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Webinar

December 14

Beyond the Black Box: Machine Learning for Equities

Andrew Li
Vice President, Quantitative Researcher, State Street Associates

Kathryn Wilkens, PhD, CAIA
Founder, Pearl Quest LLC

Welcome

We will begin promptly at 11 AM ET.

If you are unable to hear the speakers, please let us know in the chat box. You may enter your questions in the Q&A, we will address them at the end of the presentation. You can find a copy of the slide deck and recording of this webinar: www.fdpinstitute.org/webinars

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Employers increasingly seek to find professionals who have the skills to apply data science tools to solve their most challenging problems.

Introductions

Kathryn Wilkens, Ph.D., CAIA
Founder,
Pearl Quest LLC

Andrew Li
Vice President, Quantitative Researcher
State Street Associates

Today's Topic:

Beyond the Black Box: Applying Machine Learning to Equity Investing

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Beyond the Black Box
Applying Machine Learning to Equity Investing

December 2022

Andrew Li
State Street Associates

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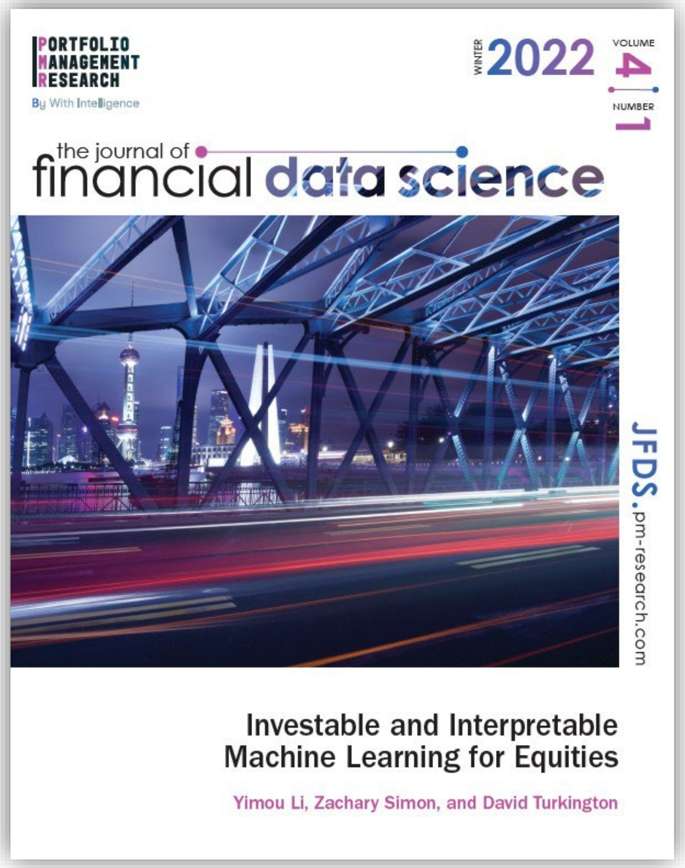
Investable and Interpretable Machine Learning for Equities

Li, Simon, Turkington. The Journal of Financial Data Science, Winter 2022



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Applying Machine Learning to Investing

Key Challenges: Trust and Transparency

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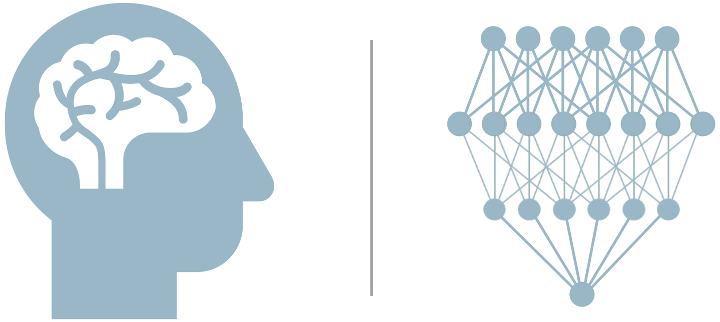
Simple or Complex?

Human brain has 86 billion neurons, but a person can easily express a simple thought.

Complicated models can find simple and interpretable relationships.



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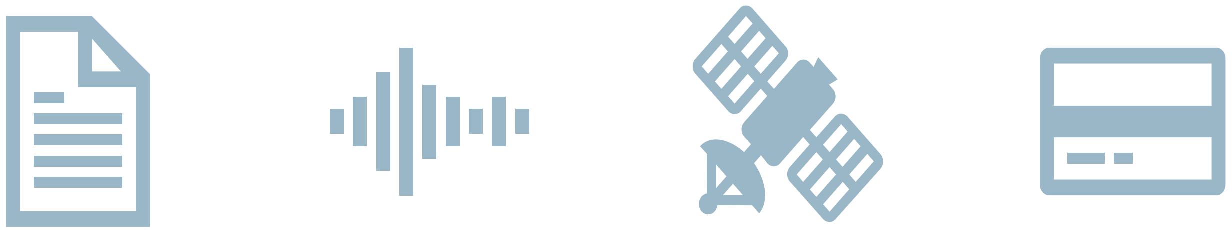
What Advantages Can Machine Learning Provide?

