



SOLVE PxTM

Power of Quotes in SOLVE Px

Table of Contents

<i>Highlights</i>	3
<i>Executive Summary</i>	4
<i>Understanding SOLVE Market Data</i>	5
<i>SHAP Analysis Perspective</i>	12
<i>Final Summary</i>	13

Highlights

- ✔ **The depth and breadth of SOLVE's real-time quote database mean that well over 50% of trades that occur, are preceded by observable Quotes, resulting in material increases in model prediction accuracy.**
- ✔ **When Quotes are included in SOLVE Px, in the absence of trades, prediction accuracy improves by 34%.**
- ✔ **When Quotes are included in SOLVE Px, when trades also exist, prediction accuracy improves by 22%, demonstrating a synergistic and powerful relationship that leads to the most substantial reduction in prediction error.**
- ✔ **According to SHAP analysis, quote-related features contribute a substantial 40% to the prediction accuracy of SOLVE Px.**

Executive Summary

SOLVE has produced an artificial intelligence-driven predictive pricing platform that accurately predicts the next trade price for 900,000 municipal bonds. SOLVE Px™ leverages our unique observable market quotes data (SOLVE Quotes™), along with reference and trade data, to generate size- and side-specific predictive prices in real time.

Since the value of predictive pricing is intrinsically tied to its accuracy, SOLVE continuously examines the impact of various factors on the accuracy of the SOLVE Px output. This includes the AI and Machine Learning (“AIML”) models themselves, as well as the data that is used by those models. Since one of the key differentiators is the addition of our proprietary Quotes data, we aim to measure that data’s impact on the accuracy of the predictions.

This paper analyzes SOLVE’s proprietary Quotes data, evaluating its significance and impact on SOLVE Px. It examines the volume of Quote contributions, the accuracy of pricing with and without Quotes, and finally, the importance of quotes within the AIML pricing model.



Understanding SOLVE Market Data

SOLVE Market Data refers to SOLVE's proprietary collection of anonymized real-time bid and offer quotes aggregated from hundreds of market participants. SOLVE is the largest provider of real-time market Quotes and parses over 20 million Quotes from over 200,000 messages, representing 130,000 unique securities each day across all fixed income asset classes, including:

1. **Municipal Bonds**
2. **Corporate Bonds**
3. **Convertible Bonds**
4. **Syndicated Loans**
5. **Structured Products**
6. **Credit Default Swaps & Indices**

For Municipal Bonds, SOLVE's Daily Market Quotes volume is summarized below and compared with Muni Trade Data for Comparison:

Daily Stats	Unique Securities	Total Quotes /Trades
Muni Quote Data	54,100	426,800
Muni Trade Data	21,700	55,700

Average Daily Stats for Aug 2024

As illustrated above, there are approximately 2.5x more bonds quoted than traded each day, and nearly 8x as many market Quotes observed as trades observed each day.

Understanding SOLVE Market Data

Comparative Error Analysis with and without Quotes

In this section, we examine the difference between the SOLVE Px predictive price and the next actual trade level; this absolute difference is referred to as “error.” We compare these errors for bonds with recent Quotes leading up to each back-testing trade to those without recent Quotes in a “side-by-side” comparison. This comparison provides valuable insights into Quote recency and effectiveness in predictive price generation. We also analyze the recency of trade data leading up to each back-testing trade and its impact on SOLVE Px accuracy alone and when combined with Quotes.

*This analysis was performed using a **15** month, **310** business-day back-testing period that included over **16,000,000** trades (“back-testing trade”) paired with predictive prices immediately before each trade to determine error.*

Quote and trade recency were analyzed over several time intervals:

- a. Within 1 business day** – observations occur within 1 business day as the Px prediction back-testing trade
- b. Within 5 business days** – observations occur within 5 business days leading up to the Px prediction back-testing trade
- c. Within 20 business days** – observations occur within 20 business days leading up to the Px prediction back-testing trade

Important Definitions in Back-Testing Analysis

1. **Quote Only** – Refers to Px predictions where only Quotes were observed in the designated time interval (and specifically, no trades were observed) before the back-testing trade.
2. **Trade Only** – Refers to Px predictions where only trades were observed in the designated time interval (and specifically, no Quotes were observed) before the back-testing trade.
3. **Quote AND Trade** – Refers to Px predictions where both Quotes and trades were observed in the designated time interval before the back-testing trade.
4. **Quote OR Trade** – Refers to Px prediction where either a Quote or trade (or both a quote and trade) were observed in the designated time interval before the back-testing trade.
5. **No Quote/Trade** – Refers to Px prediction where neither a Quote nor a trade were observed in the designated time interval before the back-testing trade. Also referred to as **no observable pricing data**.

