UBS

Global Research

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Machine Learning in Finance

Limits and potential

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Section 1

Artificial Intelligence & Machine Learning

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Artificial Intelligence

- "The study of the design of intelligent agents. An agent is something that **acts** in an environment – it does something" (Poole *et al,* 1998*)*

- Symbolic (classical) AI:
  - Dominant approach from 1950s to1980s
  - Explicitly represent (hard-code) human knowledge using rules and facts
  - Suitable to solve well-defined logical problems

- Machine learning systems
  - Gained popularity in 1990s
  - *Trained* rather than programmed

Types of machine learning tasks

Supervised	Develop predictive model given inputs and labels
Reinforcement	Maximise cumulative reward
Semi-supervised	A few labelled and many unlabelled data points
Unsupervised	Find structure in input data (no labels)

Types of machine learning applications

Classification	Categorical output
Regression	Numerical output
Clustering	Divide inputs into groups
Dim. reduction	Simplify the inputs

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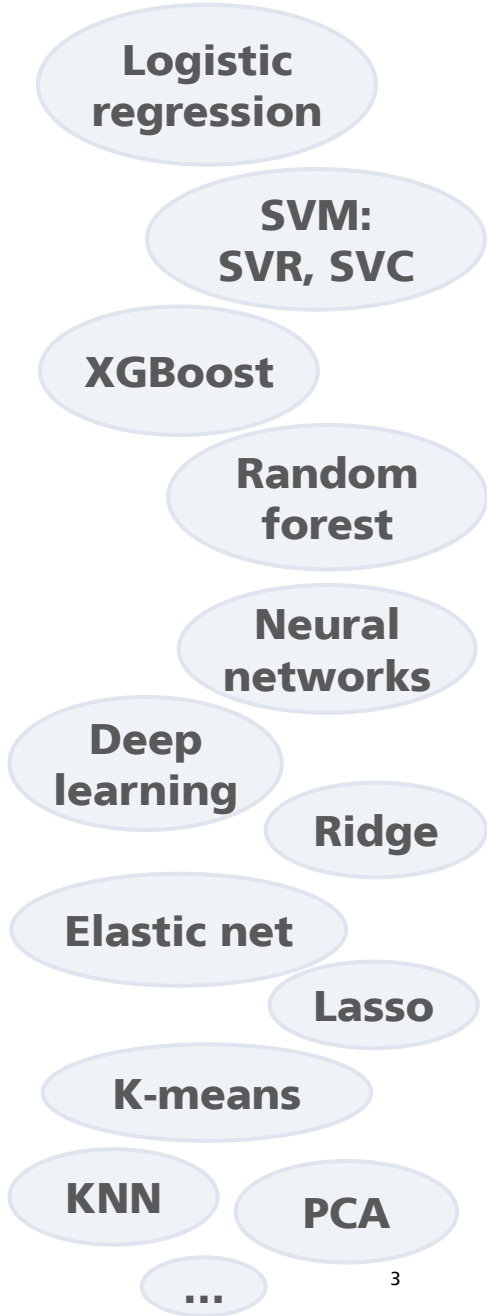
Choosing the right model

- Different models are suited for different types of applications
  - sklearn's guide to choosing the right estimator
  - Also takes in sample size into account

- Types of data: structured vs unstructured
  - Unstructured data includes audio, video, images, web-pages …
  - Which models win the most? According to Kaggle (Chollet 2017):
    Gradient boosting (decision trees) for structured/tabular data
    Deep learning (neural networks) for perceptual problems

- Practicalities:
  - To predict or to explain?
  - Linear vs non-linear models
  - Computational power
  - Production environment
  - Convergence issues



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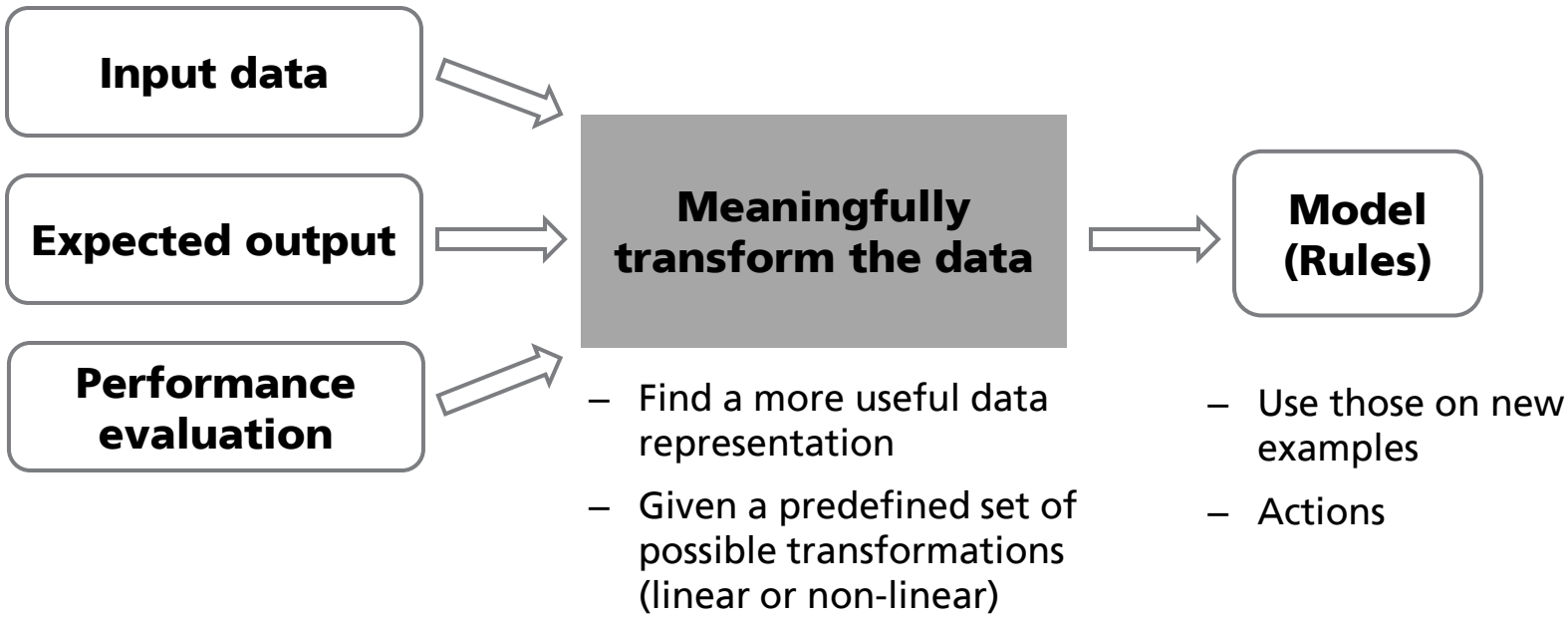
Machine learning basics



- All of machine learning involves finding transformations that turn data into more **useful representation** for a given task
- The performance of the model for the given task improves as we expose it to more training examples:
  - Predictions become closer to the actual values (low bias)
  - Robust to small fluctuations in the data (low variance)

