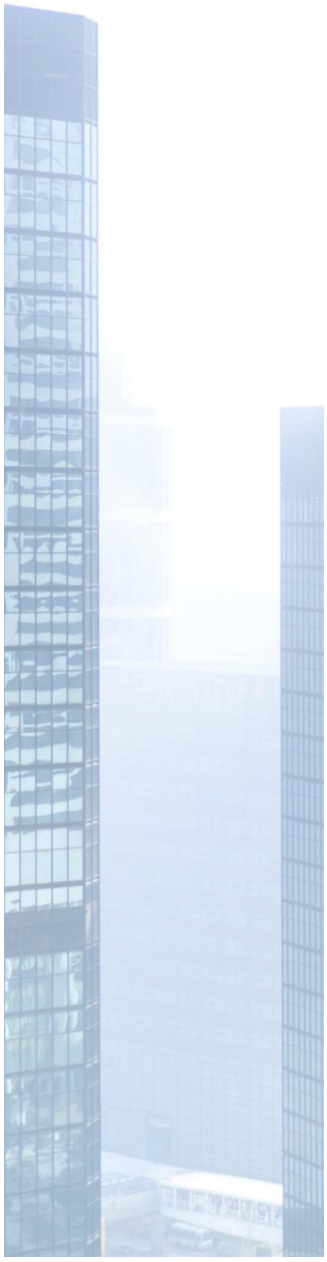
Bond Pricing AI

Liquidity Risk Management Analytics

www.overbond.com



Overbond

Fixed Income Artificial Intelligence

The financial services market is embracing digital processes and artificial intelligence applications to streamline how they do business. Bond origination and bond OTC trading are one of the few areas which have a great need to embrace the trend. The current fixed income capital market data flows are inefficient in many respects, limiting precision in assigning proper value to credit risk long term. Markets remain heavily reliant on segregated and manual data operations between counterparties and as a consequence, disparate data sets. These disparate data sets cause the market to suffer from information asymmetry and decentralization. As a result, insight from available data is fragmented and disseminated through manual exchanges between counterparties, which furthers creation of disparate data sets.

Need for centralization of information

There is a great need for a fixed income big-data centralization where advanced analytics such as price discovery, liquidity risk management, intelligence gathering, pre-trade and post-trade analytics can be performed – to increase the overall efficiency of the fixed income market and understanding of the credit risk valuations. With no centralized hub, issuers and investors operate with partial awareness. AI application utilizing deep historical data records of fundamental data elements (audited statements, dealer supplied primary bond price quotations etc.) and secondary market bond trade points can solve this problem. With this, Overbond pioneered to be the first to market with a centralized big-data hub powered with AI capabilities for fixed income analytics.

Overbond AI Focus Areas:

Price and Liquidity Discovery – Predictive price trending analytics in different liquidity buckets and tools and integrated machine-learning modules provide a reduction in credit pricing risk, enabling systematic monitoring of credit pricing tension covering large universe of issuer names as well as monitoring of likely new bond issuances.

Demand-side Pricing Validation – Buy-side investor canvassing and systematic demand feedback capabilities that are calibrated with Overbond AI models and translate into improved ability to develop and apply custom AI models to precisely determine credit risk valuations, traditional and non-traditional buyer prospects and utilizing proprietary investor preference and market sentiment signals to price illiquid securities.

Automated Information Systems – Integration and tailored analysis of historical and new indicative pricing data flows empowers trading, portfolio management and deal analytics for optimal decision-making.

Custom AI Solutions

The Overbond platform delivers on these focuses by employing state of the art visualization modules on the front end and its proprietary AI engine, the Corporate Bond Intelligence (COBI) tool. Overbond's Primary Fixed Income Pricing model, COBI-Pricing, delivers on Price Discovery with competitive indicative new issue pricing. Clients can arrive at accurate indicative new issue pricing levels for issuers with only a fraction of the time and manual work required. Through this, clients can mitigate risk, increase efficiency and generate portfolio alpha.