Note that the summation of back-testing trades that have (a) **Quote OR Trade**; and (b) **No Quote/Trade** will equal the total 16 million trade universe over the back-testing period.

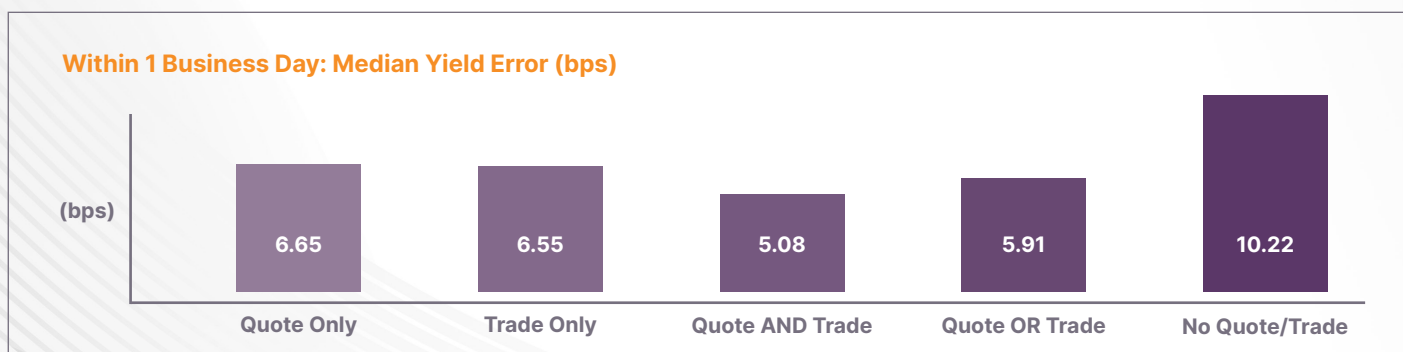
Understanding SOLVE Market Data

Within 1 Business Day Quote Comparison

Within 1 Business Day	Quote Only	Trade Only	Quote AND Trade	Quote OR Trade	No Quote/Trade
Median Yield Error (bps)	6.65	6.55	5.08	5.91	10.22
Median Price Error (\$)	0.24	0.26	0.22	0.23	0.37
Trade Count	3,611,526	2,783,902	4,926,748	11,322,176	4,791,946
% of Trades	22%	17%	31%	70%	30%

Within 1 Business Day Quote Comparison Summary:

- Quote only: When Quotes are included in SOLVE Px, where trades do not exist, error rates decrease 35% (from 10.22bps to 6.65bps)
- **Quote AND Trade: When Quotes are included in SOLVE Px, where trades also exist, error rates decrease by 22% (from 6.55bps to 5.08bps) thus demonstrating the synergistic benefit of Quote data coupled with trade data.**
- 53% of back-testing trades (8.5 million) had a Quote observation within 1 business day of the trade.



