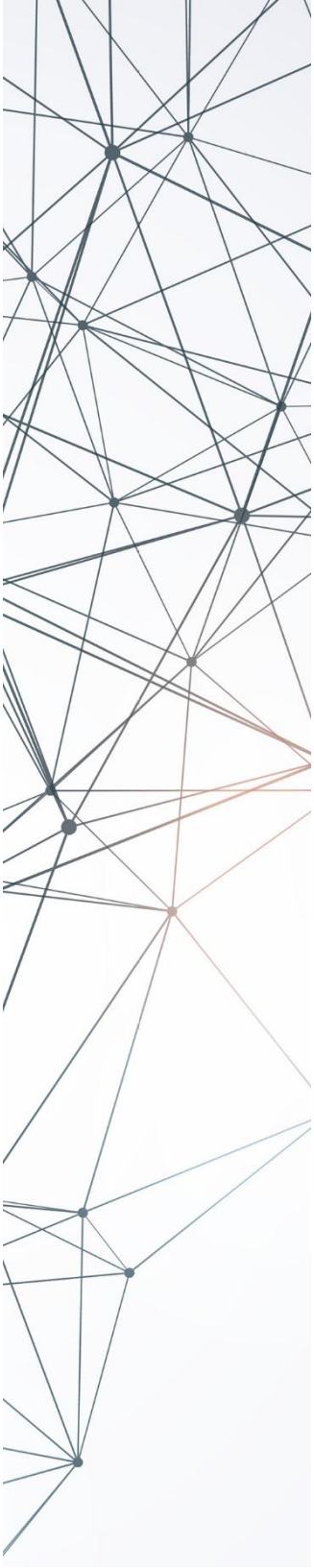
Bond Issuance AI

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Fixed Income Artificial Intelligence is Lagging

While much of the financial services market is embracing digital processes and artificial intelligence applications to streamline how they do business, bond origination and bond OTC trading is one of the few areas which have yet to fully 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, 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. There are also limits placed as a result, on applications of AI utilizing deep historical data records of fundamental data elements (audited statements, dealer supplied primary bond price quotations etc.) and secondary market bond trade points. With this, Overbond pioneered to be the first to market with a centralized big-data hub empowered with AI capabilities for fixed income analytics.

Overbond AI Focus Areas:

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

Opportunity Matching– Buy-side investor canvassing and systematic matching 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.

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 above AI focus areas by employing state of the art visualization modules on the front end and its proprietary AI engine, the Corporate Bond Intelligence (COBI) on the back-end. Overbond's Primary Fixed Income Issuance Prediction model, COBI-Issuance, delivers on Issuance Discovery with issuance opportunity monitoring and matching signal alerts. Market counterparties can focus their pre-trade analytics on most likely new bond issuances with optimal pricing and supply-demand trend, resulting in increased efficiency and portfolio alpha.



AI Powered Issuance Prediction

COBI-Issuance was created as part of Overbond's suite of predictive algorithms for the fixed income capital markets. It is an advanced AI algorithm family which makes ongoing measurements of issuer's propensity to issue bonds. COBI-Issuance assigns a score which estimates the relative likelihood a bond issuer will come to market with bonds in the near future. It analyzes factors from multiple types of data sources including:

Bond market data	Transactions occurring in the secondary market, historical issuances, macro market data
Investment banking data	Fundamental data on corporations, balance sheet indicators, outstanding securities, credit ratings, sector specific data, prospectuses
Proprietary data	Direct access to large community of issuers and institutional investors via established feedback loops

AI advantage over statistical methods

COBI-Issuance AI modeling techniques share many similarities with classical 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 issuance predictions for custom analysis