Information from alternative data



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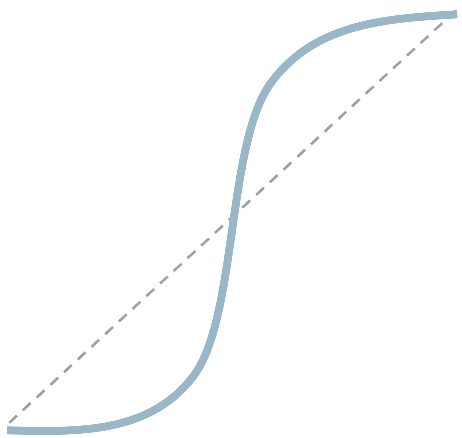
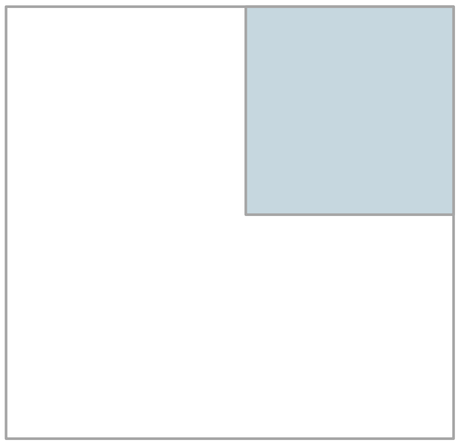
What advantages can machine learning provide?

Nonlinear relationships



Interaction effects



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Research Motivations

Investable
Focus on the most liquid and accessible market

Interesting
Portfolios can outperform relevant benchmarks

Interpretable
Probe for intuition of machine learning model behavior

Investable

Interesting

Interpretable

Test Setup

Focus on the most liquid and accessible market

- Universe: S&P 500
- Prediction Target (Y): Stock total return
- Prediction Input (X): Stock and regime indicators
- Models: Neural Networks, Boosted Trees, Random Forest, Lasso, and OLS
- Data: 1992.1 – 2019.12
- Rebalance frequency: Monthly

Model Inputs (X)

Stock Level Indicators	
Company Value	• Size • Value
Past Price Trends	• Short term mean reversion • Momentum • Sector Momentum • Long term mean reversion
Riskiness	• Volatility • Beta
Return on Equity	• Leverage • Profitability
Operating Model	• Investment • Dividend yield

Regime Indicators	
Turbulence	• Market unusualness
Recession Likelihood	• Economic Indicator • Change in level

