Securities Lending Forecast Engine

R/Finance Conference 2019

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CLIENT SEGMENTS

- Pensions
- Endowments & Foundations
- Sovereign Entities
- Fiduciary Managers
- Investment Managers
- Alternative Managers

$10.2 Trillion

Total assets under custody/administration[1]

[1] Represents total Corporate & Institutional Services business AUC/A as of March 31, 2019.

INTRODUCTION

Forecasting engine to increase client profits and reduce manual effort

Complexity

- Offer competitive fees on >40,000 securities
- Numerous geographic regions, 60+ highly rated borrower organizations
- Time consuming process for traders to analyze data per security

Objective

- **Client Profitability**

  > Leveraging market data to forecast lending fees, maximize performance

  > Quickly identify re-rate opportunities on existing loans

- **Efficiency** – Reduce manual effort, providing traders with recommendations
- **Continuous improvement** – First of many analytical capabilities that we believe are unique in the industry.

SECURITIES LENDING AND ANALYTICS

Value being forecasted…

New volume weighted market average intrinsic value

Loans opened in the current time period

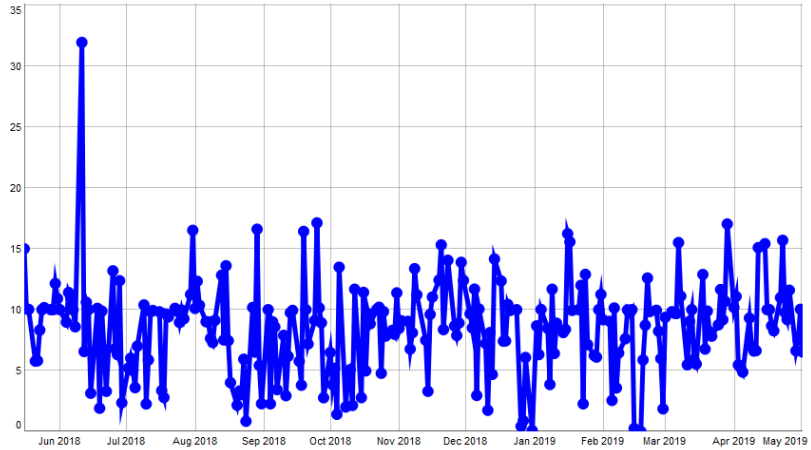
Mix of lenders / loans to control for outliers

