February 2025 | Whitepaper Update

SOLVE Px™

SOLVE's Proprietary AI-Driven Municipal Bond Predictive Pricing

SOLVE

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Executive Summary

In August 2024, SOLVE introduced SOLVE Px™, a one-of-a-kind artificial intelligence platform that accurately predicts the next trade price for over 900,000 municipal bonds. SOLVE Px™ is unique in its ability to leverage SOLVE Quotes™ data to create an accurate predictive price of a hypothetical trade (with the size and side determined by the user) for any active municipal fixed-rate bond, regardless of its liquidity. This unique feature makes SOLVE Px™ an invaluable tool for front-office municipal fixed-income professionals, enabling them to identify arbitrage opportunities and address the common lack of price transparency, even for illiquid bonds.

SOLVE is unwavering in its commitment to enhancing the accuracy and delivery of our predictive pricing. This paper presents an updated comprehensive overview of the model's methodology since its initial release, including construction, benchmarking, back-testing, and potential applications for market participants. SOLVE Px™ harnesses SOLVE's unique observable Quotes™ data, along with reference and trade data, to power AI models that incorporate several hundred feature inputs to generate size- and side-specific predictive prices. The impact of incorporating this proprietary data has been rigorously studied and measured in a **separate whitepaper**, demonstrating our continuous efforts to improve SOLVE Px™.

Methodology

DATA COLLECTION AND MODEL CONSTRUCTION

Data collection is fundamental to SOLVE Px. The model utilizes:

- **Real-time SOLVE Quotes™ Data:** Comprising bids and offers from market participants
- **Trade Data:** All trades reported in real-time
- **Reference Data:** Bond-specific reference data
- **Benchmark Curves:** Real-time treasury and AAA benchmark curves

SOLVE Px is designed to predict the next bid, mid, and offer trade for over 900,000 fixed coupon municipal bonds of any size, providing extensive market coverage. To do so, SOLVE Px uses Machine Learning ("ML") models that find patterns from a supervised set of input data. That dataset consists of reference data, trades, benchmark curves, and SOLVE's proprietary Quotes data. It's important to note that SOLVE uses trades of all sizes, and the ML model can interpret the pricing tendencies of the market as recognized from many millions of individual trades.

AI MODEL

The AI Model has two stages:
(1) the training stage and (2) the prediction stage.

During the training stage, the AI Model is retrained hourly each day using nearly 300 feature inputs to produce a size- and side-specific predictive price immediately prior to each trade. The model compares the predictive price with the actual trade price, and a raw and absolute difference between the trade price and the predicted price is measured. The model is calibrated to minimize the absolute error across all prediction/trade pairs through parameter tuning.

After the model is trained and optimized with the latest hourly calibrated parameters, the AI Model consumes real-time quotes, trades, benchmarks, and reference data to generate real-time predictive prices. It produces unique retail and institutional predictive bid, mid, and offer prices, associated yields, and spreads. As a result, SOLVE produces real-time and an hourly predictive next trade price ("Px"), for a typical retail lot size of $50,000 and a typical institutional price for a lot size of $1 million. These retail and institutional Pxs are available in SOLVE's application user interface, through various SOLVE data feeds, as functions in Excel, and via APIs available in SOLVE's Developer Portal. The model can also provide predictions at any hypothetical valid size and trade side, providing a tailored price for any unique situation.