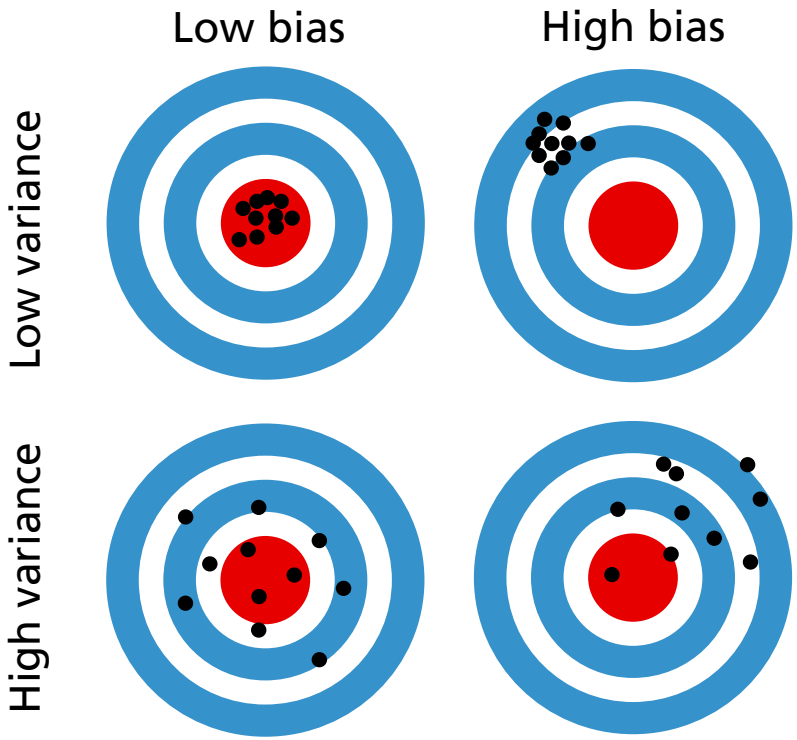
Bias-variance trade-off

Machine learning basics: Bias-variance trade-off (1)

- Suppose you are trying to predict the outcome of a referendum from a survey of 25 students.
- The **bias** is the difference between the expected prediction of the model and the correct value we are trying to predict.

  i.e. the difference between the student vote and the general population's vote
- The **variance** is how much the prediction varies between different realisations of the model.

  i.e. if you surveyed a different group of 25 students, how different would your result be?



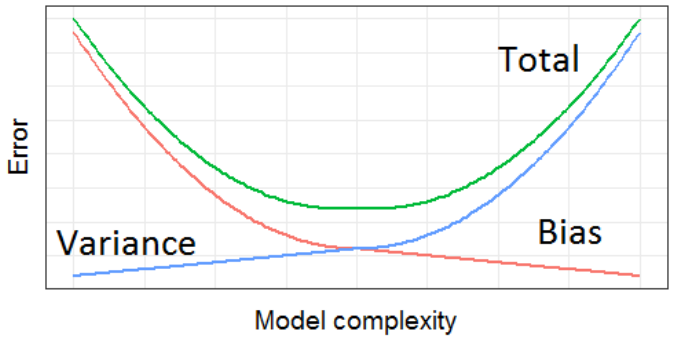
Source: UBS Quants

Machine learning basics: Bias-variance trade-off (2)

- There is typically a trade-off between bias and variance as you increase the model's complexity.

  e.g. suppose you fit a polynomial relationship between x and y with 100 data-points. As you increase the degree of the polynomial, you will decrease the bias, but increase the variance.

- If you over-fit a model you can expect to see low bias, but high variance.
- If you under-fit a model you can expect to see high bias but low variance.



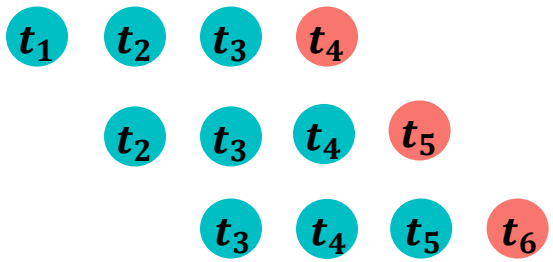
Source: UBS Quant. For illustrative purposes only.

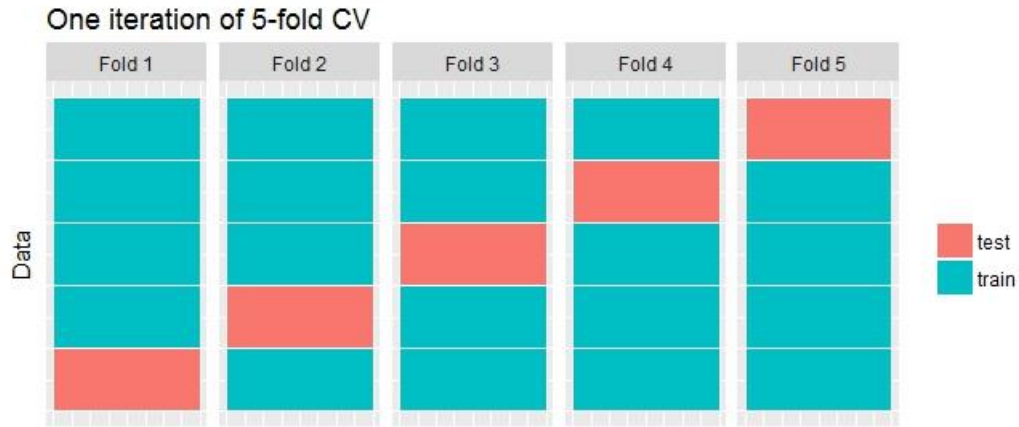
- Analysts often obsess over reducing bias, but variance is an equally important a source of error.
- Finding the best model amounts to finding the sweet spot between variance and bias.

Machine learning basics: Resampling

- The golden rule of Machine learning: Don't overfit your data!
  - Choose an appropriate evaluation protocol
  - Ideally split data into train, validation and test set
- Resampling schemes:
  - Bootstrap: sample from data with replacement
  - Cross validation (CV): split data into K groups, train on $K-1$, validate on the last
  - Time series resampling: rolling or expanding window

Time series CV: rolling window





Source: UBS Quant. For illustrative purposes only.

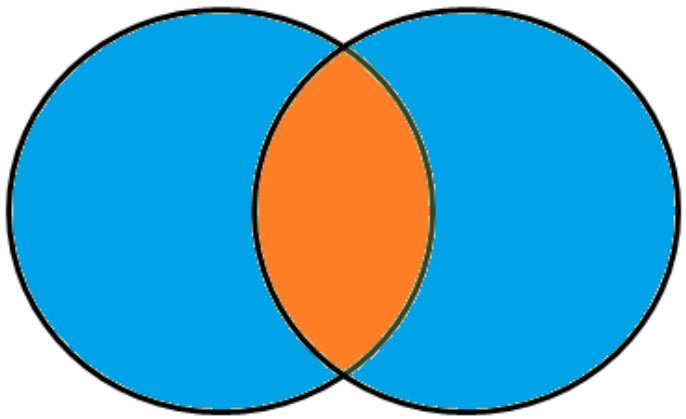
Machine learning basics: feature engineering (1)

- Use domain knowledge or experience to create new features (variables)
  - Reduce the chance of overfitting
  - Good features are crucial to make a machine algorithm work
  - Particularly important for "small data" problems , as it is hard to apply automatic feature learning (deep learning)
  - Difficult and time-consuming

Example: the XOR problem

- *XOR* or "exclusive or": either X or Y but not both
- A non-linear problem
- Do we need a non-linear model to solve it?