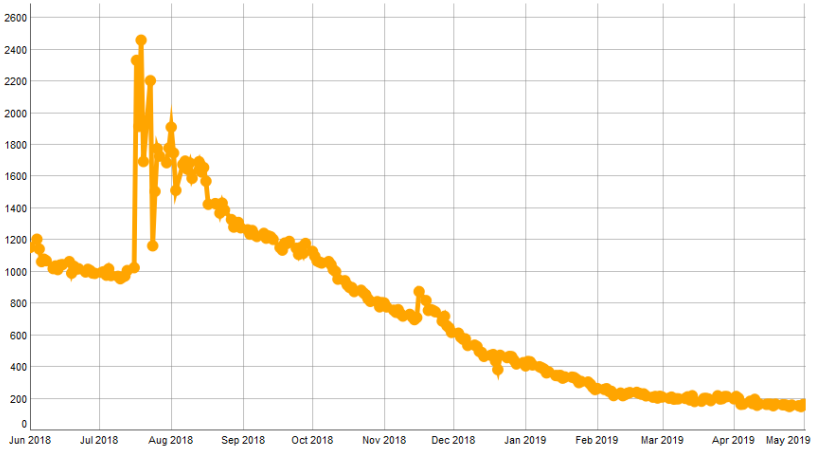
Consistent measure across loan types

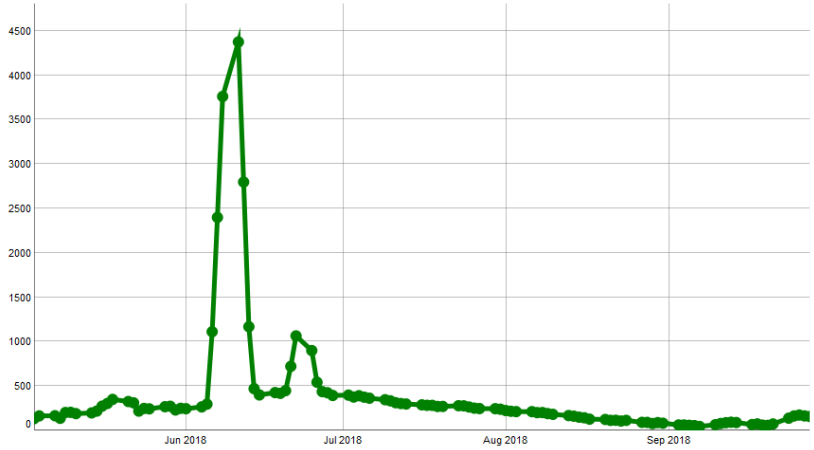
Measurement

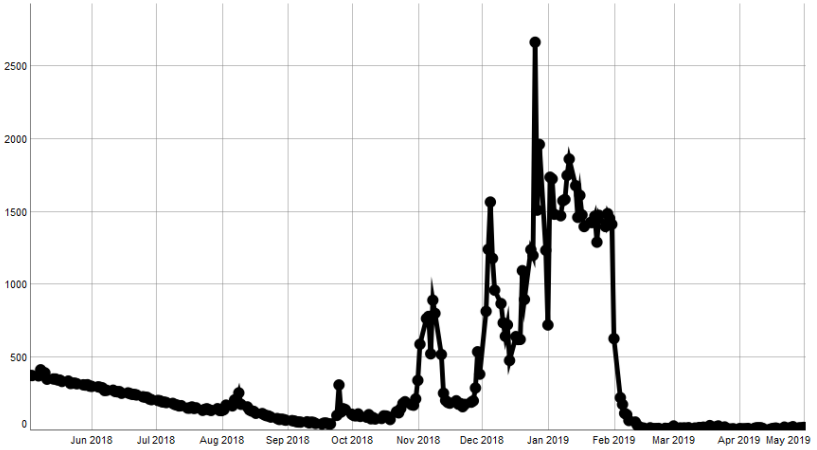
- Quoted in basis points (bps) or 1/100th of 1%
- Intrinsic value standardizes two loan types:
  - Rebate based / Cash collateralized
  - Fee based / securities collateralized
- Typically open ended (no set term)
- Fees are collected by lenders and distributed to asset owners
- Market data aggregators provide blended securities lending rates
- Cumulative values available at EoD

SECURITIES LENDING FEE









FACTORS

Potential drivers were gathered from multiple data sources

Data	Type
Securities lending market	Utilization
	Fees
Other markets	Equity
	Derivatives
	Fixed Income
Internal Data	Lending Activity
	Utilization
	Fees
External	Macroeconomic
	News
	Social Media

MODEL OVERVIEW

Several modeling approaches were considered: regime switching, recurrent neural networks, Bayesian structural time series and ARMA-GARCH

Bayesian Structural Time Series

- Observation equation linking the response, y_t, to the latent states, α_t.

$$y_{t+1} = ZtT\alpha_t + \beta_t{}^T x_t + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2{}_\varepsilon)$$

- Structural equation describing the evolution of the latent states

$$\alpha_{t+1} = T_t\alpha_t + R_t\eta_t \qquad \eta_t \sim N(\mathbf{0}, \boldsymbol{\Sigma_\eta})$$

- The two equations capture the following components:
  - *Local trend, seasonality, auto-regressive*
  - *Linear predictor with fixed/time-varying coefficients*
  - *Gaussian and Non-Gaussian errors*
- Primary computational methods:
  - *Kalman filtering*
  - *Kalman smoothing*
  - *Bayesian data augmentation*
  - *Markov chain Monte Carlo simulations*

MODEL OVERVIEW

Priors

- The join distribution of β can be written as:

$$p(\beta, \gamma, \sigma_\varepsilon^{-2}) = p(\beta_\gamma|\gamma, \sigma_\varepsilon^2)p(\sigma_\varepsilon^{-2}|\gamma)p(\gamma)$$

  - *γ is a vector of Bernoulli random variables*
  - *γ_k = 0 indicates that β_k = 0*
  - *The join distribution of γ is given by:*

$$\gamma \sim \prod_{k=1}^{K} \pi_k^{\gamma_k}(1-\pi_k)^{1-\gamma_k}$$

  - *The distribution of β_γ conditional on γ and σ_ε*

$$\beta_\gamma|\gamma, \sigma_\varepsilon^2 \sim N\left(b_\gamma, \sigma_\varepsilon^2\left(\Omega_\gamma^{-1}\right)^{-1}\right)$$