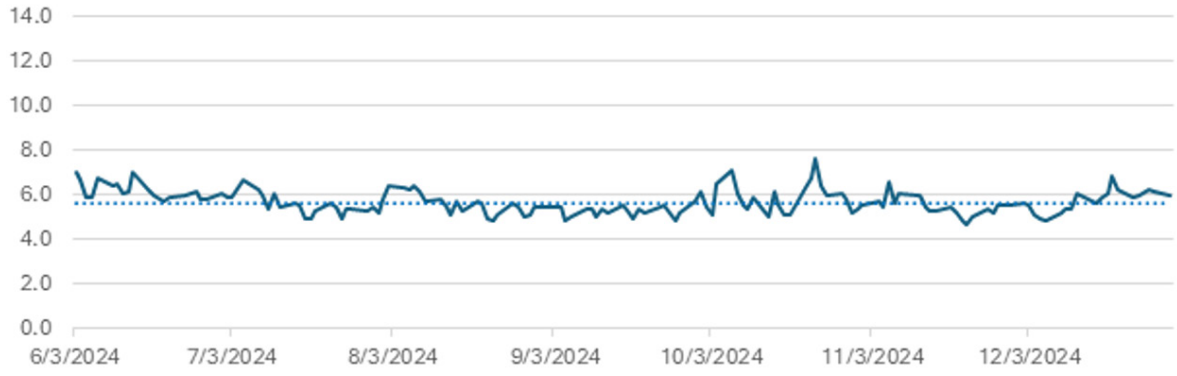
Results & Validations

MEDIAN OF ABSOLUTE ERRORS

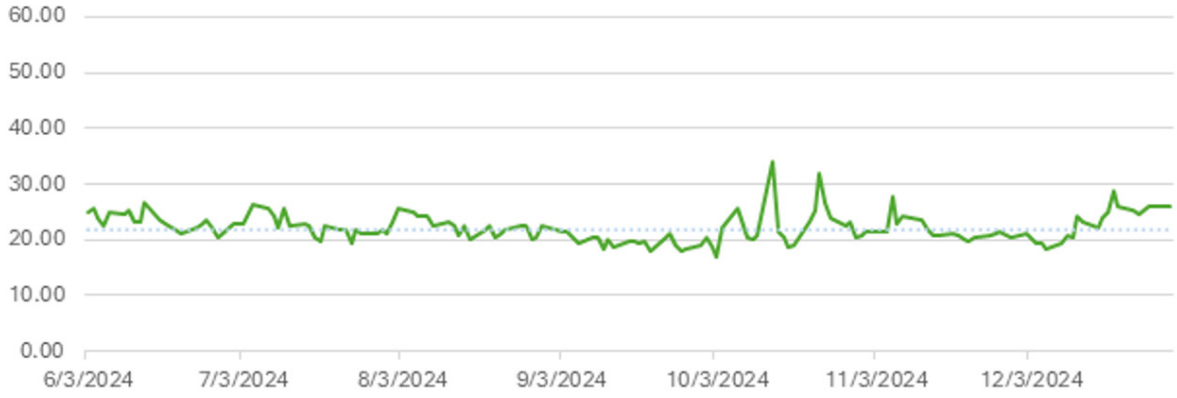
The SOLVE Px Prediction Model's primary goal is to minimize the absolute difference between the predicted price and the next trade level; this absolute difference is referred to as "error". Over the 146-business-day (7-month, 8.4m trades) back-testing period ending at YE 2024:

1. The median of all absolute yield errors was **5.7bps**
2. The median of all absolute price errors was **21.8 cents**
3. The bias was **under 1 cent**. The bias measures the average raw error for each trade-Px pair during the back-testing period.

Daily Median of Absolute Yield Error (in bps)



Daily Median of Absolute Price Error (in ¢)

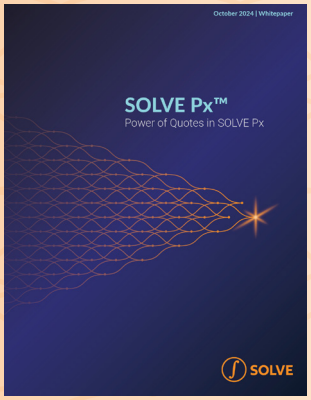


Note: I. Median absolute yield error excludes distressed securities and those to be repaid within 30 days (1.5% of all trades)
II. Median absolute price error calculations include all trades.

LIQUID VS ILLIQUID PERFORMANCE

When looking at prediction/trade pairs that had a preceding trade and quote on the same day, the error was lower than the universe at 4.3 bps compared to all bonds at 5.7 bps. **Interestingly, when Quotes are included in SOLVE Px, regardless of the existence of recent trade observations, error rates significantly decrease, demonstrating that the inclusion of Quotes in the AI Model materially improves prediction accuracy.**