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Investable

Interesting

Interpretable

Machine Learning Has More Predictive Power

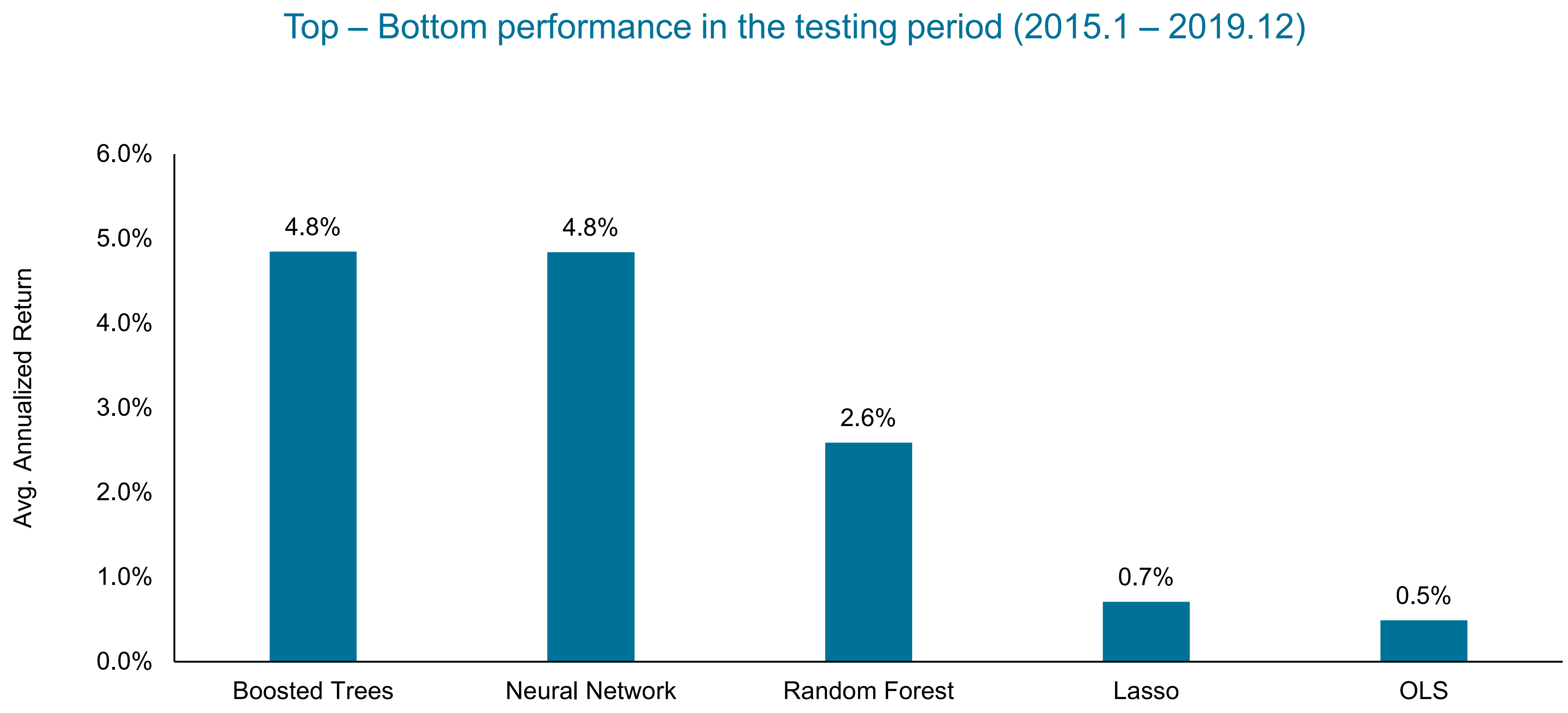


Chart covers the period January 2015 through December 2019.
Source: State Street Global Markets, DataStream.

Performance of Different Models

Portfolios of top 100 predicted stocks of each model in the testing period (2015.1 – 2019.12)

	Return	Risk	Return/Risk
S&P 500	11.9%	12.7%	0.94
OLS	10.5%	14.2%	0.74
Lasso	10.4%	13.4%	0.77
Random Forest	11.5%	9.8%	1.18
Boosted Trees	13.0%	11.8%	1.10
Neural Network	13.4%	11.8%	1.14

Chart covers the period January 2015 through December 2019.
Source: State Street Global Markets, DataStream.

Changing the Prediction Target (Y)

Instead of targeting total return, we can target excess returns over a benchmark

- Estimate CAPM-expected returns for each stock
- Performance evaluations change accordingly

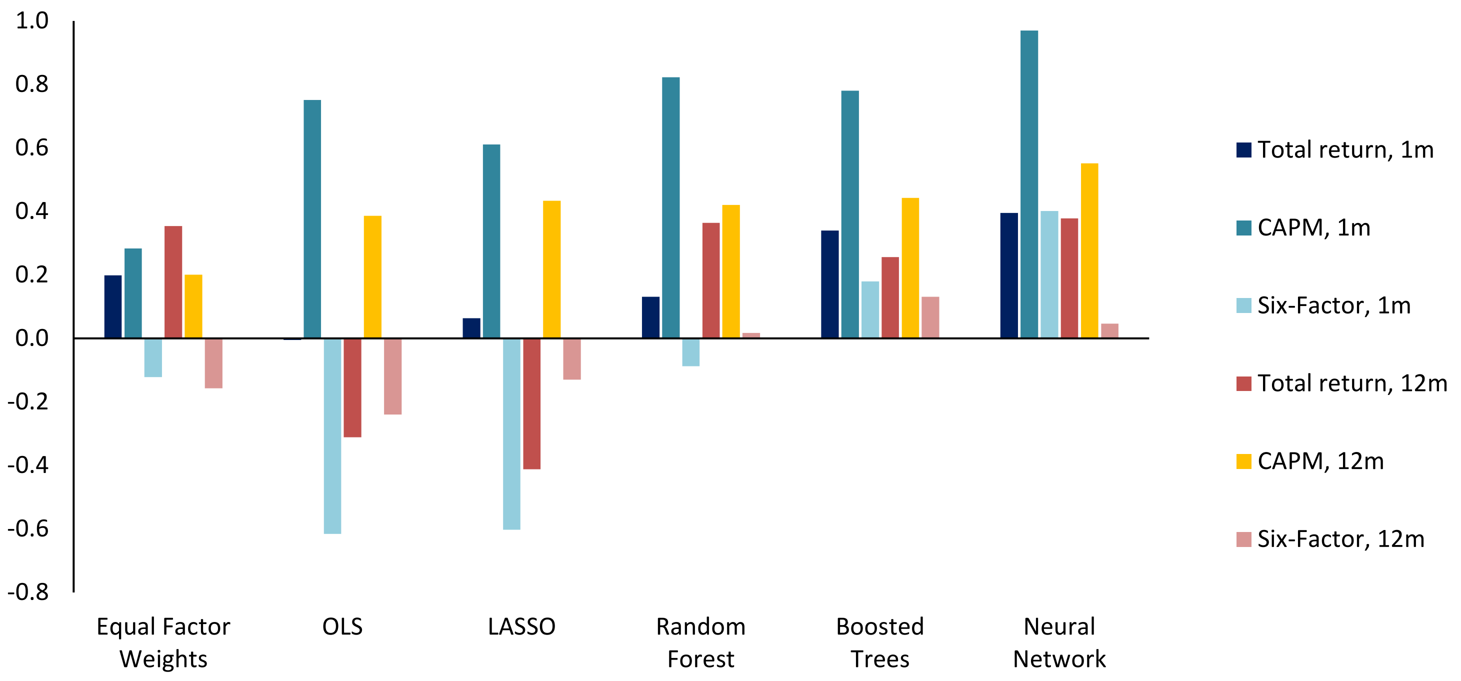
Model	Excess Return	Risk	Return/Risk
OLS	1.9%	5.0%	0.39
Lasso	3.3%	5.8%	0.57
Random Forest	4.6%	7.4%	0.62
Boosted Trees	4.2%	5.7%	0.74
Neural Network	3.9%	6.1%	0.65

