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FAIR VALUE MODEL PRICE

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This report introduces an automated, objective, transparent, near real-time model for fair value pricing for corporate bonds.

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1 Overview

For any liquid product or continuous financial marketplace, pre-trade transparency is readily available via real-time, central order books and tick-level prices. For an asset class like corporate bonds (which trade over-the-counter), liquidity should not be taken for granted since a central order book is often unavailable. Trumid believes a continuous pricing service that is both reliable and objective will improve liquidity by providing a consistent source of pre-trade transparency. For this reason, we are introducing the Trumid Labs Fair Value Model Price (FVMP). Trumid Labs' Fair Value Model Price is an adaptive model that produces a price for approximately 22,000 corporate bonds every five minutes based on price movements from multiple data sources, including the Trumid Market Center platform. In this paper, we discuss current pricing methods and Trumid's approach to pre-trade price transparency. We also frame what we believe is the best method to assess model performance.

2 Current Pricing Methods

There are two (2) dominant approaches to intraday corporate bond pricing: matrix pricing and evaluated pricing. Matrix pricing is an estimation technique based on a group of bonds with similar characteristics. Usually, the bonds chosen have comparable credit quality but exhibit greater liquidity or have traded more recently than the target bond being priced. An average yield to maturity is computed as a proxy for the bond in question. The present value of this yield is then computed. Matrix pricing offers a rough price estimate that is easy to compute for illiquid bonds. These prices are useful for back-of-the-envelope exercises but are not precise enough to inform trading. The quality of the estimate depends entirely on the choice of proxy bonds: choose the wrong bonds and get a poor estimate. Interestingly, shorter duration bonds are more sensitive to price uncertainty with matrix pricing. Large, uncorrelated moves in a proxy may distort the imputed yield, as well as introduce unjustified correlations. For matrix pricing to be credible, a clear and objective approach to selecting proxy bonds is necessary.

Evaluated pricing (EP, or similarly, continuous evaluated pricing [CEP] for intraday) aims to make price estimates more rigorous and defensible by combining a strict methodology with human evaluators. Evaluated pricing builds on matrix pricing by utilizing TRACE™ prints, broker/dealer quotes, and new issue data, in addition to data for comparable securities. Human evaluators apply weights to these inputs in order to compute a spread over a benchmark. The final price is then backed out from the imputed yield. The role of the evaluator in this process is to make adjustments throughout the day, or to address complaints when a price is challenged by a consumer of the feed. A significant shortcoming of EP becomes apparent when one examines the enormity of the corporate bond universe. With over 40,000 USD-denominated corporate bonds, scalability and consistency of rigor become difficult for any human-driven-process. The sheer quantity of tradable corporate bonds makes accurate pricing much more difficult, and the establishment of continuous liquidity over the range of securities becomes untenable. Given these characteristics, a model-based approach seems prudent.

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3 FVMP Methodology

Like the prices of other securities, bond prices are affected by numerous factors. One reason human evaluators are used to price bonds is to account for influences from exogenous markets such as equities, credit default swaps, and interest rates. FVMP automatically integrates exogenous information, removing the need for a human's judgement. Simply, FVMP is able to be more consistent, objective, and responsive to market movements than human-evaluated prices. FVMP uses both endogenous and exogenous market data to produce a single, defensible price per bond. The model is built around a customized Kalman filter[1] that integrates these data sources into a single fair value price.

Built from the ground up, Trumid's implementation takes into consideration bond-specific factors, such as trade size and external markets. The model dynamically weights inputs so leading information is held in higher regard than trailing information. Similarly, newer information is given more weight than older information. These novel approaches help Trumid achieve consistent performance across the corporate bond universe.

Models are only as good as the data that feed them. Data errors can take many forms, from duplicate records, to incorrect quoting conventions, to outright cancel/corrects. It can be expensive to identify and correct errors. Trumid addresses this problem with a machine learning classifier that identifies bad market data. Trained independently for each data source, the classifier learns the types of errors present in each feed and rejects those predicted to contain error criteria. This approach significantly improves the accuracy of FVMP as compared to other models. To illustrate, Trumid's cleaning algorithm on leading market data improves FVMP accuracy 10%-25%, depending on the cohort. For Investment Grade bonds, a 25% improvement is achieved (refer to the companion paper on cleaning market data using machine learning classifiers for more detail).