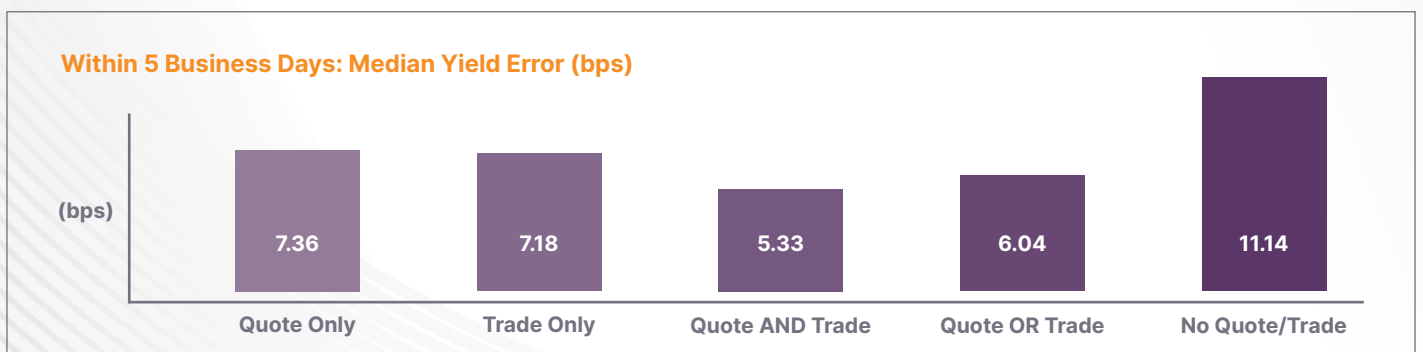
Understanding SOLVE Market Data

Within 5 Business Days Quote Comparison

Within 5 Business Days	Quote Only	Trade Only	Quote AND Trade	Quote OR Trade	No Quote/Trade
Median Yield Error (bps)	7.36	7.18	5.33	6.04	11.14
Median Price Error (\$)	0.27	0.27	0.22	0.24	0.39
Trade Count	2,014,050	2,959,298	7,467,982	12,441,330	3,672,792
% of Trades	12%	18%	46%	77%	23%

Within 5 Business Day Quote Comparison Summary:

- Quote Only: When Quotes are included in SOLVE Px, where trades do not exist, error rates decrease 34% (from 11.14bps to 7.36bps)
- **Quote AND Trade: When Quotes are included in SOLVE Px, where trades also exist, error rates decrease by 26% (from 7.18bps to 5.33bps) thus demonstrating the synergistic benefit of quote data coupled with trade data.**
- 58% of back-testing trades (9.5 million) had a Quote observation within 5 days before the trade.



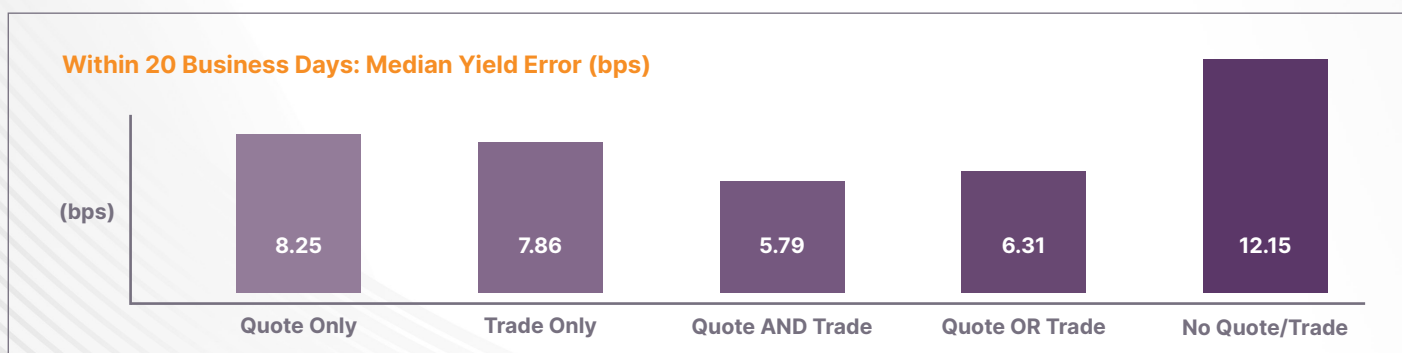
Understanding SOLVE Market Data

Within 20 Business Days Quote Comparison

Within 20 Business Days	Quote Only	Trade Only	Quote AND Trade	Quote OR Trade	No Quote/Trade
Median Yield Error (bps)	8.25	7.86	5.79	6.31	12.15
Median Price Error (\$)	0.31	0.30	0.23	0.25	0.42
Trade Count	729,694	2,938,760	10,029,018	13,697,472	2,416,650
% of Trades	5%	18%	62%	85%	15%

Within 20 Business Day Quote Comparison Summary:

- Quote only: When Quotes are included in SOLVE Px, where trades do not exist, error rates decrease 32% (from 12.15bps to 8.25bps)
- **Quote AND Trade: When Quotes are included in SOLVE Px, where trades also exist, error rates decrease by 26% (from 7.86bps to 5.79bps) thus demonstrating the synergistic benefit of quote data coupled with trade data.**
- 67% of back-testing trades (10.8 million) had a Quote observation within 20 days before the trade.