Chart covers the period January 2015 through December 2019.
Source: State Street Global Markets, DataStream.

Tailoring prediction goals to prior beliefs and preferences

Return benchmarks and time horizons

Return-to-risk ratios in the test period (2015.1 – 2019.12)



Covers the period January 2015 through December 2019.
Source: State Street Global Markets, DataStream.

Investable

Interesting

Interpretable

Coefficient-like Intuition for Any Model

Holding all else constant, how do model predictions change as we change variable x1?

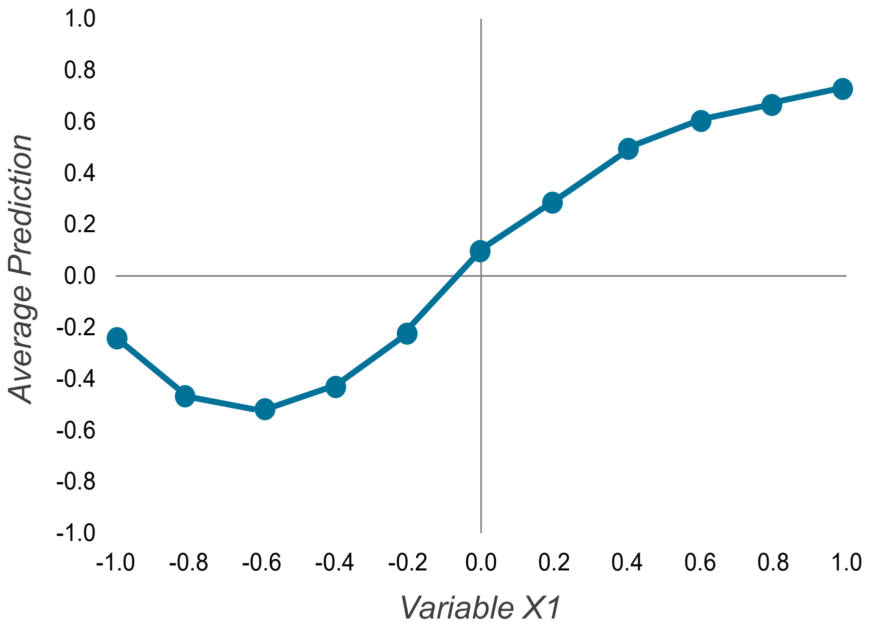
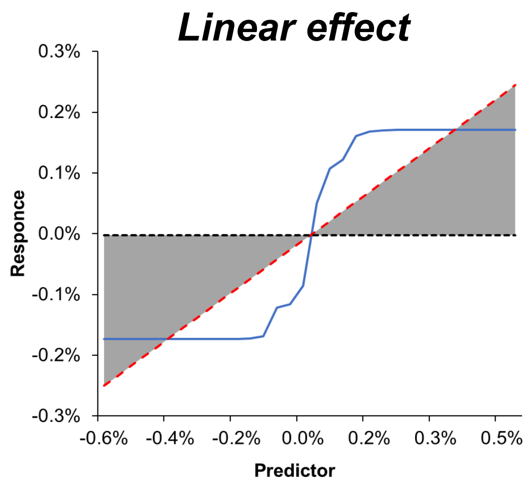
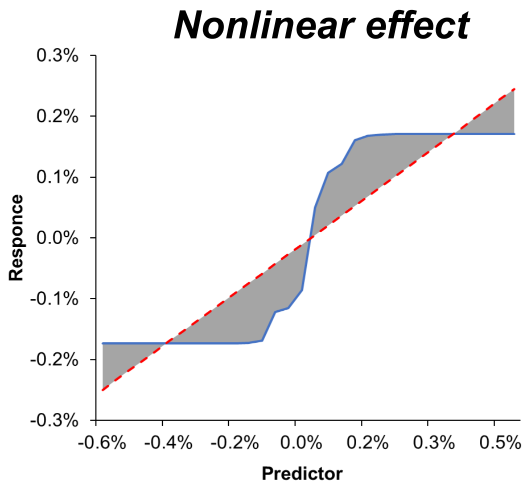