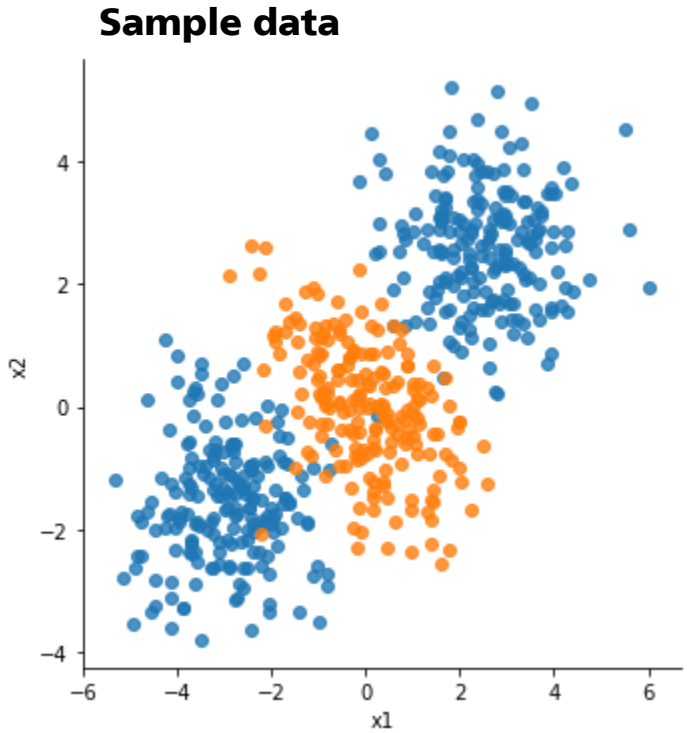
XOR: Venn diagram



Source: UBS Quant. For illustrative purposes only.

Machine learning basics: feature engineering (2)

- Separate the blue points from the orange points
- Clearly a non-linear boundary
  - Logistic regression does poorly
- Non-linear model: support vector machine
  - Very easy to run… but hard to understand and explain
- Define a new variable, equal to the product of the two original ones ($x_3 = x_1 * x_2$)
  - Artificially introducing non-linearity
  - Logistic regression does much better
  - Easy to run, understand and explain!



Source: UBS Quant. For illustrative purposes only.

	Logreg 1	SVM	Logreg 2
Accuracy	67.7%	96.7%	95%
Confusion matrix	$\begin{bmatrix} 382 & 18 \\ 176 & 24 \end{bmatrix}$	$\begin{bmatrix} 385 & 15 \\ 5 & 195 \end{bmatrix}$	$\begin{bmatrix} 375 & 5 \\ 25 & 195 \end{bmatrix}$

Supervised learning: workflow

- Formulate the problem:
  - What are the inputs and outputs? → Binary/Multiclass/Regression problem
  - Collect and label data

  Hypotheses made:

  (1) Output can be predicted given the inputs

  (2) Collected data is sufficiently informative to learn the relationship
- Choose measure of accuracy and evaluation protocol
  - E.g. MSE, Accuracy, ROC area under the curve
  - Split data in train, validation, test split vs cross-validation
- Data preparation:
  - Normalise/scale inputs
  - Feature engineering, especially for small data problems
- Develop a baseline model
- Develop a model that achieves statistical power (outperforms the baseline model)

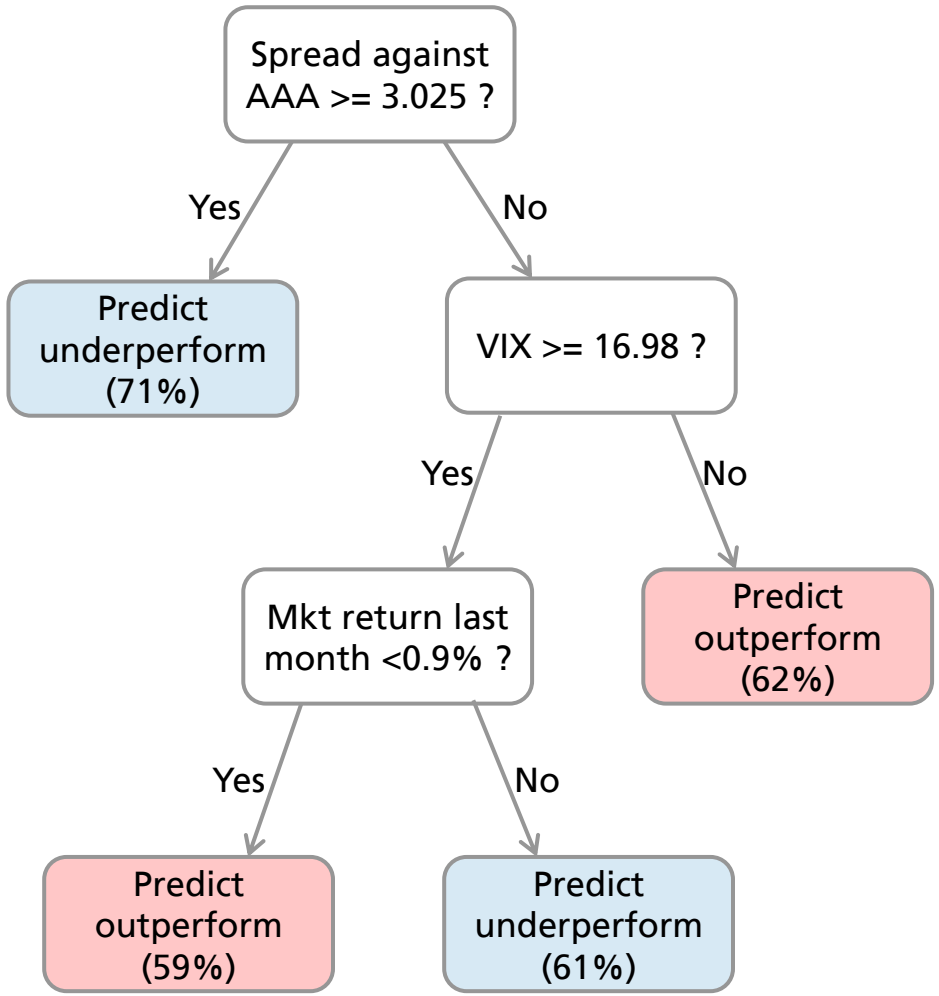
Section 2

Decision Trees

What is a decision tree?

- The output looks like a flow chart.
- To make a prediction for today, you work your way down the tree until you reach a "leaf".
- The leaf gives you a forecast class and an attached probability e.g. underperform with a probability of 71%.
- There are lots of packages to do this, we tend to use rpart:

```
library(rpart)
myTree = rpart(outperform ~., data=myData)
```



Example of a classification tree

Source: UBS Quants

Pros and cons of decision trees

Pros

- Completely transparent
- Easy to interpret and communicate
- Robust to outliers / non-normal inputs and works with categorical and continuous data inputs
- Does not rely on linear relationships

Cons

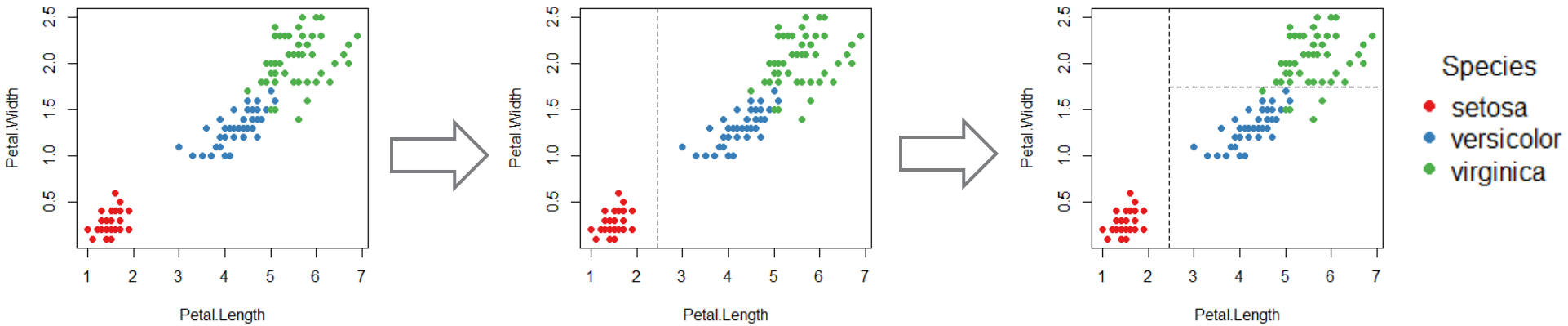
- Decision trees are often unstable i.e. the tree can change completely with the addition of an extra data-point
- Doesn't cope well with severe class imbalances
- Doesn't forecast well for inputs outside the range of its training set
- Sometimes over-fit

How do we grow a tree?