  - *The distribution of σ_ε^{-2} conditional on γ*

$$\sigma_\varepsilon^{-2}|\,\gamma \sim Ga\left(\frac{v}{2}, \frac{s}{2}\right)$$

  - *The prior parameters are:*

$$\pi_k, b, \Omega^{-1}, s, v$$

Posteriors

- Posterior distribution of β_γ and σ_ε^{-2}

$$\beta_\gamma|\gamma, \sigma_\varepsilon^2, \bar{\boldsymbol{y}} \sim N\left(b'_\gamma, \sigma_\varepsilon^2\left(V_\gamma^{-1}\right)^{-1}\right)$$

$$\sigma_\varepsilon^{-2}|\,\gamma, \bar{\boldsymbol{y}} \sim Ga\left(\frac{v'}{2}, \frac{s'}{2}\right)$$

  - $\bar{y}_t = y_t - Z_t^T\alpha_t$ *excluding* $\beta^T x$
  - $\bar{\boldsymbol{y}} = \bar{y}_{1:n}$
  - $V_\gamma^{-1} = (X^T X)_\gamma + \Omega_\gamma^{-1}$
  - $v' = v + n$
  - $b_\gamma = \left(V_\gamma^{-1}\right)^{-1}\left(X_\gamma^T\bar{\boldsymbol{y}} + \Omega_\gamma^{-1}b_\gamma\right)$
  - $s' = s + \bar{y}^T\bar{y} + b_\gamma^T\Omega_\gamma^{-1}b_\gamma - b'^T_\gamma V_\gamma^{-1}b'_\gamma$

- Posterior distribution of γ:

$$\gamma|\bar{\boldsymbol{y}} \sim C(\bar{\boldsymbol{y}})\frac{|\boldsymbol{\Omega_\gamma^{-1}}|}{|\boldsymbol{V_\gamma^{-1}}|}\frac{\boldsymbol{p(\gamma)}}{\boldsymbol{s'^{\frac{n'}{2}-1}}}$$

Markov Chain Monte Carlo

$$\boldsymbol{\alpha} \sim p(\boldsymbol{\alpha}|\boldsymbol{y}, \theta, \beta, \sigma_\varepsilon^2) \rightarrow \theta \sim p(\theta|\boldsymbol{y}, \boldsymbol{\alpha}, \beta, \sigma_\varepsilon^2) \rightarrow p(\beta, \sigma_\varepsilon^2|\boldsymbol{y}, \boldsymbol{\alpha}, \theta)$$