Chart is illustrative; no live data.

Model Fingerprint: Decomposition of Predictions

- For each value of a chosen variable, generate model predictions combining this value with all other historical inputs, and take the average. Repeat.
- Separate the resulting partial prediction curve into a linear and nonlinear effect.





Interaction effect

Predictor 2 \ Predictor 1	-0.5%	-0.4%	-0.3%	-0.2%	-0.1%	0.0%	0.1%	0.2%	0.3%	0.4%
1.0	0.4%	0.4%	0.3%	0.2%	0.1%	0.0%	-0.1%	-0.3%	-0.4%	-0.6%
0.9	0.3%	0.3%	0.2%	0.1%	0.1%	0.0%	-0.1%	-0.2%	-0.3%	-0.4%
0.8	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	-0.1%	-0.2%	-0.3%
0.7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%
0.6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.4	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%
0.3	-0.2%	-0.2%	-0.1%	-0.1%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%
0.2	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	0.0%	0.1%	0.1%	0.2%	0.3%
0.1	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	0.0%	0.1%	0.2%	0.3%	0.4%
0.0	-0.3%	-0.2%	-0.2%	-0.1%	-0.1%	0.0%	0.1%	0.2%	0.3%	0.4%

Chart is illustrative; no live data.

Prediction Fingerprint – Decomposing Predictions

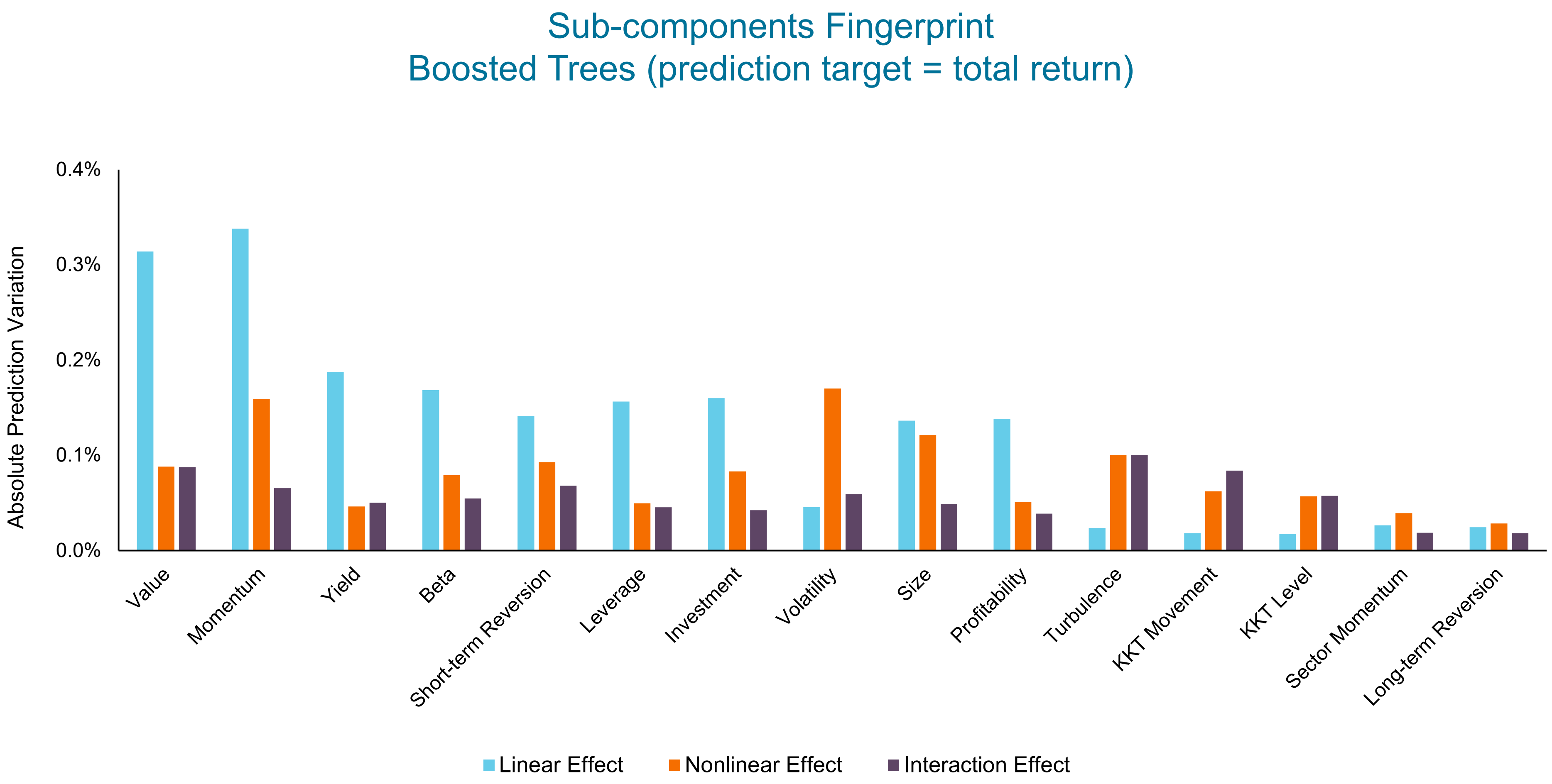