- We start with all of our data.
- If your data-set is finite then for each feature there are a finite number of possible thresholds, so we can test every possible combination of feature and threshold and choose the one which divides the data "most cleanly" into two homogenous sub-groups.
- Then we repeat the process with each of those two sub-groups separately and so on recursively.

Simple example: Two features, three classes

Which feature and which threshold should you choose to divide the data "most cleanly"?



Source: UBS Quants

Data is the iris dataset, showing petal width and petal length for three species of iris

Over-fitting

- The rules we have seen so far will make the tree grow until every node is completely homogenous.
- This will typically lead to a massive, complicated tree which over-fits the data.

- R (and other similar stats programs) have two stages to prevent over-fitting:

1. It does not allow the tree to grow out completely. It stops the tree when:
   - The node is very small
   - The best available split leads to a very small leaf
   - The best available split does not improve the fit by a certain amount
2. It returns some statistics to show what a "sensible size" is. Then you can prune the tree back so that it doesn't overfit.

Section 3

Random Forests

Overview of random forests (1)

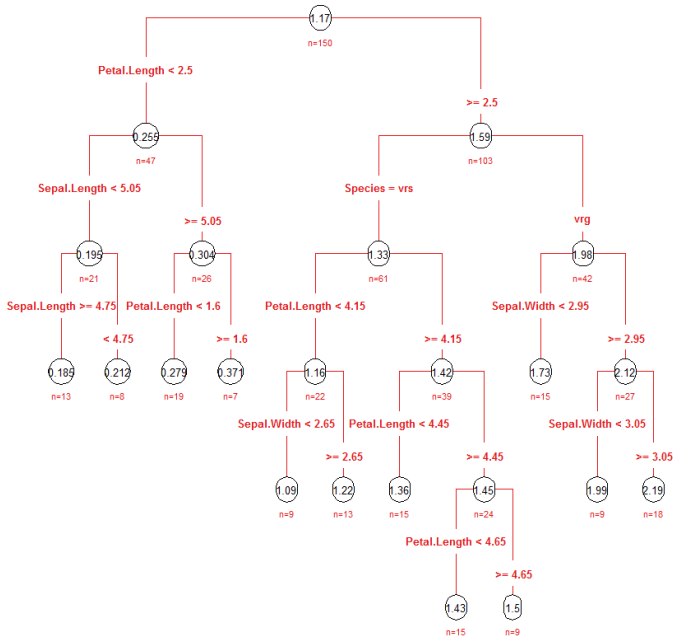
- Random forests (Breiman, 1999) is an algorithm which uses decision trees.
- We use the package "randomForest" to create these models.
- In brief, a random forest is a large collection of trees, each grown independently, with two additional sources of randomness.
- For each tree in the forest:
  1. Start with a bootstrap sample of the data.
  2. At each node, select M of the available features at random. Find the best feature and threshold to use at this node.
     - In R, the default value for M is set to $\sqrt{}$(# of variables).
  3. Continue this process with each of the two sub-groups until you have completely grown the tree out and each node is homogenous.

  Repeat until you have a large number of completely grown out trees.

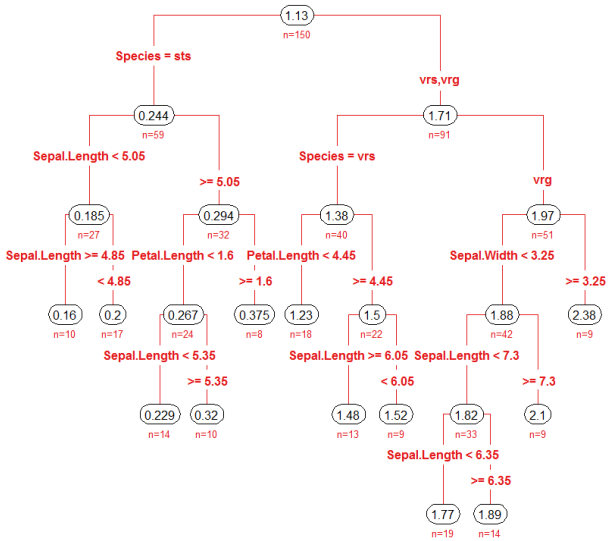
Overview of random forests (2)

- To use the forest for prediction, you take the prediction from each of the individual trees and combine them with a majority vote.

Tree 1,

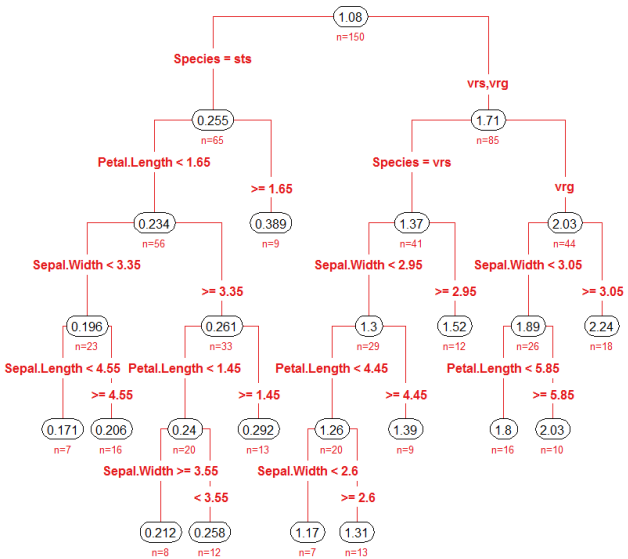


Tree 2,



....,

Tree 500



Source: UBS Quants

Why should a forest be better than a tree?

Intuitive argument:

- If you have multiple (somewhat independent) models with different pieces of useful information, then choosing just one of them, even if it is the best, means throwing away some of that information.
- If you instead combine models, you can keep the insights from all the models, which should produce a stronger, more robust overall model.

Bias vs Variance argument:

- In a random forest, the bias of the forest is equal to the bias of an individual (overgrown) tree, but the variance of the forest is much smaller than the variance of an individual tree, so the overall error is much lower.
- We ensure that each individual tree has low correlation to its peers by allowing them to grow all the way out, using bootstrap sampling and using random feature selection, so that the variance decreases more rapidly.

Importance

- A random forest can also tell us which of our features is most important:
  - For each feature, we look across all the trees and find every node which uses that feature.
  - Then we compute how much each node which uses that feature decreases the Gini impurity.
  - We take the average.

- A higher value indicates the feature is very effective at distinguishing between classes and a lower value indicates the feature is less effective.