COMPUTATIONAL METHODS

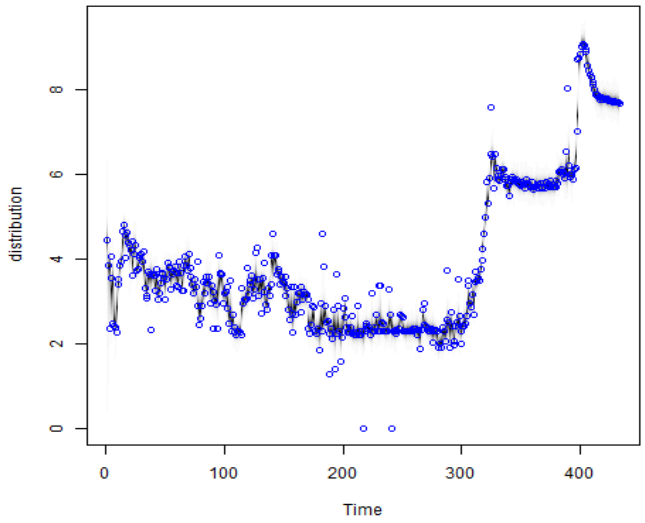
Posterior Distribution

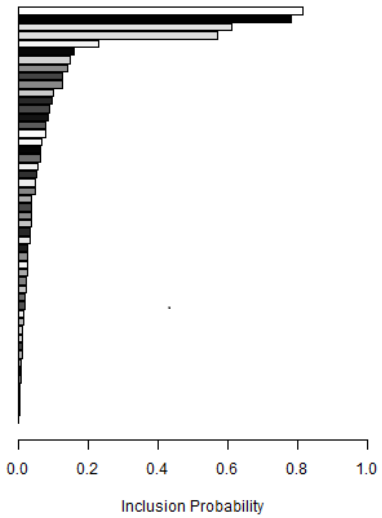
- Gibbs sampling algorithm that generates a Markov chain sequence with stationary distribution $\mathrm{p}(\theta, \beta, \sigma_\varepsilon^2, \alpha | \mathrm{y}_{1:\mathrm{n}})$
- The algorithm alters between simulating model parameters $\theta, \beta, \sigma_\varepsilon^2$ and states space α
- Forecasting relies the posterior distribution of the model parameters and state space

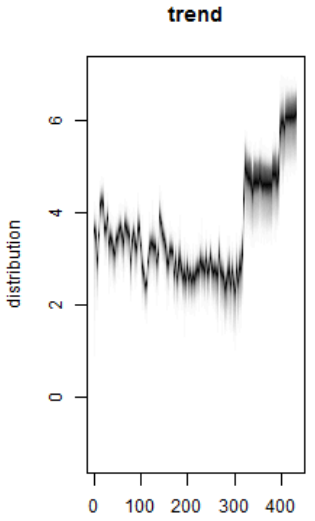
Methods	Probability Distribution	Citation
Kalman Filtering	$p[\alpha_{t+1} \mid y_{1:t}]$	Durbin and Koopman (2001) Hamilton (1994)
Kalman smoothing	$p[\alpha_t \mid y_{1:n}]$	Durbin and Koopman (2001) Hamilton (1994)
Bayesian data augmentation	$p[\alpha_{1:n} \mid y_{1:n}]$	Carter and Kohn (1994) Frühwirth-Schnatter (1995) de Jong and Shepard (1995) Durbin and Koopman (2002)
Markov chain Monte Carlo Forecasting	$p(\theta, \beta, \sigma_\varepsilon^2, \boldsymbol{\alpha} \mid y_{1:n})$ $p(y_{n+1} \mid y_{1:n}) = \int p(y_{n+1} \mid \phi) p(\phi \mid y_{1:n}) d\phi$	Durbin and Koopman (2002) George and McCulloch (1997)

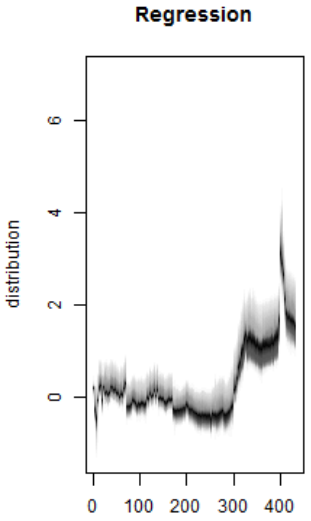
For further details see Scott and Varian (2014), BSTS R package documentation, and Brodersen, Gallusser, Koeller, Remy, and Scott (2015) among other sources.