Chart based on data that covers the period January 1992 through December 2014.
Source: State Street Global Markets.

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Prediction Fingerprint – Comparing Models

Most influential interaction effects

Total return, 1-month

	Random Forest	Boosted Trees	Neural Network
Top 3 Overall	Beta, Recession (Shift)	Size, Turbulence	Volatility, Turbulence
	Volatility, Recession (Shift)	Value, Turbulence	Size, Turbulence
	Beta, Turbulence	Sector, Turbulence	Momentum, Turbulence
Top 3 (Without Regime Variables)	Beta, Volatility	Short Reversion, Sector	Momentum, Sector
	Beta, Yield	Momentum, Sector	Long Reversion, Momentum
	Beta, Sector	Value, Sector	Beta, Momentum

Total return, 12-month

	Random Forest	Boosted Trees	Neural Network
Top 3 Overall	Value, Sector	Leverage, Sector	Beta, Momentum
	Investment, Value	Sector, Recession	Beta, Yield
	Value, Volatility	Value, Sector	Size, Recession
Top 3 (Without Regime Variables)	Value, Sector	Leverage, Sector	Beta, Momentum
	Investment, Value	Value, Sector	Beta, Yield
	Value, Volatility	Yield, Sector	Momentum, Sector Momentum

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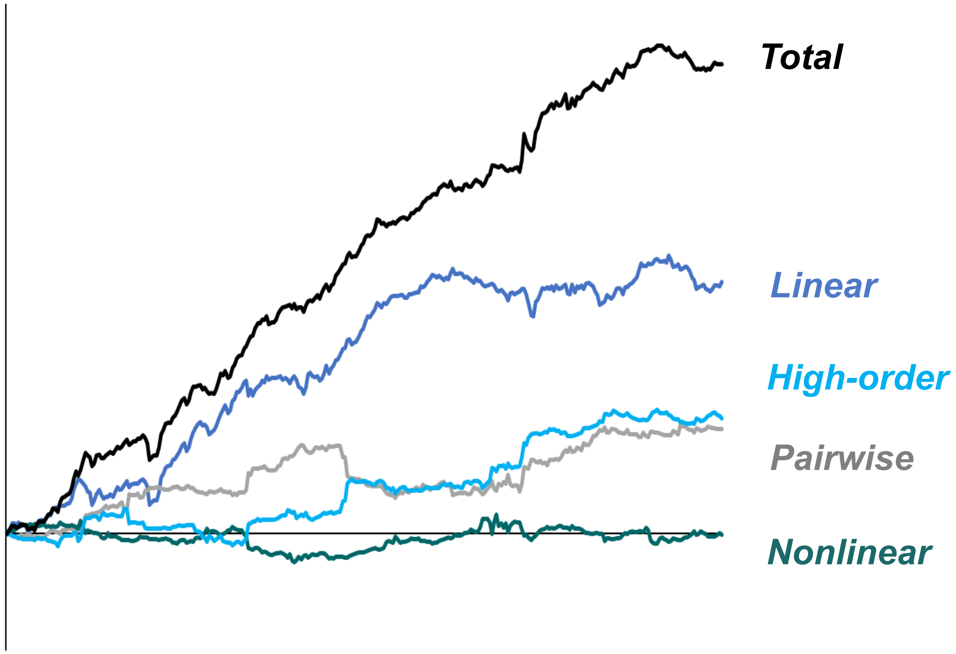
Model Fingerprint: Decomposition of Performance