- It can be helpful to use random forests to order a list of features to understand your data better, even if you then go on to use a different model.
  - Be careful though; this statistic does not take into account the correlation between features. Two very highly correlated features will have similar importance, but there is little to be gained from including both in your model.

Pros and cons of the random forests

Pros

- Much more effective than a single decision tree.
- Very little pre-processing of your signals is required. Random forests can handle outliers, non-normal inputs and both categorical and continuous inputs.
- Easy to parallelise which allows for faster runtimes.
- Identifies important signals, which is helpful when you build other models.

Cons

- Random forests are (to some extent) a black box. They are far harder to interpret and communicate than a simple decision tree.
- Can still struggle with severe class imbalances
- Random forests can struggle to generalise to new data if it lies outside the range of data it was trained on
- Random forests tend to be biased towards continuous variables or categorical variables with lots of splits.

Section 4

Random forest example: Forecasting dividend cuts

Random Forests: forecasting dividend cuts (1)

The problem:

- Forecast which stocks in the Russell 1000 will cut their dividend by more than 5% in the next 12 months
  - 5% requirement reduces "noise"
  - We only use ordinary dividends per share (no special dividends or stock dividends etc.)
  - We exclude firms which have had large corporate actions in the 12m before the ex-div date.

The features:

- We selected 116 factors from our daily factor database and supplemented each variable with its 3-month and 12-month changes. In total this gives us 348 explanatory variables
  - The model does not include information about the companies' dividend policies nor does it attempt to forecast changes in dividend policies
- We use 7 year rolling windows for the analysis
  - There are secular changes in dividend yields, so an expanding window is misleading
  - For long periods of time, almost no stocks cut their dividends so you need a long window.

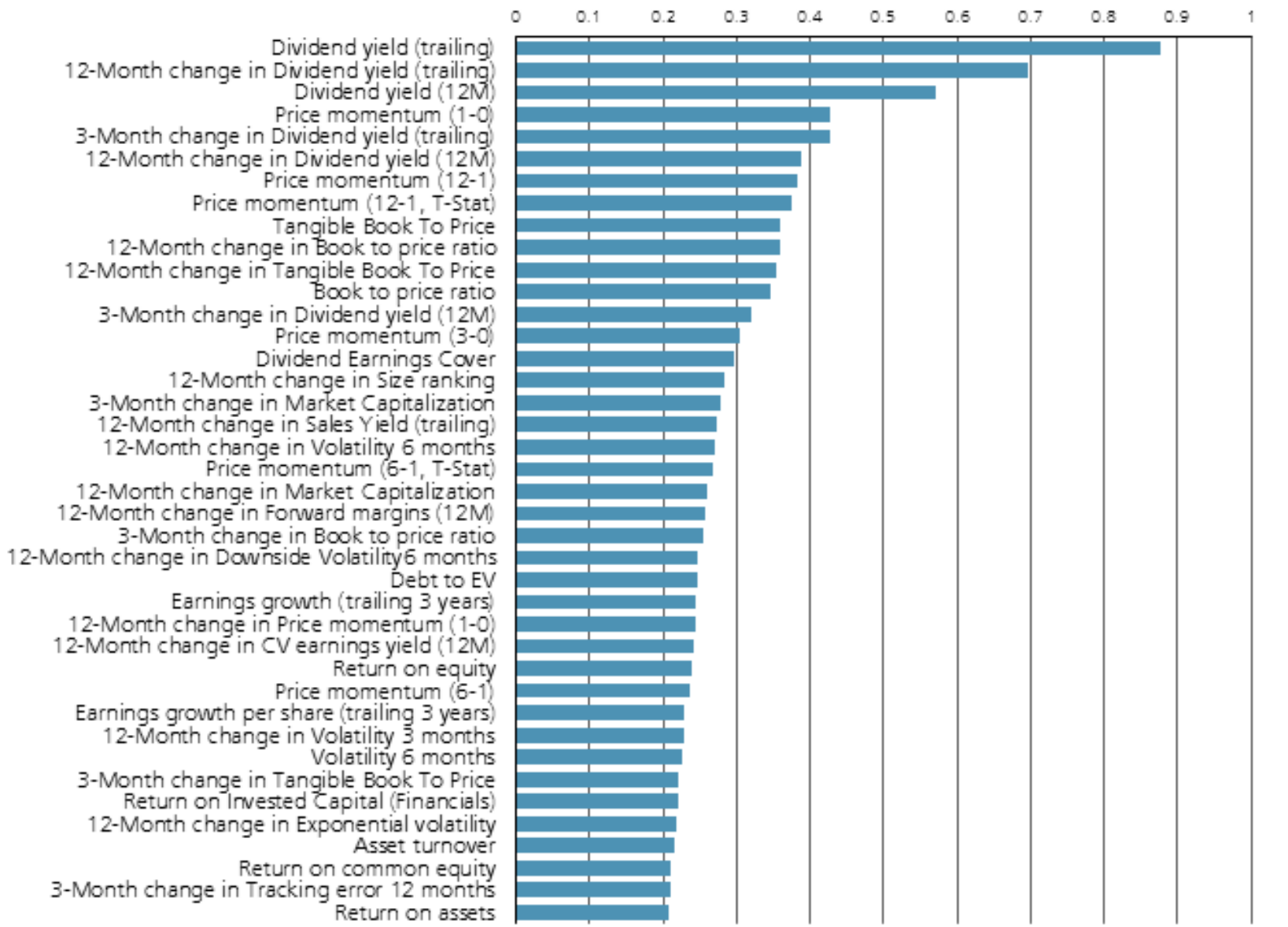
The model:

- Random Forest with 2000 decision trees.

Random Forests: forecasting dividend cuts (2)

1. Dividend yield
2. Changes in dividend yield
3. Price momentum
4. Book to price
5. Dividend cover
6. Debt to Enterprise Value
7. Historic earnings growth
8. Profitability
9. Volatility

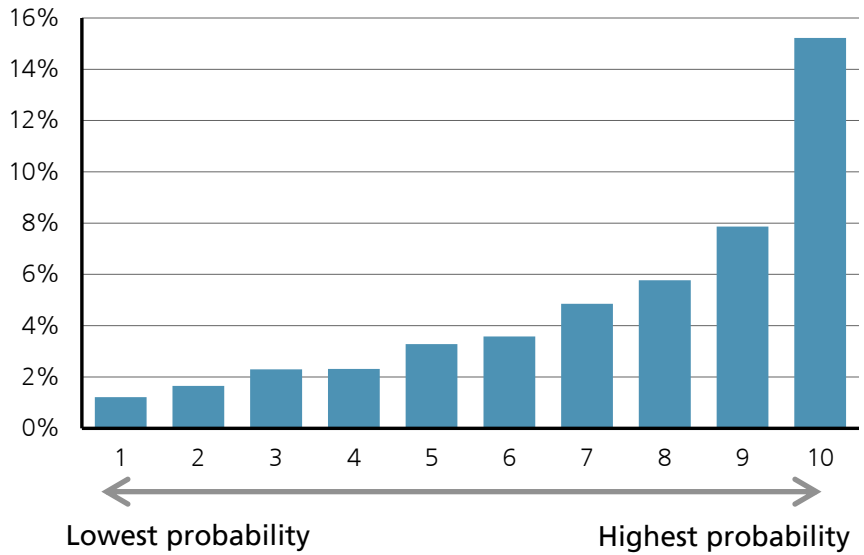
The 40 most important explanatory variables (average importance across the 30 panels, rescaled)



