (*Black-Karasinski process with 15% vol, tax-neutral OAS*)

Work in progress:
- Improve fit by solving for par curve and volatility simultaneously
- Build volatility surface – by maturity and lock-out
  E.g. Vol of 5% bond maturing in 15 years callable in 8 years is 17.3%
Municipal Benchmark Curve

Powered by MBIS and Kalotay Analytics

Date: 07/06/2017  Curve: Benchmark  Rates as of 01:00 PM

AP Tax Exempt Municipal Benchmark Yields

Benchmark 5% Non-Call 10yr Curve
Municipal AAA N/C Curve

Powered by MBIS and Kalotay Analytics

Date: 07/06/2017  Curve: AAA N/C  Rates as of 01:00 PM

AP Tax Exempt Municipal AAA N/C Yields

AAA N/C Par Equivalent Non-Call Curve
In Summary

Muni market has lacked a live benchmark yield curve

Standard curves represent yields of hypothetical 5% callable bonds
  Opaque process, often defective and misused

New AP/MBIS curves are derived from ask prices of selected bonds across maturity spectrum
  Methodology transparent
  Currently updated hourly
  Approach allows for ongoing enhancements
    More frequent updates
    Interest rate volatility surface
Contact Information

Andrew Kalotay

andy@kalotay.com

(212) 482 0900