AI Powered Bond Pricing

COBI-Pricing was created as part of Overbond's suite of predictive algorithms for the fixed income capital markets. It algorithmically predicts the most optimal indicative new issue bond price as well as relative value secondary market bond price for global IG and HY issuers, utilizing machine-learning (ML) algorithms. The ML algorithms analyze millions of data points related to factors such as secondary levels, recent indicative new issue price quotations, company fundamental data elements, investor sentiment and sector comparables. Data is aggregated from multiple types of data sources including:

Bond market data	Transactions occurring in the secondary market, and historical issuance spreads
Investment banking data	Fundamentals on corporations, their balance sheet indicators, proprietary data sets treasury groups of the corporations themselves had on file such as dealer quotations and trade points
Proprietary data	Direct access to large community of issuers and institutional investors via established feedback loops

AI Advantage over Statistical methods

COBI-Pricing AI modeling techniques share many similarities with classic statistical modeling techniques starting from the fact that they both deal with data. However, the key difference, between statistical techniques and AI models Overbond applies is in the goal of these approaches. While statisticians start with a set of known assumptions that are given to the model and best explain the expected behavior of the financial outcome in consideration, AI techniques rather aim at finding by themselves the method (with underlying assumptions that are unknown) that best predicts the outcome in consideration.

Clients can use bond pricing feed for custom analysis

The predictive time horizon the COBI-Pricing algorithm in standard use cases is optimized from daily-trending to weekly prediction on new issue indicative price. Price is assigned for each company in each issuance tenor and yield curve is constructed. COBI-Pricing can systematically price large number of liquid and illiquid securities and issuer names and identify pricing tension metrics across large coverage book systematically.

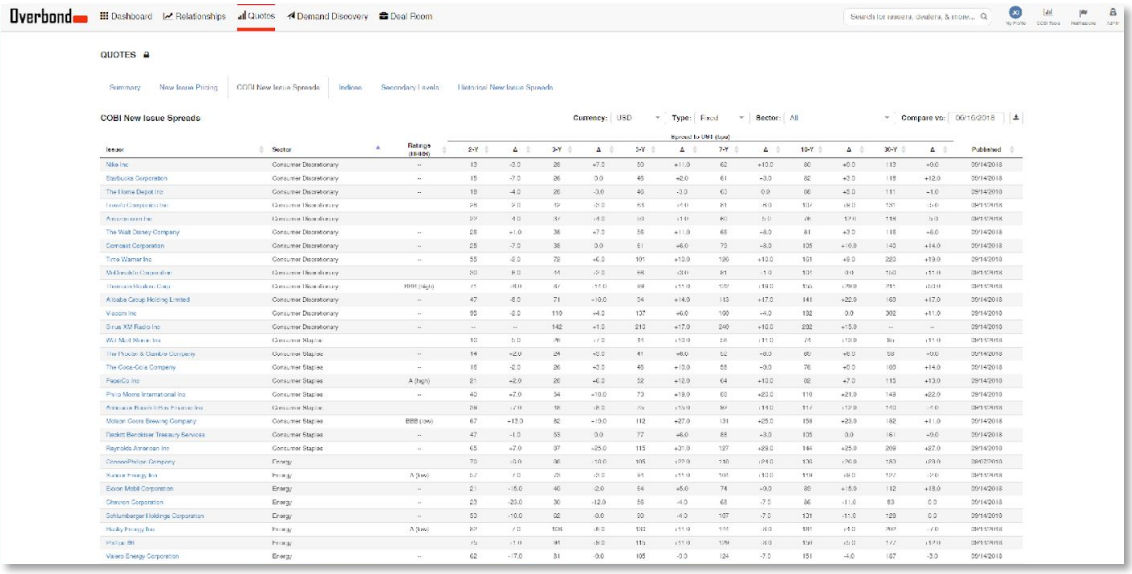
COBI-Pricing Output

COBI-Pricing AI output (data-feed) can be refreshed near-real-time or on a weekly basis depending on the user need. COBI-Pricing runs on the big-data set sourced from Overbond data lake covering the entire universe of bond issuers. Overbond product team works with clients to customize coverage baskets based on portfolio strategy or trading style, models are then trained and back tested utilizing all data sources. The COBI-Pricing output can be integrated into a data feed, presented as custom visualization, or viewed on the Overbond Platform as downloadable table.