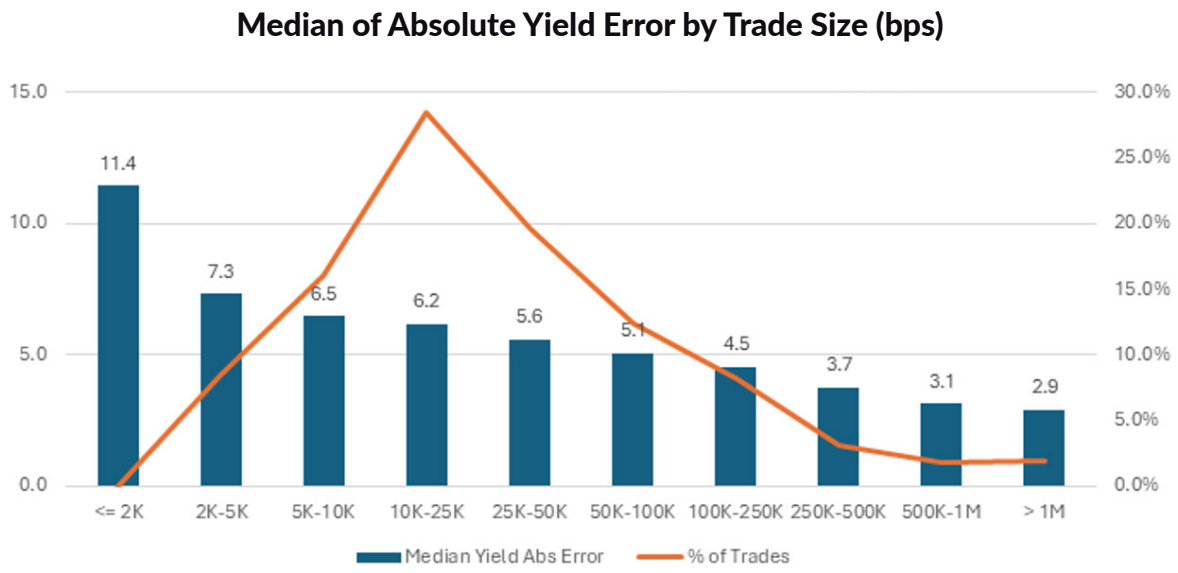
LIQUIDITY ANALYSIS								
	Median of Absolute Price Error				Median of Absolute Yield Error			
Time	Trade	Quote	Trade or Quote	Trade & Quote	Trade	Quote	Trade or Quote	Trade & Quote
≤ 1 Day	$0.201	$0.186	$0.195	$0.186	4.7bps	4.6bps	4.9bps	4.3bps
≤ 5 Days	$0.198	$0.188	$0.200	$0.182	4.8bps	4.6bps	5.0bps	4.3bps
All Days	$0.218				5.7bps			



*Please refer to our White Paper titled **"Power of Quotes in SOLVE Px"** for further information on Quotes' impact on SOLVE Px.*

TRADE SIZE ANALYSIS

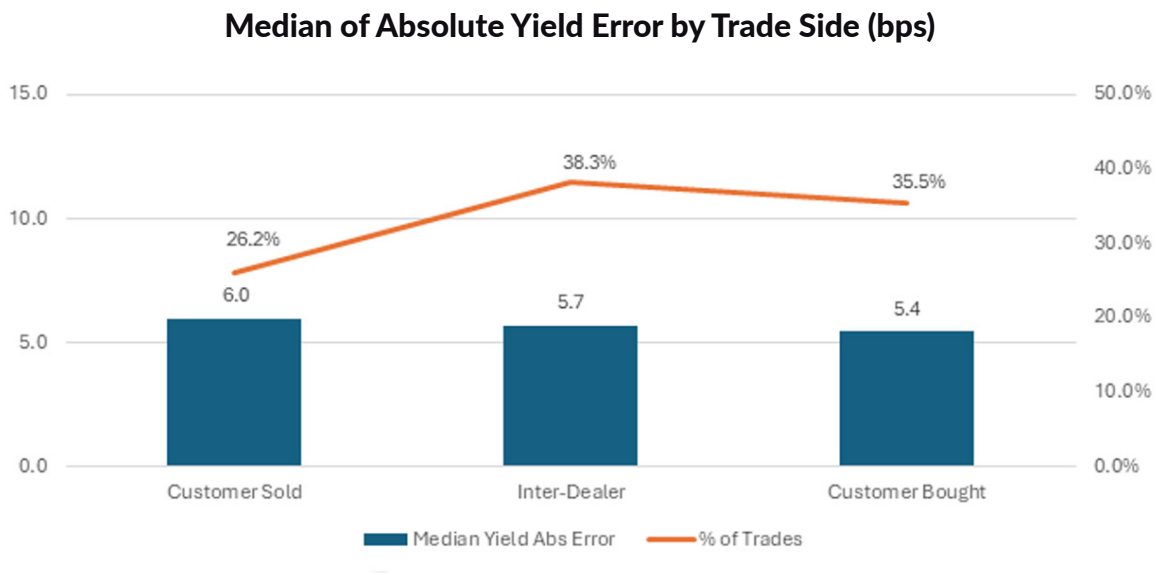
Our analysis reveals that error rates decrease consistently as trade size increases, with the lowest MAE found in trades greater than $1m face value. Unsurprisingly, the smallest retail trades (< $2,000) exhibited the highest error rates. Trades between $5k and $100k represented 76.4% of all trades during the back-testing period.