Source: UBS Quantitative Research

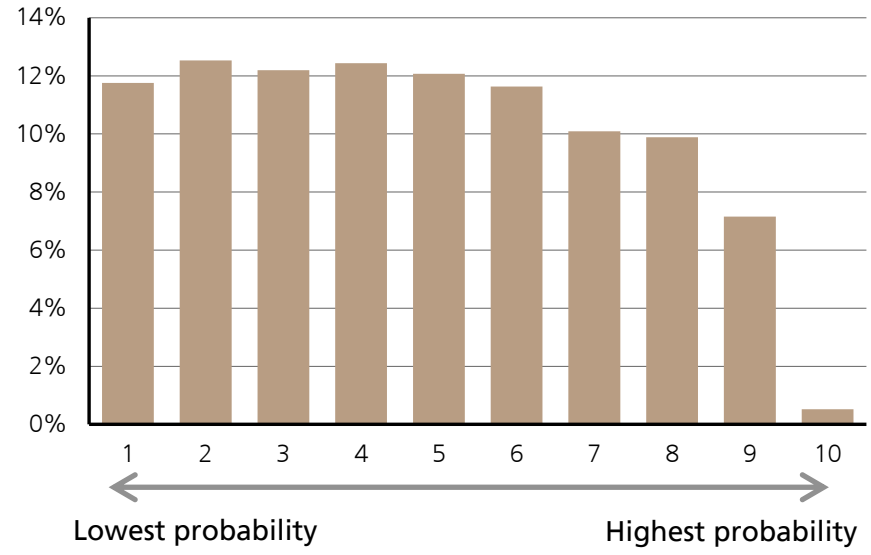
Random Forests: forecasting dividend cuts (3)

Proportion of dividend reduction in each decile



Source: UBS Quantitative Research. US largest 1000 stocks.

Average DPS growth rate in each decile



Source: UBS Quantitative Research. Trimmed average. US largest 1000 stocks.

- More than 15% of the companies with the highest estimated likelihood of a dividend cut ended up reducing their dividends compared to just 4.8% across all the deciles.
- Companies with the highest expected probability of a dividend cut grew their dividend per share by much less over the next year than other firms.

Section 5

Deep learning

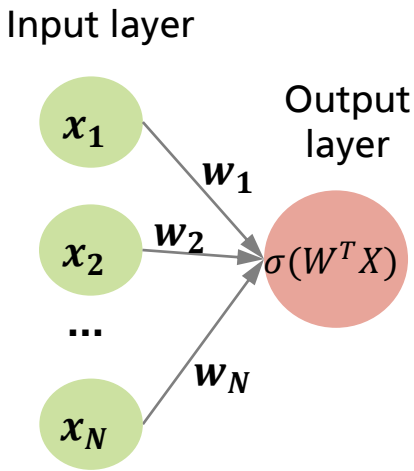
Deep Learning

- Class of machine learning algorithms
  - "Learning": Discover useful representation of some input data, using guidance from a feedback signal
  - "Deep": Use **successive layers** of increasingly useful representations
  - Automates the most crucial step in classical machine learning – feature engineering
- Layered representations are learned via neural networks
- Notable achievements
  - Image classification
  - Self-driving cars
  - Speech recognition, NLP
  - Go!

  } **Perceptual problems**
- Why is deep learning successful?
  - Simplicity
  - Scalability
  - Reusability

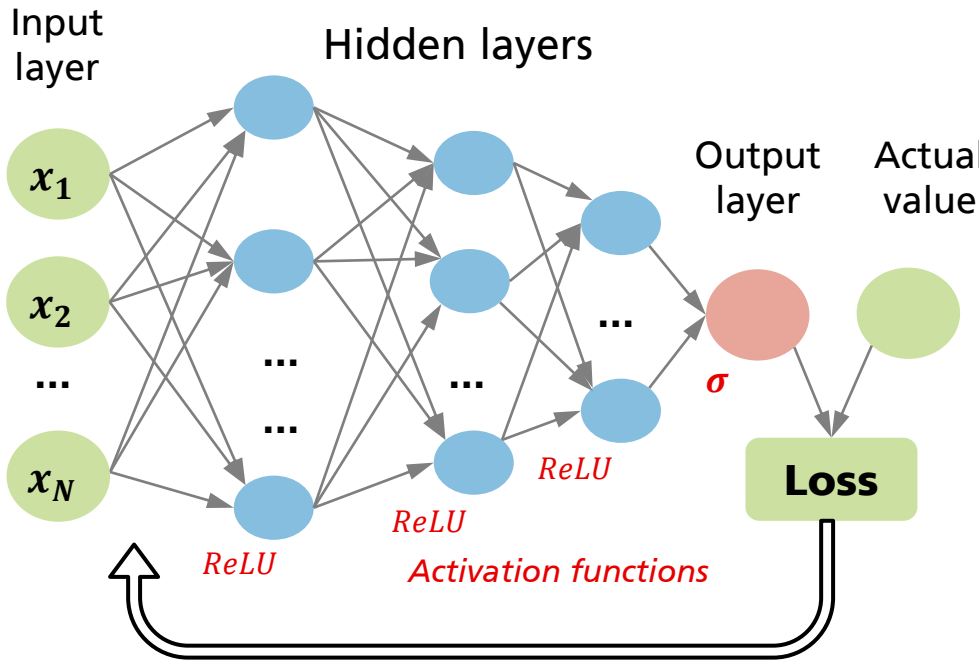
Neural networks basics (1)

Logistic regression



- X is the design matrix, W is a vector of parameters, aka **weights**
- We have ignored the intercept (aka the **bias** term)
- $\boldsymbol{\sigma(x) = \frac{1}{1+x^{-1}}}$ is the sigmoid function
- Logistic regression can be viewed as a single layer neural network

Fully connected feed-forward NN



Source: UBS Quant. For illustrative purposes only.

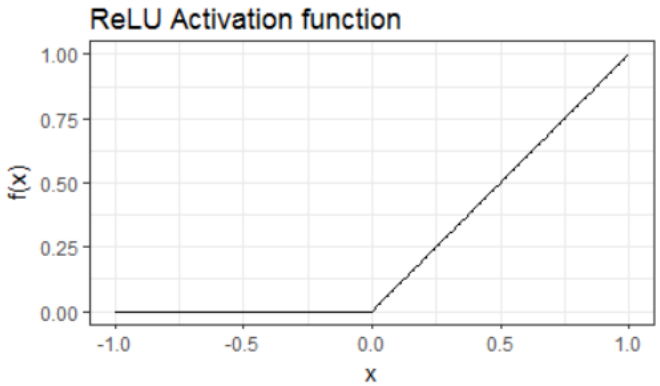
- Every edge has an associated weight
- The value of every neuron is a non-linear function (e.g. σ), applied to a linear combination of the neurons in the previous layer (e.g. $W^T X$)
- N-layer network consists of $N-1$ hidden layers and an output layer

Neural networks basics (2)

- Network configuration
  - Number (and type) of the hidden layers
  - Size of layers (number of hidden neurons)

} **Hyperparameters** → tuning

- Activation functions
  - Non-linear (usually), differentiable (almost everywhere)
  - Hidden layers: ReLU, ELU, hyperbolic tangent
  - Output layer: Identity, softmax, sigmoid



- Loss functions:
  - Regression: mean squared error (*MSE*)
  - Classification: cross-entropy

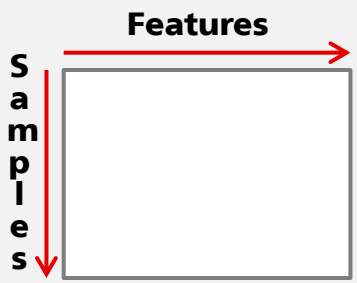
- Fitting neural networks: Backpropagation algorithm
  - Forward pass: make predictions given some weights
  - Backward pass: optimise weights (gradient descent + chain rule)

Source: UBS Quant. For illustrative purposes only.