Output Schema for Apple – US$

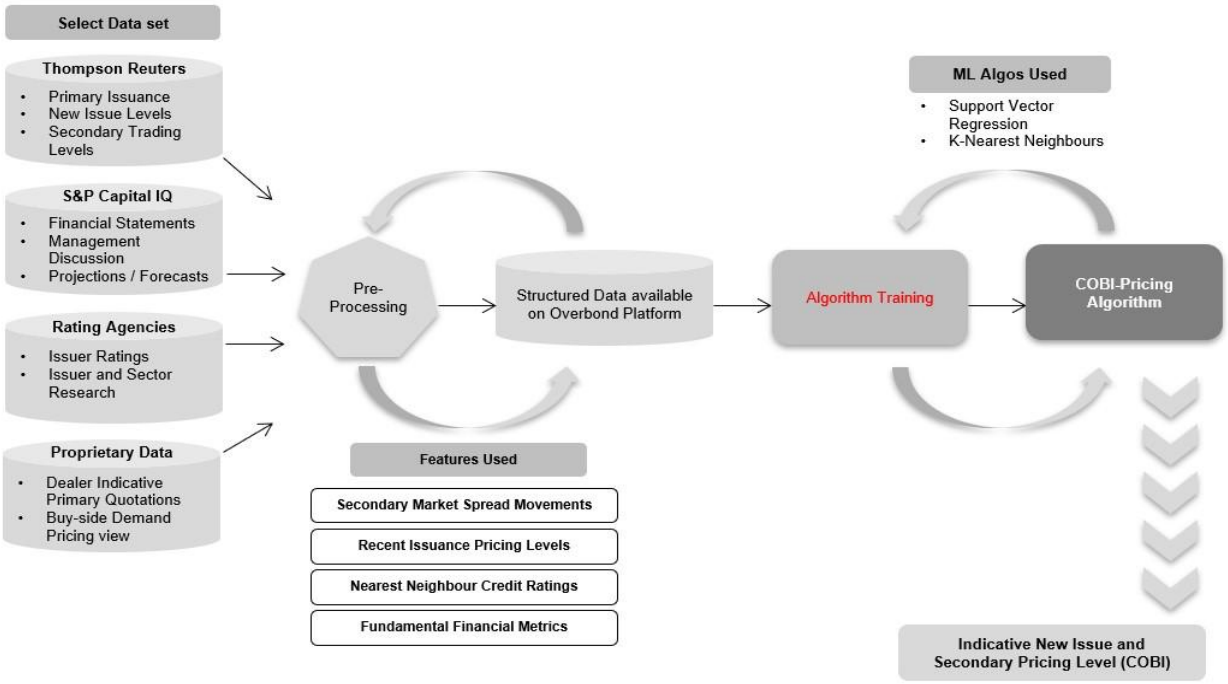
	3 Year	5 year	7 Year	10 Year	30 Year
Underlying UST Yield	2.69%	2.76%	2.83%	2.86%	2.97%
Average Spread to UST	35 bps	52 bps	70 bps	83 bps	111 bps
Re-Offer Yield	3.04%	3.28%	3.53%	3.69%	4.08%
Average Comparable Spread	37 bps	56 bps	65 bps	80 bps	108 bps

Output Visualization for Designated Portfolio



How COBI-Pricing Algorithm works

The diagram below and the following paragraphs provide a description of how the Overbond COBI-Pricing algorithm works.



Data Intake & Pre-processing

The Overbond platform sources raw trading and fundamental data via automated nightly scripts. Our data sources include Thompson Reuters (secondary bond issuance and trading levels), S&P Global Market Intelligence (company level fundamental data), Rating agency composite (company ratings and macro market data), as well as various other sources. Overbond sources proprietary data, aggregated and anonymized dealer quotations from a community of large IG issuers, and investor preferences through direct feedback loops.

This raw data is then structured in the Overbond databases. Trading data and fundamental data are structured and mapped to the appropriate issuer ID. The data is systematically scrubbed for anomalies and null values. Finally, a set of key input factors are generated based on the raw input. These include but are not limited to factors that measure secondary market spread movements, recent issuance pricing levels, nearest neighbor credit ratings and fundamental financial metrics. These factors are divided between sector and company specific and are used as inputs to the machine learning models.

Model Training

The subsequent stage for the machine learning algorithm is to train and apply several models to calculate the output pricing levels. An Ensemble Learning strategy is used in three phases, meaning multiple models are combined to elevate overall robustness at each training stage. These models are each trained using a subset of the past data, ranging from one day, one month to a maximum of ten years. Advanced sampling techniques were used to account for data gaps for illiquid issuers in order to construct yield curves for all tenors and all issuers in coverage universe.