TRADE SIDE ANALYSIS

Error rates are also analyzed based on the side of the trade. Although the differences were subtle, the MAE for Customer-Bought trades was 0.6 bps lower than for Customer-Sold trades. This discrepancy can be attributed to two main factors. First, Quotes data is predominantly composed of offer-side indications. Second, offer-side prices are significantly influenced by the preceding customer-sold trade data.

The following chart illustrates the error rates by trade side:

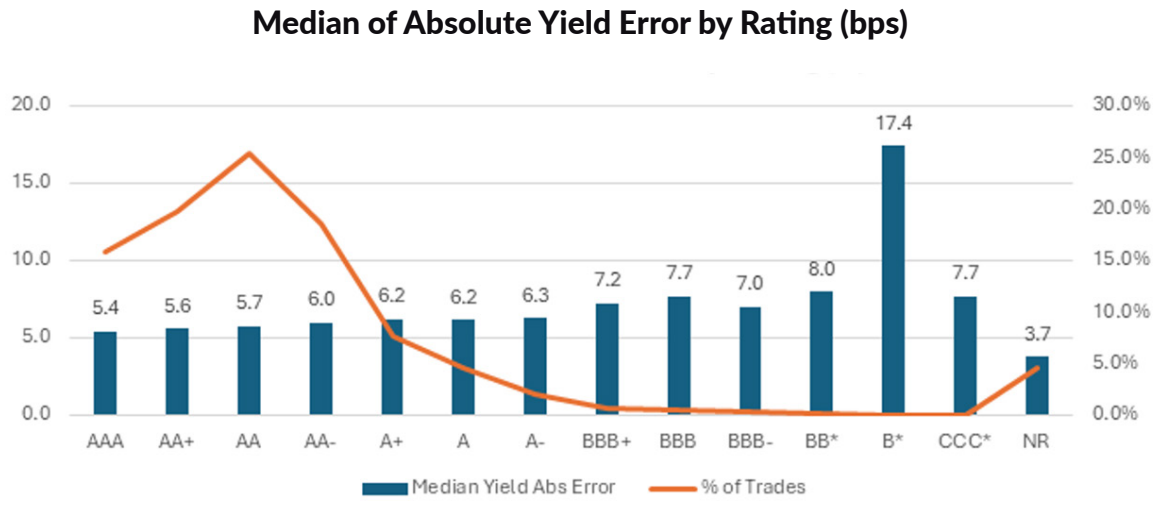


SOLVE considers trades of all sizes (institutional and retail) to extract and understand insightful data as part of our front-office pricing solution.

RATING ANALYSIS

We examined the MAE for trades across the spectrum of bond ratings. Higher-rated bonds exhibited the lowest error rates, while the lower-rated bonds had the highest error rates. Trades involving AAA-rated bonds had an MAE of just 5.4bps, with error rates increasing slightly as bond ratings worsened. Only 0.3% of trades fell into the High Yield (HY) category, compared to 95.2% in Investment Grade (IG) and 4.5% in Not Rated (NR). Interestingly, NR bonds showed the lowest MAE.