Data formatting

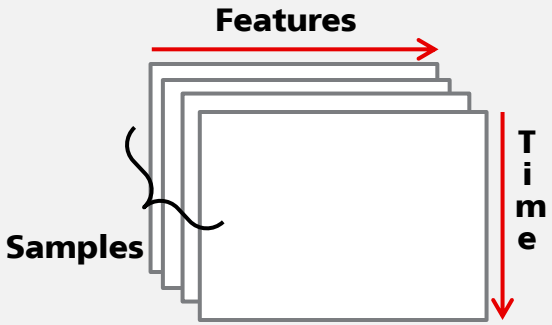
- Data representations:
  - Tensors: multidimensional arrays of numbers

2D Tensor: vector data



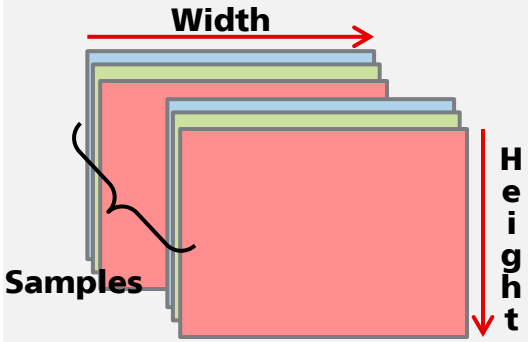
- **House prices**: for each property consider its *value*, *post-code*, *square meters*. Dataset of 100K properties → (100,000; 3)
- **Text documents**: count how many times each word appears in a it. Given a dictionary of 50K common words and 500 documents → (500; 50,000)

3D Tensor: time series



- **Stock prices**: Every minute store *current price*, *highest, lowest* price and volume traded in the past minute. Each trading day is represented as (390; 4) tensor. 1 year worth of data for one stock → (250; 390; 4)

4D Tensor: images



- **Gray-scale images:** 100K images of size 256×256 → (100,000; 256; 256; 1)
- **Colour images**: 100K images of size 256×256 → (100,000; 256; 256; 3)

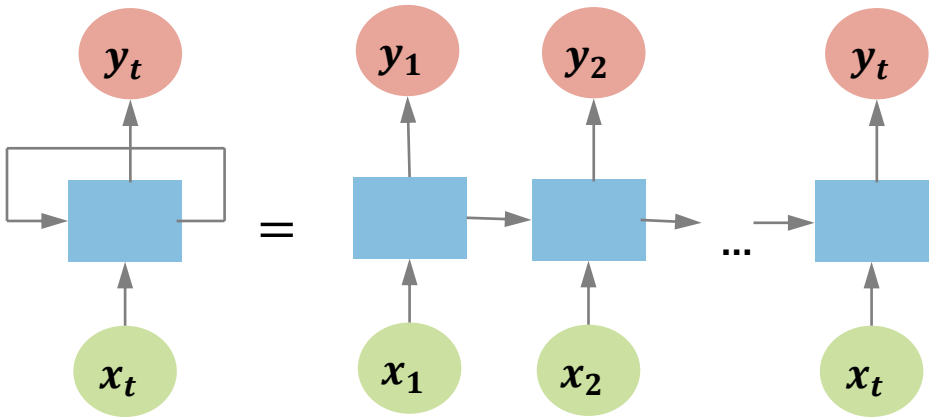
Source: UBS Quant. For illustrative purposes only.

Networks architectures

- Data representation (usually) determines the type of layers used in networks

Architecture	Suitable for	Data format	Layer type
Fully connected	Simple vector data	2D tensors	Fully (densely) connected
Convolutional (convnets)	Image data	4D tensors	Convolutional layers (e.g. Conv2D)
Recurrent (RNN)	Sequences (time series)	3D tensors	Long-short term memory (LSTM), Gated recurrent unit (GRU)

- Recurrent neural networks:
  - Have loops, allowing information to persist
  - LSTMs (Hochreiter *et al.*) solve the problem of learning long-term dependencies



Section 6

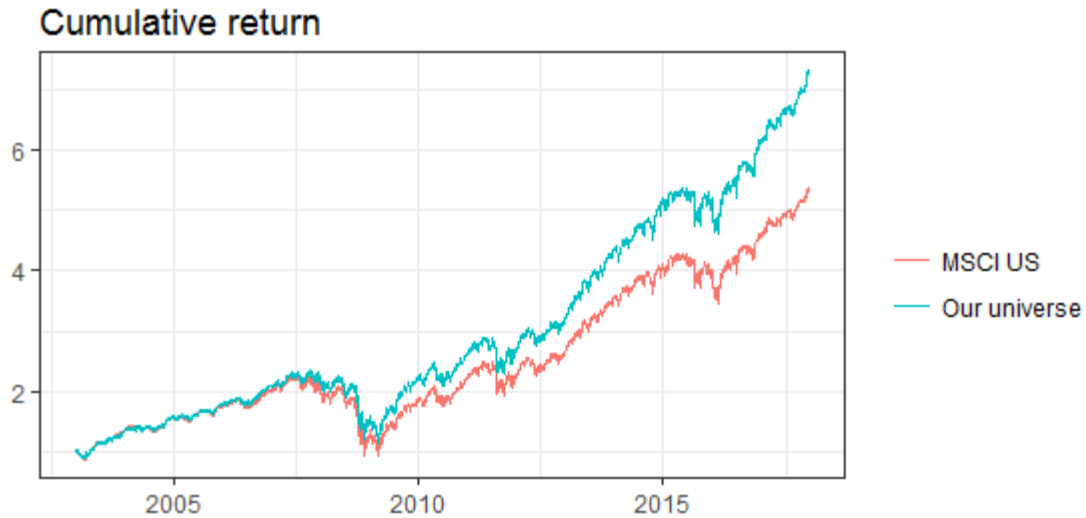
Deep learning example: Portfolio Returns

Setup (1)

- Example from Introduction to Deep Learning (implementation in TensorFlow/Keras available in recent Quantessentials)
  - n stocks, equally weighted in portfolio

$$r_p(t) = \sum_{i=1}^{n} \frac{1}{n} r_i(t)$$

  - Learn the relationship between all previous stock returns and directional change in the portfolio return
  - Observed data: historical daily returns, $\{X_t\}_{t=1}^{T}$, $X_t = r_1(t), \ldots r_n(t)$
  - The universe is MSCI US, restricted to those companies that have price data throughout the period from January 2003 through Nov 2017 (look-ahead + survival bias)



Source: UBS Quant, MSCI.