1. Compute returns of portfolios formed from the linear predictions in isolation.
2. Compute returns of portfolios formed from the linear and pairwise interaction predictions, minus those from step 1. This isolates pairwise interaction effects.
3. Compute returns of portfolios formed from the linear, nonlinear, and pairwise interaction predictions, minus those from steps 1 and 2. This isolates nonlinear (sizing) effects.
4. Compute returns of portfolios formed from the full model predictions, minus those from steps 1, 2, and 3. This isolates higher-order effects.

Cumulative returns



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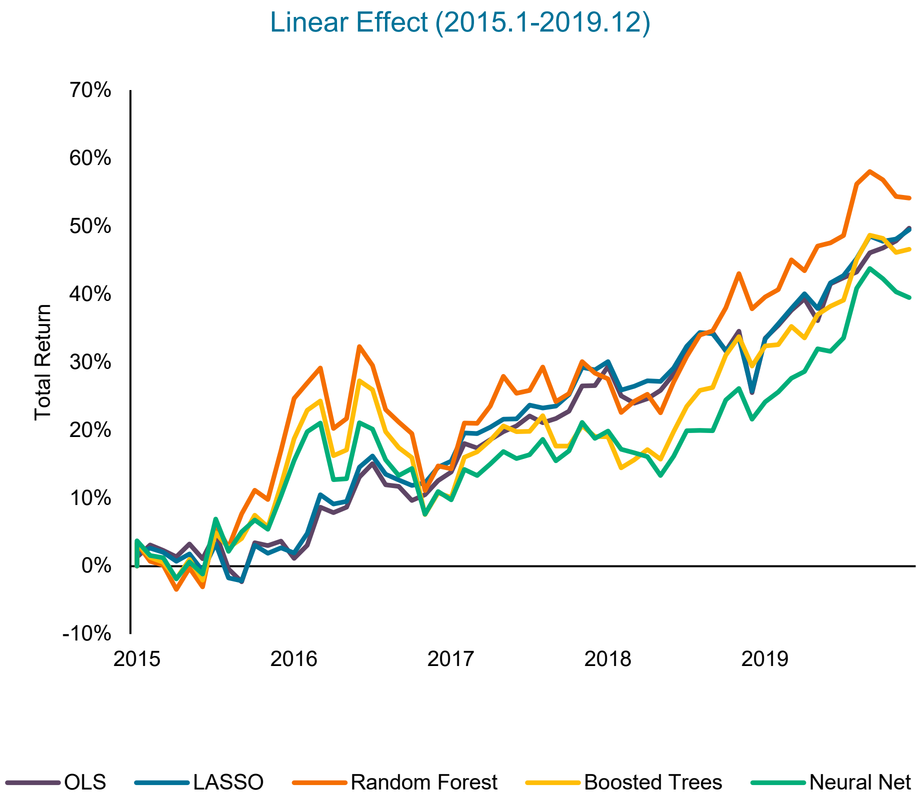
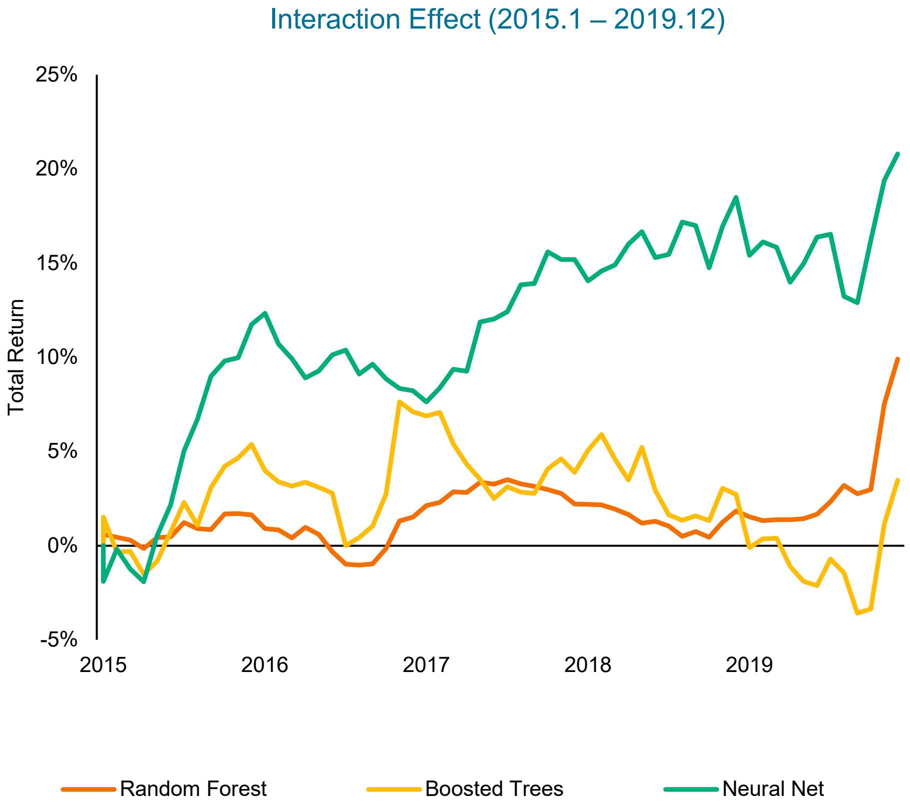
Performance Fingerprint – Comparing Models