4 Measuring Model Performance

End of day EP models measure performance based on the price of the next trade. Trumid calls this the next trade metric (NTM), which has a variable time period between estimate and realized price. Even some CEP products exhibit the same behavior. The reason is that some prices under EP are either event-driven or scheduled. Prices only update when a trade is reported over TRACE or at a predetermined time(s). The time until the next trade is indeterminate, and the longer the time, the less accurate the previous price is. This is a fact of life in any forecast, as illustrated in Figure 1.

1 An introduction to Kalman filters can be found at: http://www.cs.unc.edu/~tracker/media/pdf/SIGGRAPH2001_CoursePack_08.pdf

10D PRICE FORECAST

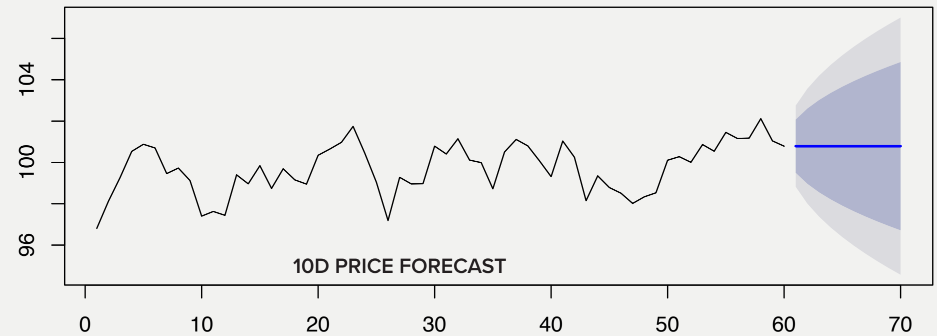

FIGURE 1: Simulated bond price with 10 day price forecast. The uncertainty of the forecast grows over time. As liquidity decreases, the accuracy of event-based pricing degrades quickly.

FVMP does not solely rely on TRACE, so updates happen more frequently. Regular updates occur no less than once every five minutes. The update frequency ensures the interval between any FVMP update and a TRACE print is never more than five minutes. This allows each FVMP value to provide a more comprehensive and reliable estimate than competing pricing methods at a particular given time. By comparing and measuring the difference between any recent TRACE print and the prior FVMP value of that bond, Trumid is able to calculate the absolute error of each estimate. Trumid calls this approach the regularized next trade metric (RNTM), to highlight the time regularization of the price series by FVMP.

5 FVMP Accuracy

Trumid FVMP achieves competitive performance across the corporate bond universe. Table 1 shows the performance of FVMP using RNTM for a nine month backtest. At the 95th percentile, the absolute error of FVMP is typically under 1 point. For example, for high yield bonds, FVMP is within 0.82 of the next TRACE print 95 percent of the time. Investment grade bonds show FVMP within 0.55 points 95% of the time. Even for distressed bonds, FVMP is within 1.36 points at the 95th percentile. While this is wider than for other groups of bonds within FVMP, the error is less than the spread of leading bid/offer quotes (at 2.984 points) and the spread in TRACE between dealer-client buy/sell, which is 1.964 points. Over time, the performance of FVMP is stable. Figure 2 shows weekly absolute errors since the beginning of the year. A recent report found that Interactive Data Corporation's CEP product results in ~0.5 point of absolute error for trade sizes over $1 million, 80% of the time.[2] At the 80th percentile, the absolute error of the FVMP model is 0.351 points, and when looking only at $1 million or greater trades between dealers the error improves to 0.276 points. Trumid will continuously assess the performance of FVMP and research ways to improve the model. Backtesting results are updated monthly and posted to https://www.trumid.com/Labs.html.

2 "Corporate Bonds: The Price is Right," © 2015 The TABB Group, LLC

Dimension	Cohort	Bonds	Trades	95% Abs. Error
Credit quality	Investment grade	8361	138106	0.548
Credit quality	High yield	3237	82037	0.816
Company health	Healthy	11224	208604	0.612
Company health	Distressed	374	11539	1.361
Issue amount	< 500mm	5195	37258	1.021
Issue amount	500mm - 1b	3898	69489	0.691
Issue amount	1-2 billion	1929	71126	0.549
Issue amount	> 2 billion	576	42270	0.435
Time since issuance	0-1 year	3029	89158	0.513
Time since issuance	2-3 years	3375	63602	0.612
Time since issuance	3-5 years	2520	39636	0.770
Time since issuance	5+ years	2674	27747	0.990

TABLE 1: FVMP performance using RNTM from December, 2016 through August, 2017. RNTM was measured for 1MM + interdealer trades.