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COBI-Pricing Data Intake

The successful data pre-processing is the key stage and pre-requisite for the COBI-Pricing algorithm operation. The precision of the algorithm output is critically dependent on the accuracy, timeliness, and relevance of the pre-processed input data. Overbond sources raw data from major data suppliers in the financial sector, including Thomson Reuters, S&P Global Market Intelligence, major credit rating agencies, as well as other sources. The data COBI-Issuance Propensity algorithms use includes the following:

Pre-processed Data	Source	Update Frequency	Relevance
Secondary market spread movements	Thompson Reuters	Interday	The closing prices of companies' bonds are used to measure spread movements and the current cost of funding for all companies in the coverage universe.
Recent issuance pricing levels and dealer quotations	Thompson Reuters and Proprietary Network	Interday	At issuance securities pricing levels allows for comparison of at issuance pricing versus first 5 days of trading. Primary dealer quotation averages allow for model calibration with respect to pre-issuance quotations and supply-demand metrics versus at issuance and post issuance price performance.
Nearest Neighbour Credit Ratings	Thompson Reuters, DBRS (Canada)	Weekly updates, quarterly filing cadence	Issuer's past bond issuances and their ratings as well as composite rating for the issuer overall indicate the company's risk level and benchmarking category. They are used to train the models and to back-test the accuracy of COBI-Pricing output.
Fundamental Financial Metrics	S&P Global Market Intelligence	Weekly updates, quarterly filing cadence	The company's fundamental financial data is an indicator of the company's credit-worthiness, and by extension, their cost of borrowing across tenors. In addition, fundamental metrics indicate the liquidity need of the company and its short term need to raise financing as well as leverage ratios. The financial profile of a company aids with clustering analysis of companies with similar characteristics.

COBI-Pricing Model Training for Different Liquidity Buckets

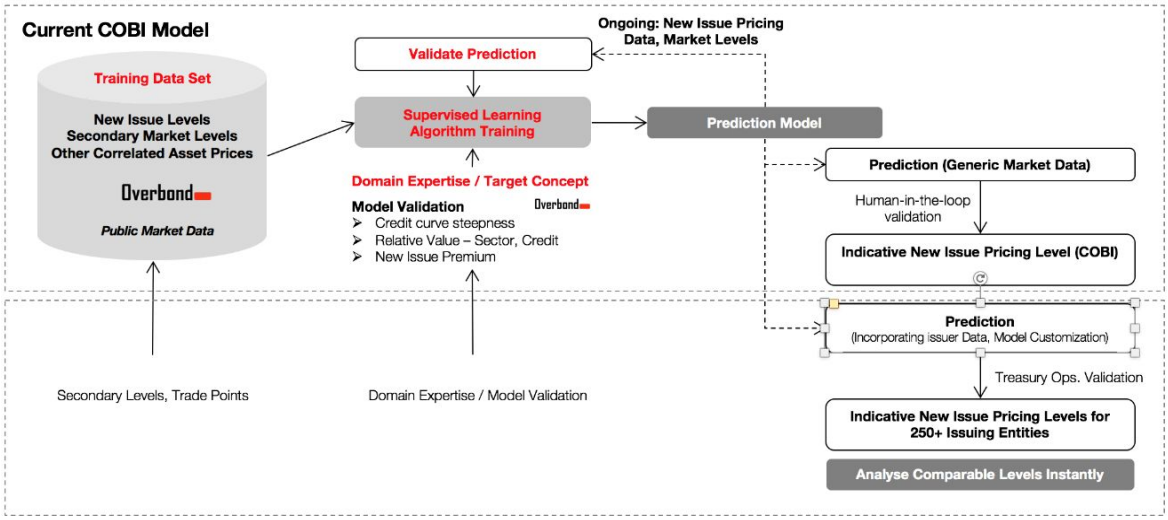
COBI-pricing is an advanced three-phase AI algorithm engineered to measure best-fit correlations with respect to company fundamental valuation and secondary market pricing for their bonds across sector peers and markets conditions at large. Models are tuned for different liquidity scenarios. A variety of pre-processed inputs flow into COBI-Pricing's algorithm, to generate bond pricing output.