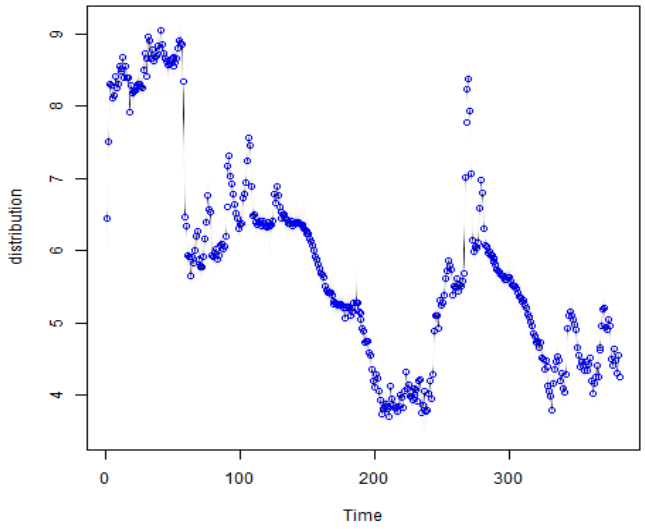
MODEL DIAGNOSTICS

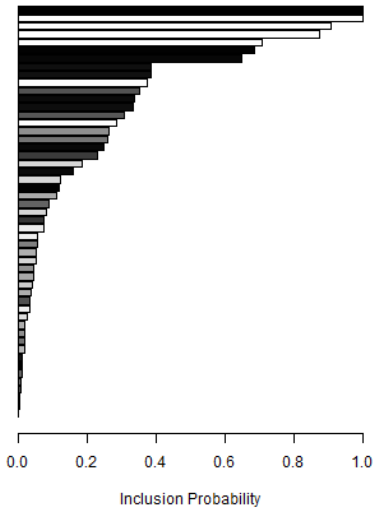


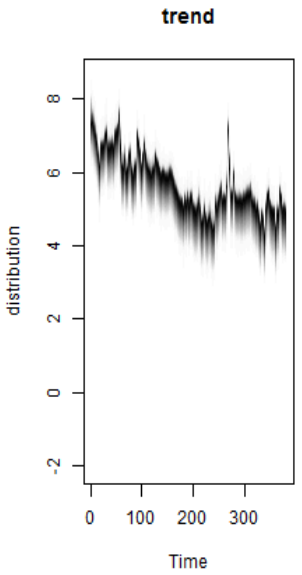


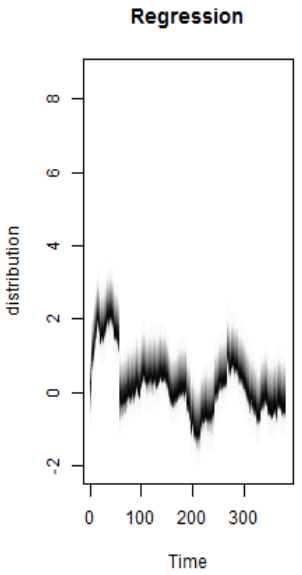






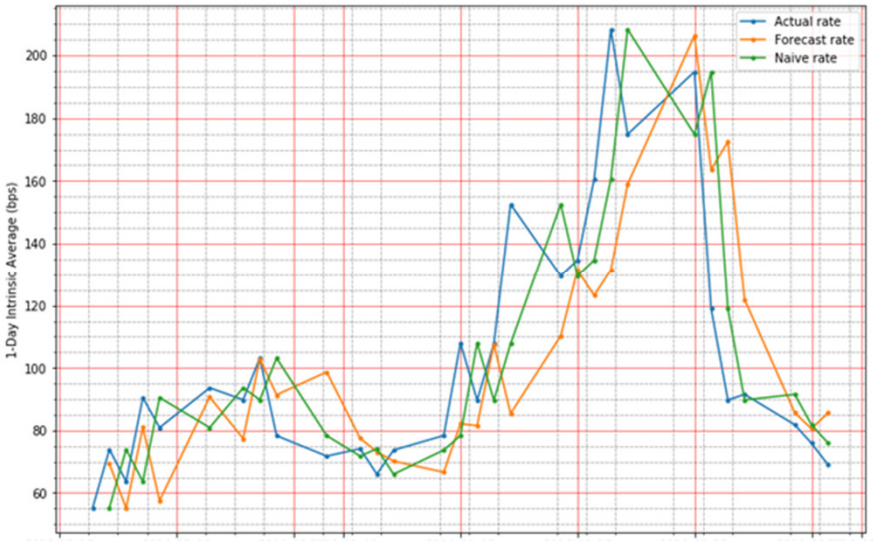


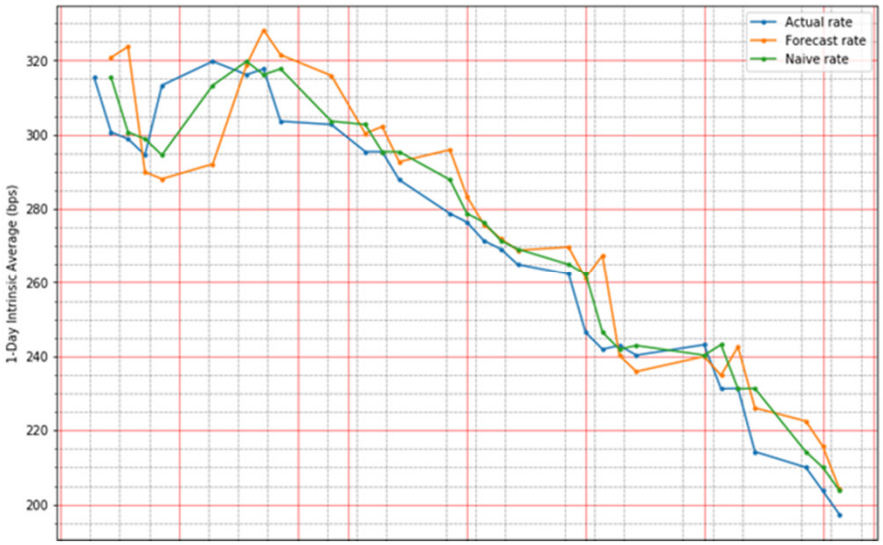




BENCHMARKING

Compared 1-day ahead prediction with several challenger models for a sample of U.S. equities