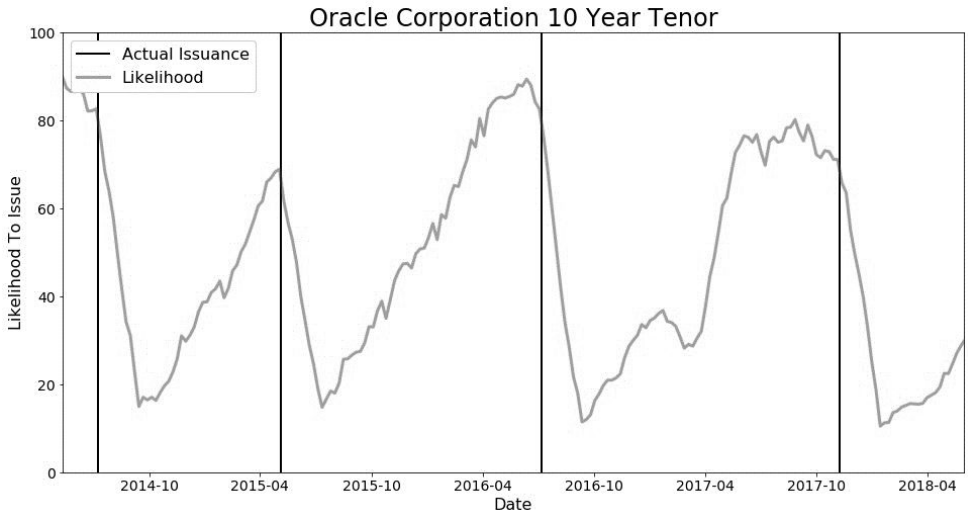
The predictive time horizon the COBI-Issuance algorithm in standard use cases is optimized to four weeks. A score is assigned for each company in each potential bond issuance tenor. Scores are on a scale of 0-100 and are relative to other issuers and other bond issuance tenors. A higher score in general means that company is more likely to issue in that tenor compared to a company or a tenor that receives a lower score. High scores (~70-80 or higher) across all tenors imply that an issuer is likely to issue a bond in any tenor. High scores in only one tenor implies issuer is more likely to issue in that tenor compared to other tenors. Low scores across all tenors imply issuer is less likely to issue in any tenor. It is important to note that propensity scores are not probabilities. For example, a score of 90 does not mean that issuer is likely to issue new bond in that tenor with 90% probability. It means that issuer is in the 90th percentile in a ranking against all other companies in all other issuance tenor possibilities.

COBI-Issuance Propensity Output

COBI-Issuance Propensity output comes in two formats - historical, and current.

Historical COBI Propensity

Historical propensity is given as a separate time series going back two to five years for each tenor (2, 3, 5, 7, 10, and 30 years) for each issuer. The time series is shown in a graph below with the time across the x-axis, and the COBI-Issuance propensity score on the y-axis labeled as 'Likelihood To Issue'. The graph also shows black vertical bars at the dates where that issuer actually issued in a given tenor. The following is an example of an output graph for the historical propensity for a single issuer and single tenor prediction:



Current COBI Propensities

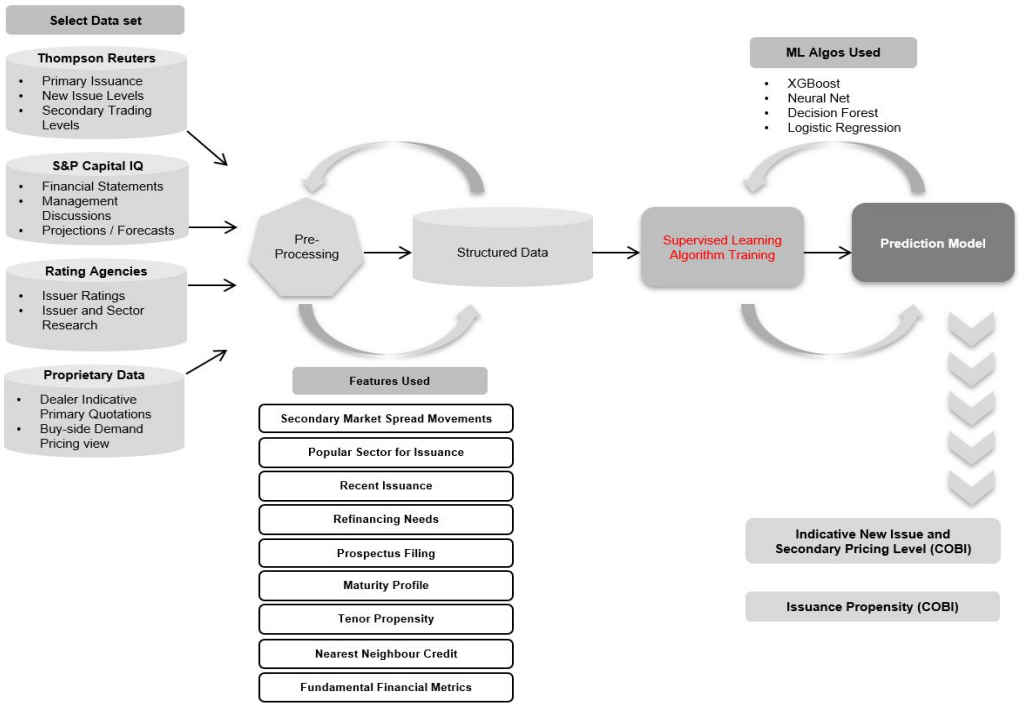
Current propensities can be supplied on a weekly basis, although frequency can be scaled according to a client use case need. For example pre-deal analytics applications in investment banking usually require one month or longer time horizon COBI models optimization while use cases in fixed income trading world often entail model optimizations that are as close to real-time as possible.

For the purpose of additional transparency and explain-ability, Overbond exposes underlying factors which would be commonly understood by analysts to contribute to a propensity score at any given time. Breaking down the propensity scores into more detailed categories, factors include: Upcoming Maturity; Average Maturities per Year; Overdue Issuance; Popular Sector for Issuance; Recent Issuance etc.. Note that the COBI-Issuance algorithm is a non-linear, non-parametric algorithm, and the overall propensity scores are not directly proportional to a weighted average of the sub-scores. These sub-scores are intended to give a deeper level of explain-ability to the indicators used to derive the propensity scores.

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How COBI-Issuance Algorithm Works

The diagram below and the following paragraphs provide a description of how the Overbond COBI-Issuance Propensity 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 (primary and secondary bond issuance and trading levels), S&P Global Market Intelligence (company level fundamental data), DBRS (company ratings and macro market data), as well as various other sources.

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 recent issuance, issuance frequency, maturity schedule gap, propensity for specific tenors. 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 propensities. An Ensemble Learning strategy is used, meaning multiple models are combined to elevate overall robustness. These models are each trained using a subset of the past data, ranging from one month to a maximum of ten years. Advanced sampling techniques were used to account for class imbalance between positive (will-issue) and negative (will-not-issue) predictions. Finally, the results are back-tested against the entire ten years of data and measured for precision and recall metrics.