The **first phase** of the algorithm generates indicative new issue pricing curves for a list of companies specified by a domain expert. This list contains companies from diversified sectors and are frequent issuers with liquid outstanding secondaries (High Issuer). Curves are created with Support Vector Regression on all secondary trades for the previous trading day. The Issuer should have a minimum number of bonds outstanding and minimum number of trades in secondary market for the algorithm to build a curve. These minimum thresholds can be hyper-tuned as required to fit client needs.

The **second phase** uses a K-Nearest Neighbors algorithm to generate indicative new issue pricing curves for issuers with illiquid or insufficient secondaries (Low Issuers). Peers for each Low Issuer are identified using a score based on fundamental financial metrics, credit ratings, secondary spreads, and issuances. The top three High Issuers with the lowest blended score vis-à-vis a Low Issuer are classified as the peer set. The secondary data from the top three peers, along with the secondary data from the Low Issuer, is used to form a enhanced dataset for phase three to build curves.

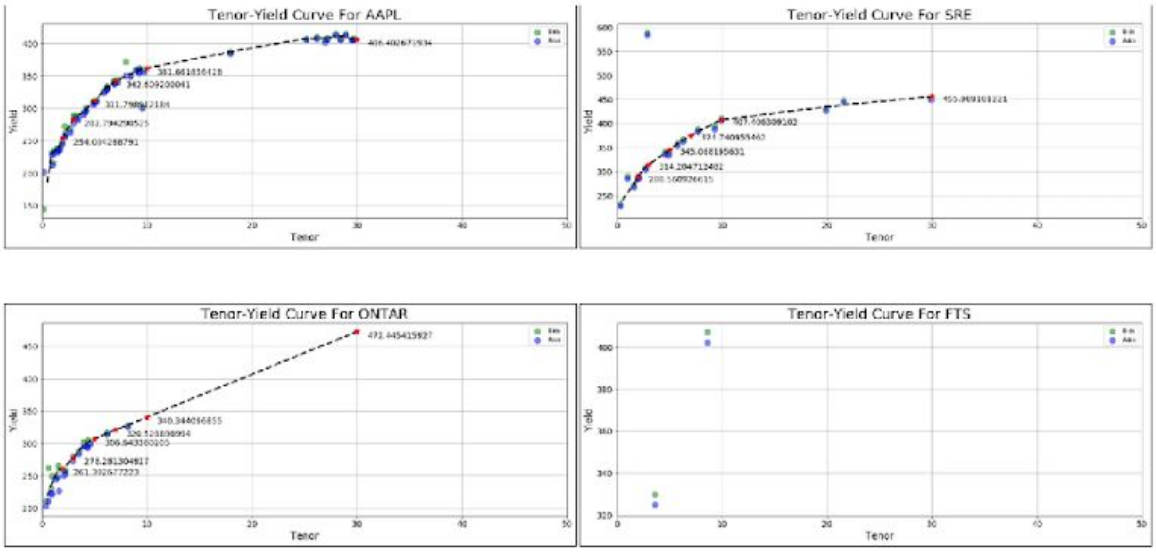
The **third phase** creates indicative new issue pricing curves for all Low Issuers using Support Vector Regression on the combined secondary set of the Lower Issuer and the peer set as derived from the second phase.



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How COBI-Pricing Handles the Illiquid Nature of Primary and Secondary Market

AI algorithms in general require large amount of data to internalize market characters to produce accurate results. Due to the illiquid nature of the fixed income market, secondary market data has a lot of gaps. An issuer with high illiquidity in their bonds that has a low number of bonds outstanding translates into sparse data sets for AI algorithms to train on. Apple (first quadrant below) has bid/ask recorded in most of the tenors across the curve. However, many issuer curves look like the one in the fourth quadrant with very scarce bid/ask information.



COBI-Pricing handles the problem of sparse data sets, by filling the data gaps with balance sheet fundamentals and primary new issue quotation pricing levels to arrive at best fit or relative-value price for secondary market securities. Companies with only a minimal historical data available from secondary market trades of their bonds are enhanced with indicative new issue pricing curves and fundamentals to successfully generate yield curves across all tenors. COBI-Pricing finds observable secondary trade data-points during the pricing coverage period.