6 Alternative NAV Calculations

To further demonstrate the accuracy of the model, Trumid used FVMP as an estimate of the intraday NAV for the bond ETFs LQD and HYG. Trumid believes the NAV calculations suffer from the same liquidity challenges as individual bonds. It is therefore difficult to obtain a reliable intraday NAV estimate. Since FVMP generates a new price every five minutes, a NAV for the ETF (or any basket of bonds) may be computed on demand, in near real-time.

To begin, Trumid computed the end of day FVMP NAV estimates, which are closer to end of day prices of the ETFs than traditional NAV calculations. The FVMP-based NAV also removes the underestimation bias typical of traditional NAV calculations. Trumid then compared six months of price and NAV data for LQD and HYG. Table 2 shows the increased accuracy of FVMP compared to traditional NAV calculations.

For intraday NAV estimates, Trumid normalized the ETF price into five-minute intervals. Trumid then compared each FVMP NAV estimate to the corresponding price. Using the next ETF price as a comparison point, the FVMP NAV estimate showed absolute error of 0.46 points at the 95th percentile for HYG. Despite being an intraday measure, the performance is only a few basis points worse than the end of day performance. The same is true of LQD, which has an intraday absolute error of 0.30 points at the 95th percentile. These statistics show how FVMP can be reliably used for a variety of real-time pricing applications.

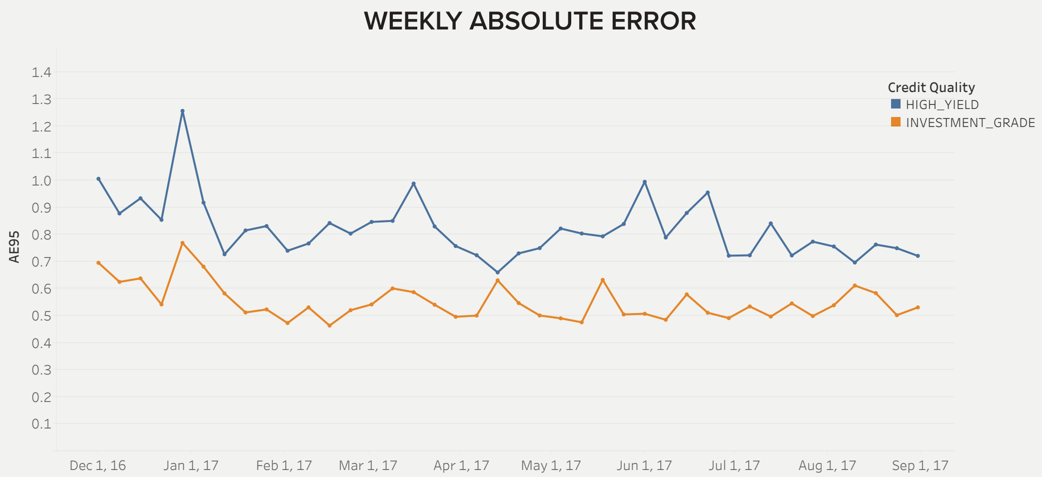

FIGURE 2: RNTM 80% error over time.

		End of day		Intraday
ETF	Model	μ_ϵ	95% $\lvert\epsilon\rvert$	95% $\lvert\epsilon\rvert$
LQD	NAV	-0.222	0.369	NA
LQD	FVMP	-0.044	0.261	0.303
HYG	NAV	-0.248	0.456	NA
HYG	FVMP	0.003	0.435	0.459

TABLE 2: Six month backtest comparing NAV to price and FVMP-based NAV to price.

7 Conclusion

Trumid Labs' FVMP is a new source of intraday bond prices that is automated, objective and highly accurate. A small subset of the tradeable universe in the corporate bond space trades frequently enough to be considered genuinely liquid. Trumid believes a credible source of continuous bond pricing like FVMP will help spread activity across an increased subset of bonds through improved pre-trade transparency. FVMP performance in our backtesting is strong, yielding estimates within prevailing bid-offer context at a 95% confidence interval.

The model is available for public use on the Trumid website, and backtesting results are updated each month. We are excited about the addition of Trumid Labs' FVMP to our family of products and services.

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