Charts cover period January 2015 through December 2019.
Source: State Street Global Markets, DataStream.

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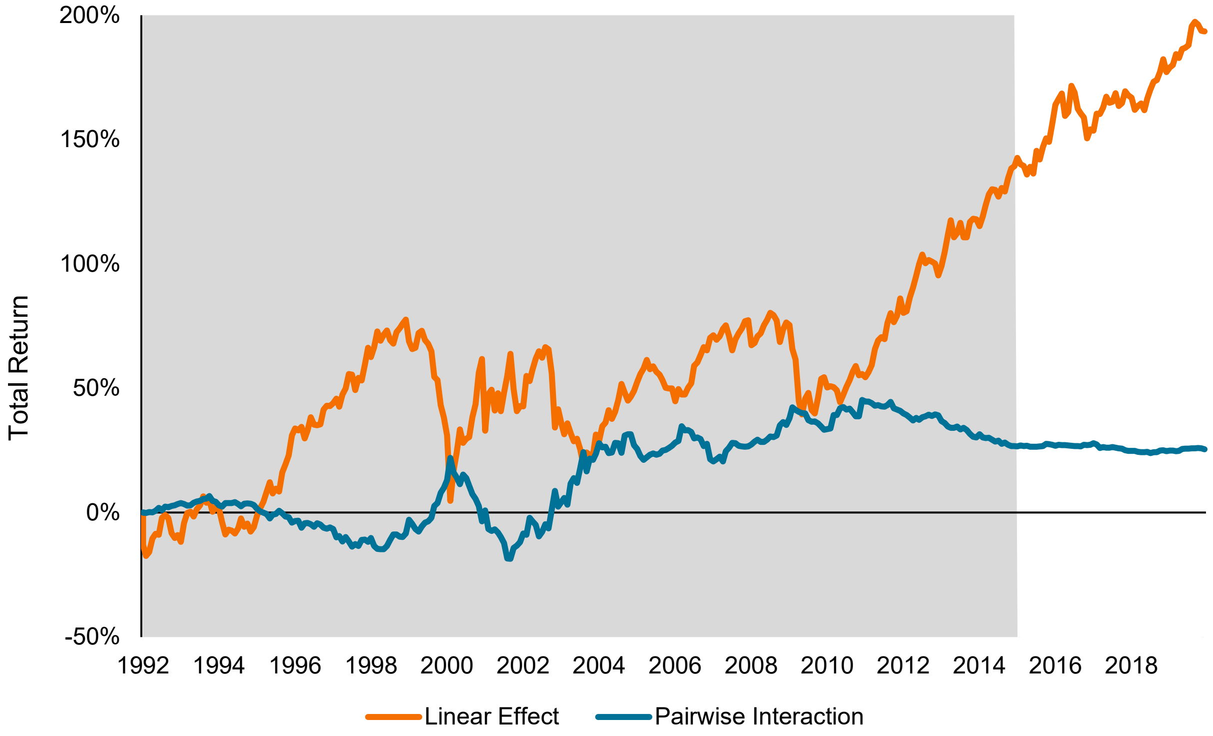
Hedging by Interactions

Random forest as an example



Correlation between pairwise interaction and linear effects

-55%

Chart covers period January 1992 through December 2019.
Source: State Street Global Markets, DataStream.

Summary: Machine Learning for Equities

Predictive

- ML models are shown to outperform linear models, due to their ability to model interactions and nonlinear effects

Flexible

- ML models can be made to be goal oriented, hence helping predict most relevant measures of performance

Interpretable

- A helpful way to approach machine learning is to compare machines to people. Even complicated models can find simple and interpretable relationships.
- Model fingerprint is a model-agnostic statistical framework that decomposes ML predictions into linear, nonlinear, and interaction components.
- The “black box” can be cracked open to understand how a ML model thinks

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