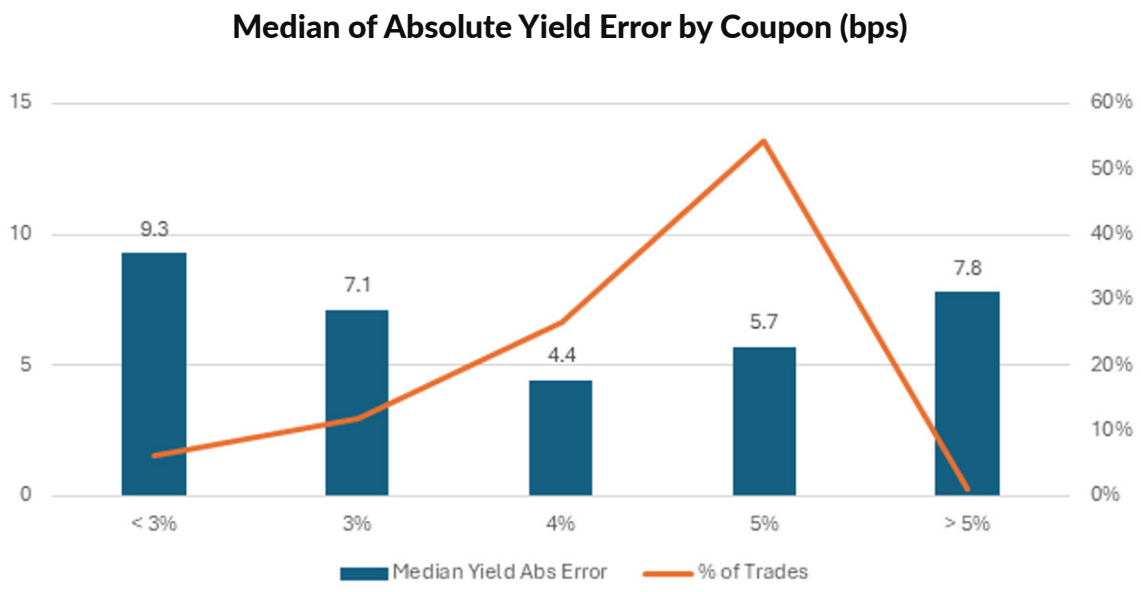
The following chart illustrates the error rates by bond rating:



COUPON ANALYSIS

Our analysis of MAE across bond coupons revealed that the lowest error rates were found in bonds with coupons ranging from 4% to 5.99%, which accounted for 81.0% of trades during the back-testing period. Bonds with coupons between 2.99 and 3.99% (3% category) represented 11.8% of all trades. Both very low and very high coupons exhibited the highest error rates.

The following chart illustrates error rates by Coupon:



STATE & TERRITORIES ANALYSIS

Our analysis of MAE across states found that the states of ID, TX, VA, DC, and UT had the highest prediction accuracy of under 5.2bps, aggregating to 16.0% of all back-testing trades.

The most significant errors were associated with U.S. territories of AS, VI, and MP, followed by the states of MS and MT, with all having low trade counts aggregating to less than 0.5% of all back-testing trades.

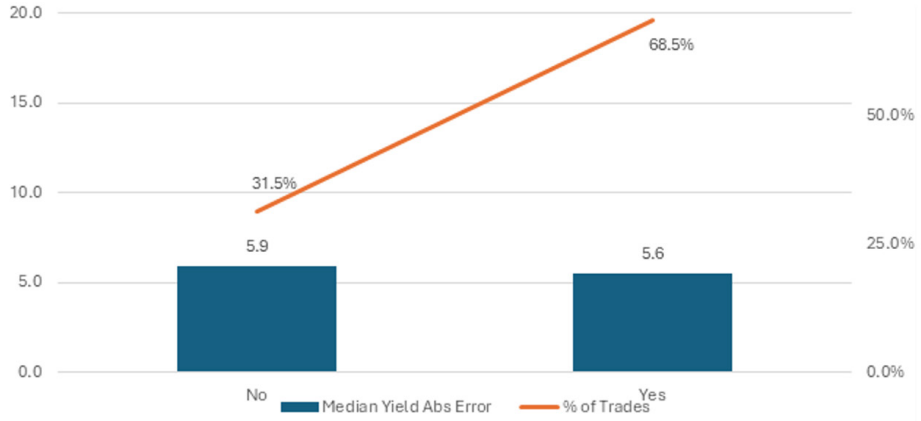
The following chart displays the distribution of number of States and territories by error rates:

Median of Absolute Error	# of States & Territories	States & Territories
≤ -5.5bps	14	AL, CO, DC, DE, GA, GU, ID, MD, NH, NV, RI, TX, UT, VA
> 5.5bps and ≤ 6bps	23	CA, FL, IA, IN, MA, ME, MI, MN, MO, NC, ND, NE, NM, NY, OH, OK, PR, SC, SD, TN, WA, WI, WY
> 6bps and < 7bps	16	AK, AR, AZ, CT, HI, IL, KS, KY, LA, MS, MT, NJ, OR, PA, VT, WV
> 7bps	3	AS, MP, VI

CALLABILITY ANALYSIS

Our analysis of callability revealed a 2-to-1 ratio of callable bond trades compared to non-callable bond trades during the back-testing period. Callable bonds were associated with slightly lower error rates primarily due to larger training data sets. The following chart illustrates the error rates by Callability:

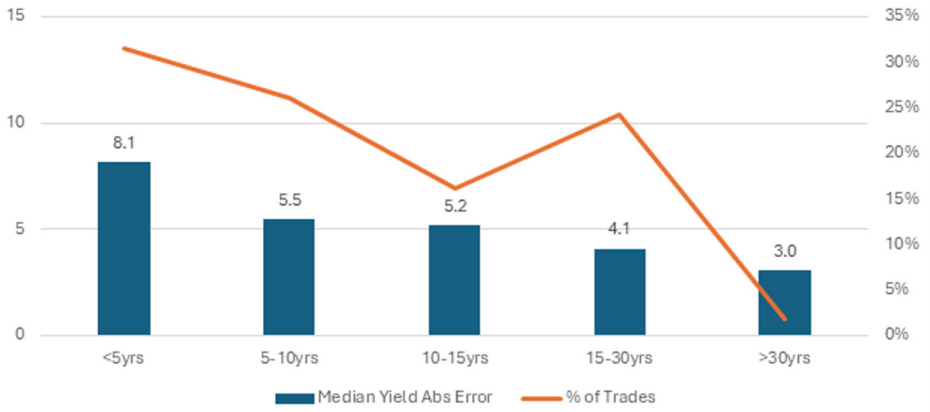
Median of Absolute Yield Error by Callability (bps)



MATURITY ANALYSIS

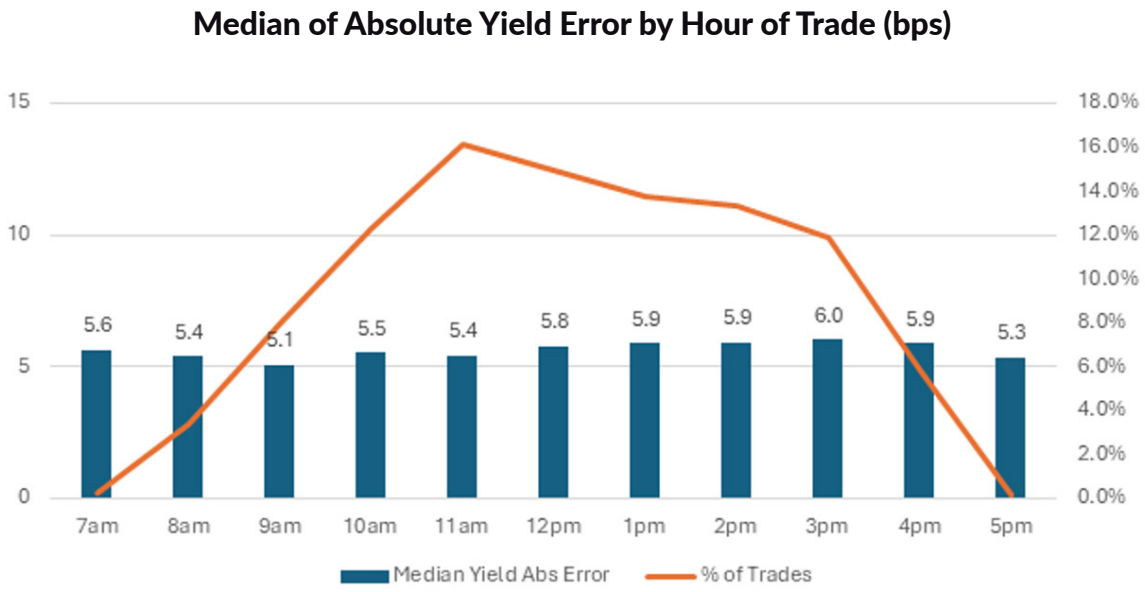
Our analysis of maturity revealed that error rates decrease as bond maturities increase. During the back-testing period, 58% of trades were for bonds with maturities inside of 10 years. The following chart highlights error rates by Maturity:

Median of Absolute Yield Error by Maturity (bps)



TRADE TIME OF DAY ANALYSIS

Our analysis of hourly trades reveals that 99.6% of trades occur between 8 am and 4:59 pm. Generally, we observe higher error rates in the afternoon, while the morning hours between 8 am and 11:59 am EST, exhibit lower error rates. This morning period is particularly significant as over 75% of daily Quotes data are received during this time, with 26% of daily Quote volume received during the 9am hour, significantly influencing Solve Px. The following chart displays error rates by the time of day for each back-testing trade:



Market Coverage

SOLVE Px predicts the next trade price for 900,000 fixed-coupon municipal bonds. This represents 99% of all live, fixed coupon bonds and over 93% of the entire universe of live municipal bonds. Bonds not priced currently include variable rates, floaters, zero coupon, and fixed coupon bonds that are missing critical reference data (e.g., missing coupon or maturity).

*SOLVE Px provides an unbiased ML-driven price designed and calibrated to best predict the next trade price based on size and side, including several hundred feature inputs for over **900,000 Municipal bonds**.*

Market Application

- **Pre-trade pricing insights:** Enhancing visibility into pricing before trades.
- **Independent pricing source:** Unique, independent pricing source using both trades and SOLVE's vast collection of market quotes.
- **Relative Value comparisons:** Facilitating value comparisons across bonds.
- **Client model input:** Serving as an external comparison metric or input for client models.
- **Size and Side-Specific Pricing:** Offering precise pricing data based on trade size and side.

SOLVE Px: Revolutionizing Predictive Pricing in Fixed-Income Markets

- **AI-Generated Predictive Pricing**
  Harnessing the power of advanced Artificial Intelligence (AI) and Machine Learning (ML), SOLVE Px dynamically responds to market dynamics in real-time, analyzing hundreds of critical data points to deliver precise pricing.
- **Superior Set of Quotes and Trade Data**
  SOLVE Px leverages exclusive SOLVE Quotes™ data, incorporating real-time bids and offers from market participants. Additionally, it integrates near real-time trade data from the MSRB, providing a comprehensive view of market activity.
- **Comprehensive Trade Consideration**
  As part of SOLVE Px construction, in addition to institutional trades, SOLVE Px takes retail trade levels into consideration.
- **Institutional and Retail**
  SOLVE Px delivers predictive pricing insights tailored for both institutional and retail trades, making it a versatile tool for diverse market participants.
- **Unmatched Precision and Accuracy**
  The core objective of SOLVE Px is to minimize the disparity between predicted prices and actual executed trade levels. Our continuous model enhancements ensure increasingly accurate pricing predictions.

Summary

- SOLVE Px provides an unbiased ML-driven price designed and calibrated to best predict the next trade price based on size and side, including several hundred feature inputs for over **900,000 Municipal bonds**.
- SOLVE Px is unique in that it includes SOLVE's proprietary Quotes data in addition to trade data to drive predictions with low error rates.
- SOLVE considers trades of all sizes (institutional and retail) to extract and understand insightful data as part of our front-office pricing solution.
- For the 7-month back-testing period, the median of all absolute yield errors was **5.7bps**, and the median of all absolute price errors was **21.8 cents**.

About

SOLVE is the leading market data platform provider for fixed-income securities, trusted by sophisticated buy-side and sell-side firms worldwide. Founded in 2011, SOLVE leverages its AI-driven technology and deep industry expertise to offer unparalleled transparency into markets, reduce risk, and save hundreds of hours across front-office workflows. With the largest real-time datasets for Securitized Products, Municipal Bonds, Corporate Bonds, Syndicated Bank Loans, Convertible Bonds, CDS, and Private Credit, SOLVE empowers clients to transform the way they bring new securities to market, trade on secondary markets, and value highly illiquid securities. Headquartered in Connecticut, with offices across the globe, SOLVE is the definitive source for market pricing in fixed-income markets.

For more information, visit **https://solvefixedincome.com**.

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