Illiquid Companies with only minimal trading activity will now have modeled and relative-value prices for secondary market securities across all tenors. Their sparse data sets are enhanced with data from its peers, as determined in phase two of the algorithm. Human oversight ensures the output from COBI-Pricing is accurate by regularly re-tuning the ML algorithm to maintain a minimized mean absolute error (MAE) with respect to the new issue prices available in the market.

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Business Impact

Over the past two years, we have witnessed profound changes in the fixed income marketplace with counterparties increasingly adopting quantitative investing and liquidity risk monitoring techniques. These include systematic alpha and algorithmic trading, liquidity risk management strategy and reported thresholds, merging of fundamental discretionary and quantitative investment styles, consumption of increasing amounts of alternative data, and adoption of new methods of analysis such as AI analytics like COBI-Pricing algorithm.

Specific use cases for COBI-Pricing algorithm application are examined to identify business objectives and key benefits below. Overbond client organizations include buy-side institutions with over $2 trillion of assets under management globally, across both passive and active strategies as well as regulatory reporting regimes. Their innovation groups actively explore new technologies that can serve as the catalyst for innovation and improve risk management, trade flow, pre-trade and post-trade analytics.

AI Application	Business Objectives	Key Benefits
Intelligent automation	• Automate liquidity risk monitoring and reporting • Enhance independent pricing verification, mark-to-market and book of record pricing feeds	**Intake fundamental and alternative data** (i.e. past issuance pricing across peer group, timing vs. size vs. price prediction, pricing tension based on market sentiment and fundamentals etc.) **Scale coverage and increase analysis speed** using machine learning to test correlations on large issuer coverage universe, reducing the required resources and time (cost) and improving precision (revenue)
Enhanced decision-making	• Use auto-pricing models to improve reporting and risk systems • Realize better investment disclosure with pricing accuracy and coverage	**Monitoring of pricing and liquidity changes** using machine learning can improve portfolio reporting and pricing shifts monitoring. Proprietary data from in-house trade flow can be infused into AI models to understand client preferences and buying patterns **Algorithmic supply-demand matching** can validate at scale pricing levels that would not otherwise be considered with high-confidence and would enter expensive external validation cross-check process
Advanced risk management	• Advance real-time pre-and post-trade risk management solutions	**Pre-trade risk analysis** can monitor impact of different trade strategies and systematically incorporate the cost of risk capital in profitability calculations **Continuous risk monitoring** enables institutions to automate risk models on-demand, understand underlying market exposure in near real-time and recalibrate capital levels **Intaking alternative datasets** with machine-learning algorithms can improve the coverage and robustness of risk models, as well as improve the quality of data intake

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Implementation Considerations

Institutions considering AI predictive analytics implementation and big-data transformation projects, can employ acceleration utilizing externally calibrated models and market signals. Below are several key considerations and questions for executives in charge of AI roadmap:

1. What is the current state of our fixed income in-house data?
2. What are our data science and engineering capabilities?
3. Are we building AI capabilities to grow revenue or cut cost?
4. How can we redefine the boundaries of our data universe or identify alternative data sources necessary to feed AI engine?
5. Given that AI learning curve is steep where do we begin?
6. How do we create and execute AI proof of concept use cases rapidly?
7. What are key success factors for our AI roadmap?

Custom AI Services
Overbond works with clients to identify and recommend practical AI analytics use cases that are aligned with strategic goals of the financial institution. We help assess current-state AI capabilities, and define roadmap to help clients realise value from AI applications. We manage cross-channel data flows across multiple systems and enable custom font-end visualizations.

Proven Methodology
With our targeted approach and implementation methodology, we quickly demonstrate value of AI analytics to test use cases, enabling client-side change management approach and stakeholder buy-in.

Operational Acceleration
We help clients build and deploy custom AI solutions to deliver proprietary analytics and tangible business outcomes. Our experience combines calibrated models, design patterns, engineering and data science best practices, that accelerate value and reduce implementation risk.

AI Analytics As-a-Service
Overbond helps customers design and oversee mechanisms to optimize and improve existing fixed income credit valuation, issuance and pricing prediction and pre-trade opportunity monitoring using AI. Our team of world-class data scientists and engineers manage an iterative implementation approach from current state assessment to operational handover.

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About Overbond

Overbond specializes in custom AI analytics development for clients implementing risk management, portfolio modeling and quantitative finance applications. Overbond supports financial institutions in the AI model development, implementation and validation stages as well as ongoing maintenance.

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