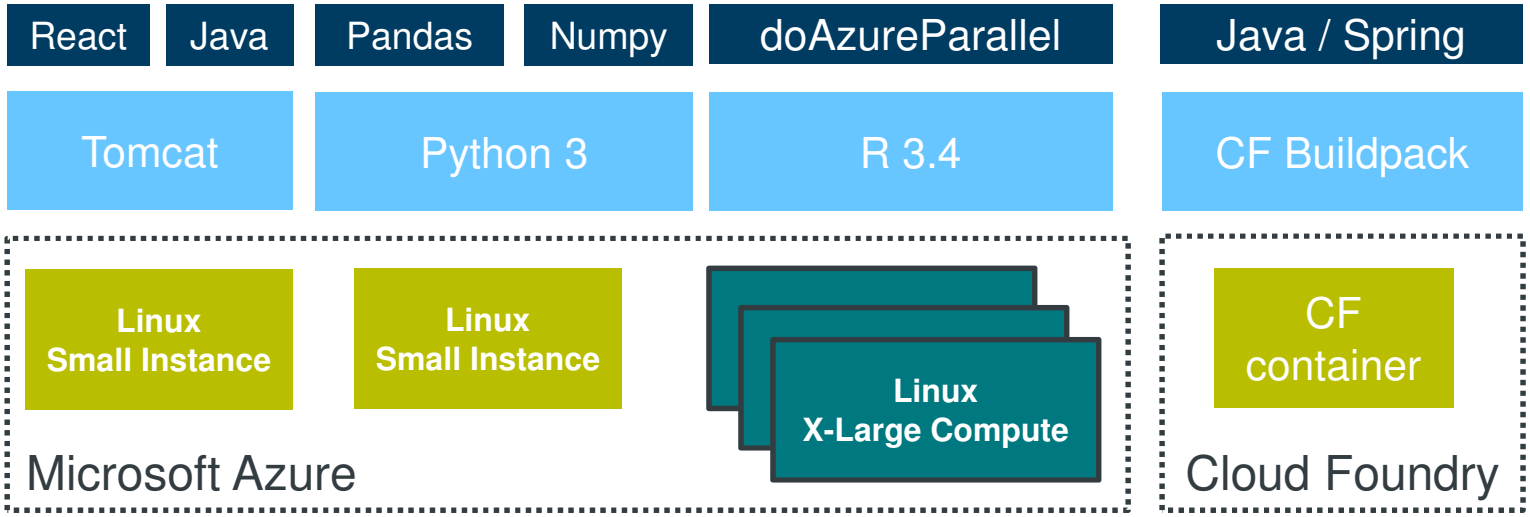


Results

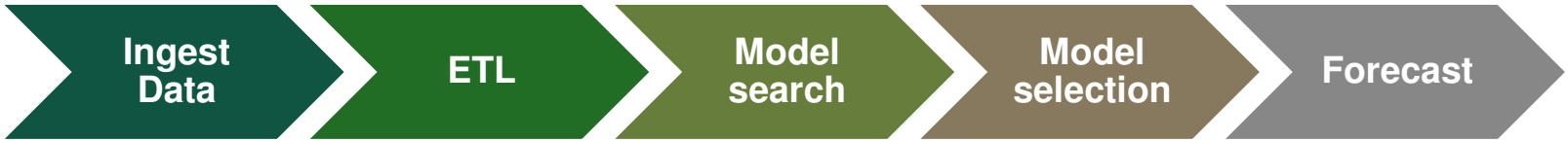
- Noteworthy improvement over model that uses current price as the 1-day ahead forecast
- Outperform challenger models, including recurrent neural network model

PLATFORM

Deployment Architecture



Pipeline



- DataLend API
- Options market API
- NT proprietary DB
- Etc.