Comparative Error Analysis with and without Recent Quotes Summary

- 1. 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 AIML pricing model materially improves prediction accuracy.**
 - a. When Quotes are included in SOLVE Px, where trades do not exist, prediction accuracy improves by 34%.
 - b. When Quotes are included in SOLVE Px, where trades also exist, prediction accuracy improves by 25%, thus demonstrating a symbiotic and synergistic benefit leading to the most accurate predictions.

- 2. Quotes are available leading up to the majority of trades**
 - a. 67% of back-testing trades had Quotes within 20 days before the trade.
 - b. 58% of back-testing trades had Quotes within 5 days before the trade.
 - c. 53% of back-testing trades had Quotes within 1 business day of the trade.

SHAP Analysis Perspective

In this section, we utilize SHapley Additive exPlanations (“SHAP”) analysis to help explain the output of the AIML-generated SOLVE Px. By measuring the contribution of each of the several hundred feature inputs, SHAP analysis provides a detailed understanding of how each feature influences the final SOLVE Px prediction. Unlike correlation, which only indicates the global relationship across all data points, SHAP values offer insights at the local data point level, thereby enhancing the transparency and interpretability of the pricing model.

We conducted SHAP analysis daily over a three-month period (May-July 2024) to quantitatively identify and quantify the most significant features. Quote- and trade-related features represent 27% and 29%, respectively, of all features used in the SOLVE Px pricing model. Our findings focus on Quotes and trades to understand the relative importance of both.

The following table represents trade and Quote Feature importance:

Feature Importance	Quotes	Trades	Quotes & Trades
Average	39.3%	46.0%	85.3%
Median	40.3%	43.8%	84.2%

SHAP Analysis Summary

Based on the SHAP analysis:

- 1. Although quote-related features constitute 27% of all feature inputs, they account for approximately 40% of the prediction accuracy for SOLVE Px.**
- 2. Trade-related features represent 29% of all feature inputs, yet they represent approximately 45% of the prediction accuracy for SOLVE Px.**
- 3. Combined quotes and trades contribute approximately 85% of the prediction accuracy for SOLVE Px.**

- ✓ SOLVE Px significantly benefits from the inclusion of SOLVE's extensive and proprietary Quotes data, enhancing prediction accuracy.
- ✓ When Quotes are included in SOLVE Px, in the absence of trades, prediction accuracy improves by 34%.
- ✓ When Quotes are included in SOLVE Px, when trades also exist, prediction accuracy improves by 22%, demonstrating a synergistic and powerful relationship that leads to the most substantial reduction in prediction error.
- ✓ The depth and breadth of SOLVE's real-time Quote database mean that well over 50% of trades that occur, are preceded by observable Quotes, resulting in material increases in model prediction accuracy.
- ✓ According to SHAP analysis, Quote-related features contribute a substantial 40% to the prediction accuracy of SOLVE Px.
- ✓ Both the SHAP and Comparative analyses underscore the significant impact of quotes on prediction accuracy.

ABOUT

SOLVE is a leading market data platform provider for fixed income securities. Industry-leading firms trust the SOLVE Market Data Platform, powered by Deep Market Insight™, to reduce risk for securities investments and save hundreds of hours in pre- and post-trade research and validation.

CONTACT

SOLVE

600 Summer Street, Suite 503
Stamford, CT 06901

info@SOLVEfixedincome.com

www.SOLVEfixedincome.com

+1 646 699 5041



SCAN CODE
TO LEARN
MORE ABOUT
SOLVE Px