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COBI-Issuance Data Intake

The successful data pre-processing is the key stage and pre-requisite for the COBI-Issuance 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 pricing data	Thompson Reuters	Interday	The closing prices of companies' bonds are used to calculate an indicative new issuance price across tenors.
Outstanding securities	Thompson Reuters	Interday	The outstanding securities allows for calculation if the company has upcoming maturities that need to be refinanced. The maturity schedule of the outstanding securities is used to calculate gaps which may make the company more likely to issue in a specific tenor.
Historical bond issuance	Thompson Reuters	Interday	Issuer's past bond issuances. They indicate the company's issuance frequency, seasonality, and propensity for specific tenors. They are used to train the models and to back-test the accuracy of COBI-Issuance's predictions.
Company fundamental data	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. The financial profile of a company aids with clustering analysis of companies with similar characteristics. It is expected that companies with similar financial characteristics and balance sheets would have similar bond issuance patterns.
Company credit rating	S&P, Moody's, DBRA (Canada), Fitch (USA)	Periodic/ as they change	The company's credit rating impacts the company's cost of funding, and by extension their likelihood to issue bonds. In addition, credit rating is used to cluster companies of similar ratings.
Company sector information	Thomson Reuters, public sources	When profile is created, systematically updates	Companies in different sectors have vastly different bond issuance patterns and frequencies The models are tuned to each sector specificity and companies are grouped to their closest peers.
Prospectus filings	SEDAR (Canada), EDGAR (USA), public filings	Daily/when filed	Prospectus filings is an indicator that a company deterministically plans to raise additional financing.
Macro Market data	Central Banks/Treasuries, public sources	Interday	Changes in interest rates and economic data has an impact on the attractiveness of the fixed income markets and the availability of credit, and by extension, likelihood for companies to issue bonds.

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Data Pre-Processing and Model Training

COBI-Issuance is an amalgamation of algorithms which predict if an issuer will come to the market and issue bonds. A variety of pre-processed inputs are fed into COBI-Issuance's algorithms, to predict issuances. The following is a subset of indicators used:

Sector Specific Indicators:

a. **Spread Compression Relative to Sector:** In a situation where the spreads (bond valuations) in a specific sector have compressed relative to other sectors, issuers could capitalize on lower spreads, which translates to lower cost of borrowing, by coming to market and issuing bonds.
b. **Popular Sector for Issuance**: Companies in sectors which issue bonds frequently are more likely to issue.

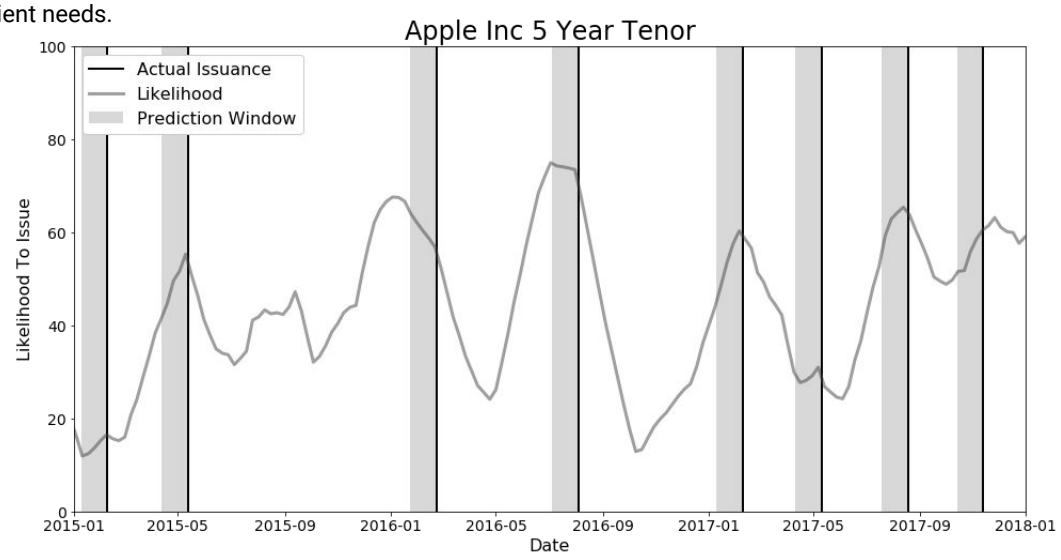
Issuer Specific Indicators:

a. **Recent Issuance**: If a company has issued bonds recently, they may be less likely to come to market soon. COBI-Issuance tracks recent issuances on a monthly time horizon, quarterly time horizon, and yearly time horizon.
b. **Refinancing Need**: An issuer's sources of funding and uses of funds are analyzed to determine if an issuer has a need for funding. Issuers would be more likely to issue if their funding position is negative. Refinancing need is analyzed on a monthly, quarterly, and annual basis.
c. **Seasonal/Monthly Issuance**: If an issuer tends to issue during certain months or seasons, they may continue to follow a similar pattern. An example underlying cause for a pattern in their issuances would be blackout periods.
d. **Overdue Issuance**: An issuer who regularly issued a certain number of bonds and amount of debt in previous years may issue the same number of bonds and amount of debt in the current year. Deviation from regular issuance pattern in current year versus past years in the sample set is measured and correlations are identified not only with respect to that particular issuer but their sector peer issuers as well.
e. **Prospectus Filing**: An issuer has recently submitted a prospectus to securities regulators indicating they are seeking to raise capital.
f. **Spread Compression Relative to Self**: Monitoring if spreads of an issuer have compressed compared to its indicative spreads from recent weeks or recent months. Issuers could capitalize on lower spreads, translating to lower cost of borrowing, by coming to market and issuing bonds.

Within the COBI-Issuance model, multiple supervised machine learning algorithms are trained using past data to predict issuances. The algorithms used include: XGBoost, Neural Network, Random Forest, and Logistic Regression. COBI-Issuance uses a robust ensemble method to combine the results from each algorithm and generate an output score. This score represents the propensity of an issuer to issue a bond in a specific tenor.

Results of COBI-Issuance

The sample back-tested performance of COBI-Issuance algorithm can be seen in the following graph, plotting predictions for a specific issuer to issue bonds in a specific tenor. Propensity values are plotted over time, with black bars representing when actual issuances have occurred. The gray area trailing each issuance on the first graph is indicating the issuance prediction window. The default time horizon for the COBI-Issuance propensity issuance prediction is four weeks. However, this can be adjusted according to client needs.



Taking above specific issuance prediction back-test, Overbond data science team then ran systematic back-test on a basket of 600 issuers, testing 6 standard issuance tenors for 500 weeks, representing around 1.1 million predictions. For each issuer and every tenor COBI-Issuance algorithm calculated likelihood to issue every week.

General Confusion Matrix

		Actual Issuance		
		False	True	Issuance Percentage
Propensity To Issue	Highly Likely	3561	16132	81.92
	Likely	32833	13552	29.22
	Unlikely	155293	18751	10.77
	Very Unlikely	1211269	30465	2.45

To display overall result predictions were categorized in 4 buckets: Highly Likely to Issue, Likely to Issue, Unlikely to issue and Very unlikely to Issue. As you can see in the table below, the majority of issuers/tenors that algorithm predicted as being highly likely to issue did in fact issue, above 81% precision. Similarly the vast majority of the issuers/tenors that algorithm predicted as being very unlikely to issue did not issue. This is true for all issuer industry sectors and in general.

Business Impact

Over the past two years, we have witnessed profound changes in the fixed income marketplace with counterparties increasingly adopting quantitative investing techniques. These include systematic alpha and algorithmic trading, 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-Issuance algorithm.

Specific use cases for COBI-Issuance 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 sell-side dealer institutions. Their innovation group's mandate actively explore new technologies that can serve as the catalyst for innovation and improve investment performance, deal flow, pre-trade and post trade analytics.

AI Application	Business Objectives	Key Benefits
Intelligent automation	• Automate pre-trade research and diligence • Automate pre-trade opportunity monitoring	**Intake fundamental and alternative data** (i.e. past issuance across peer group, timing vs. size vs. price prediction, refinancing need based on audit trail 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 predictive models to improve pre-trade/deal identification • Realize better investment performance	**Monitoring of market opportunities** using machine learning can improve portfolio alpha and deal flow /sales efficiency. 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 unlock opportunities at scale that would not otherwise be considered and the most important factors underlying non-traditional /exotic trades or deals
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 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.

Contact:
Vuk Magdelinic
Chief Executive Officer
+1 416-559-7101
vuk.magdelinic@overbond.com

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