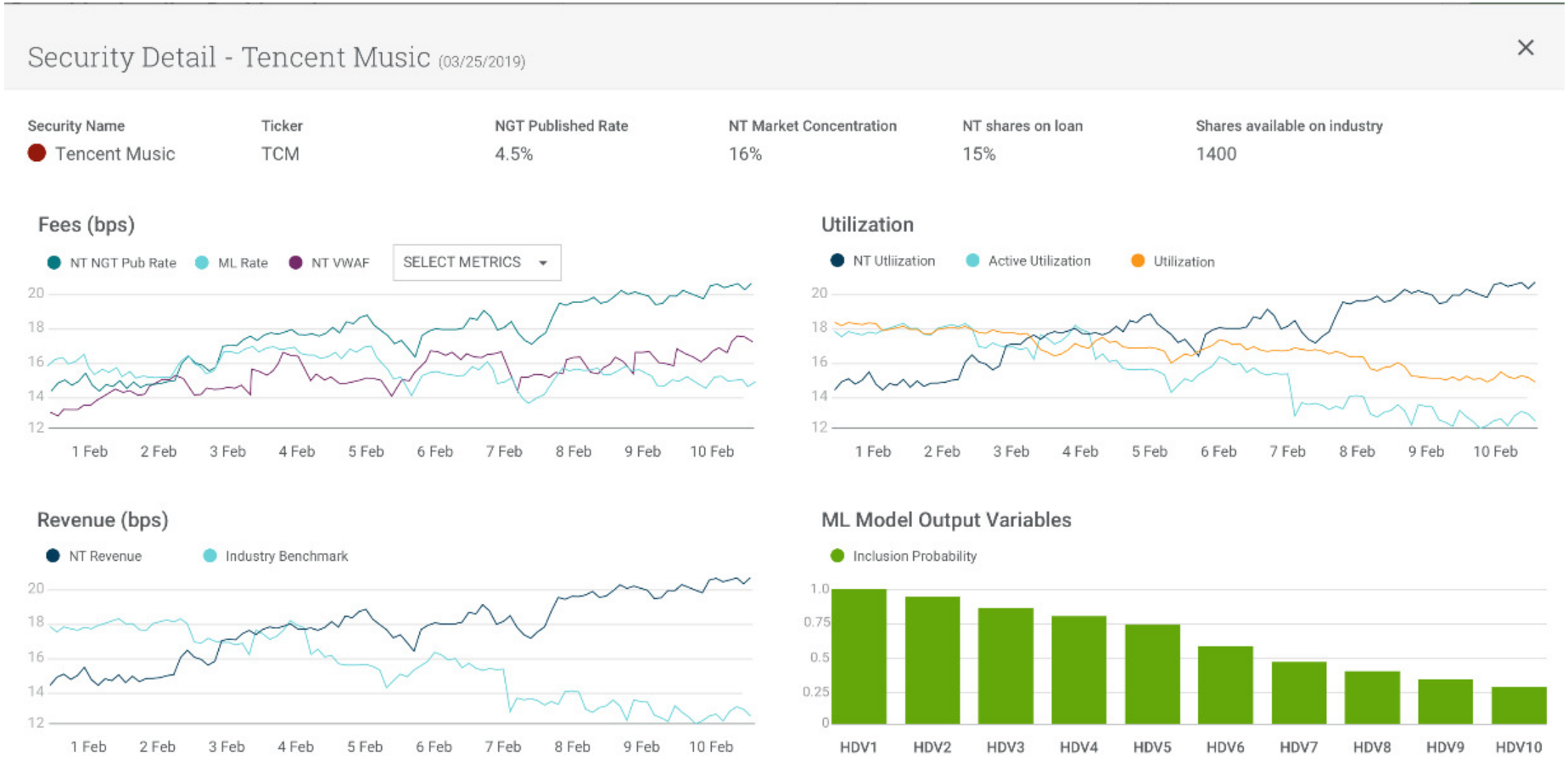
- Python based
- Aggregation
- Feature engineering

- Massively parallel
- Azure for short-lived large-scale

- Evaluate 1000's
- Choose best based on many fit statistics

- Use best model to calculate current rate and short term projections
- Store output for display on GUI

DASHBOARD (DUMMY DATA)



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