Setup (2)

- Inputs: daily returns of 215 stocks
- Target:

$$Y_t = \begin{cases} 1, & r_p(t+1) > \epsilon \\ 0, & |r_p(t+1)| < \epsilon \\ -1, & r_p(t+1) < -\epsilon \end{cases}$$

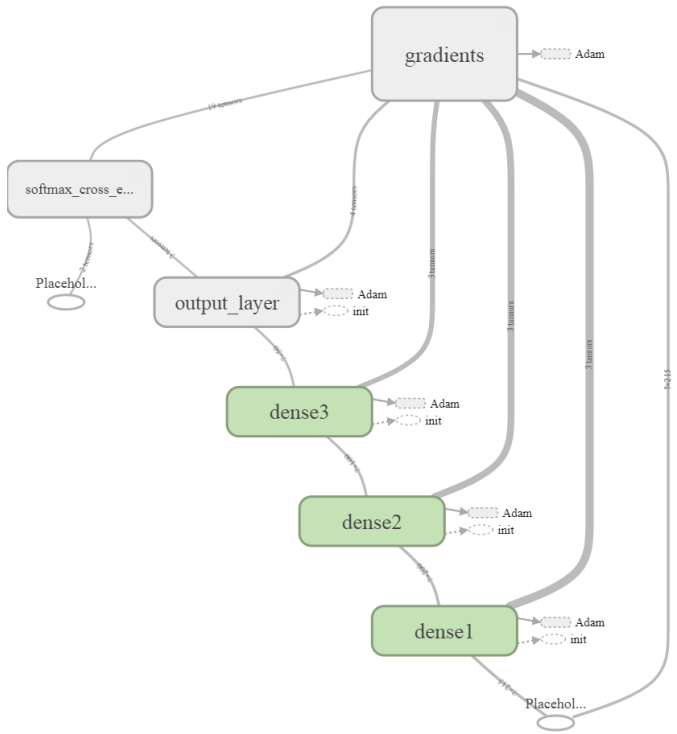
  - ϵ is determined from the training data to avoid class imbalance
- Standardise the inputs (based on the training data)
- One-hot encode the target
  - Example:

$$Y_t = \{0,\ 1,\ 1, -1\} \Rightarrow \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

- Training over 3500 data points, forecast one step ahead

Network architecture

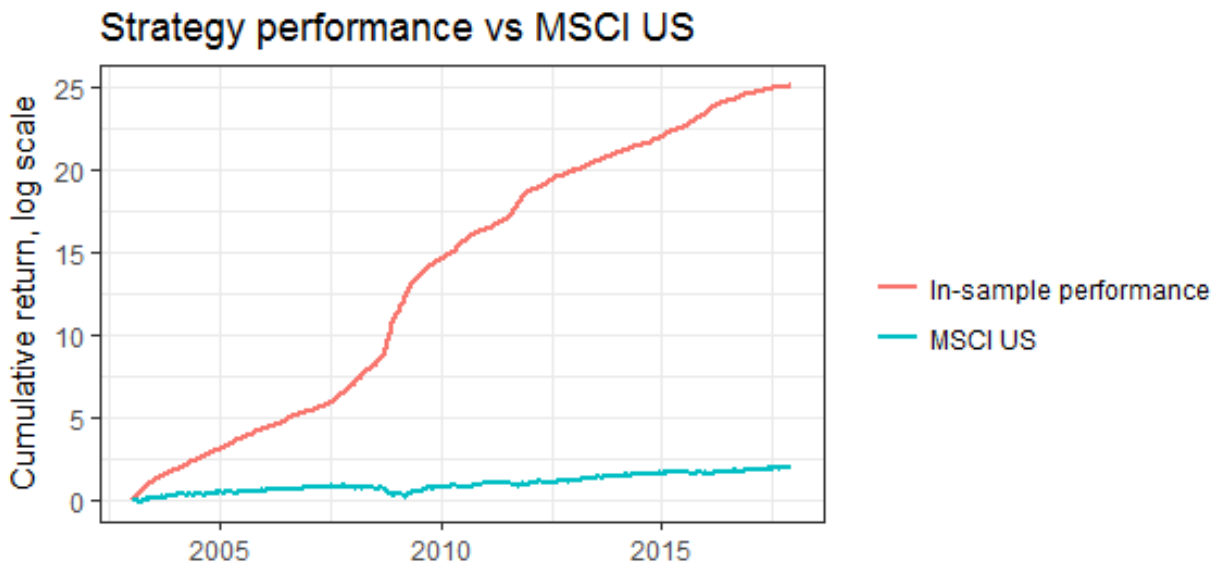
- Fully connected feed-forward
- 3 hidden layers with 200, 100 and 50 neurons and *ReLU* activation function
- Output layer consists of 3 neurons (one for each class), *softmax* activation
- *Cross-entropy* loss function



Source: UBS Quant, generated with TensorBoard.

In-sample results

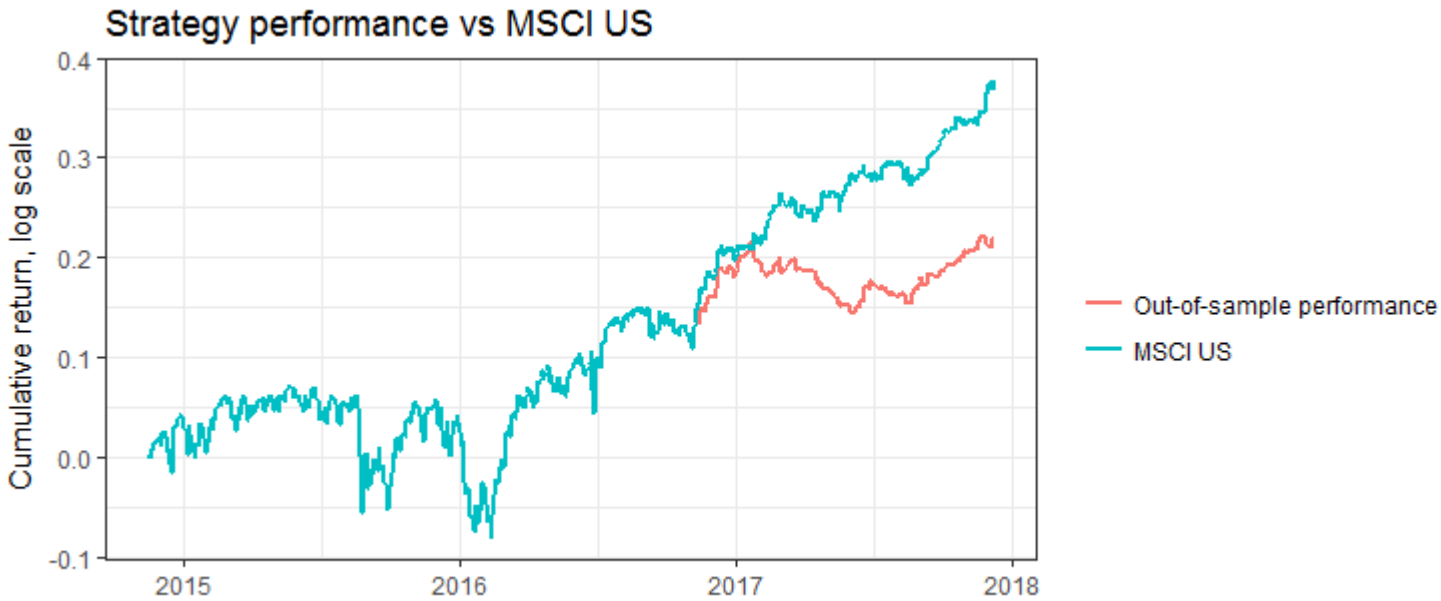
- We train the network on the entire dataset, mini-batch size of 100, 20 epochs (trained with *keras* + *TensorFlow* backend*)*
- In-sample accuracy: **93%**



Source: UBS Quant, MSCI.

Out-of-sample performance

- As one would expect, the deep network predictor is very high variance
- Out-of-sample accuracy (based on 275 samples): ~35%
- Slightly outperforms a naïve logistic regression classifier (accuracy of 33%)



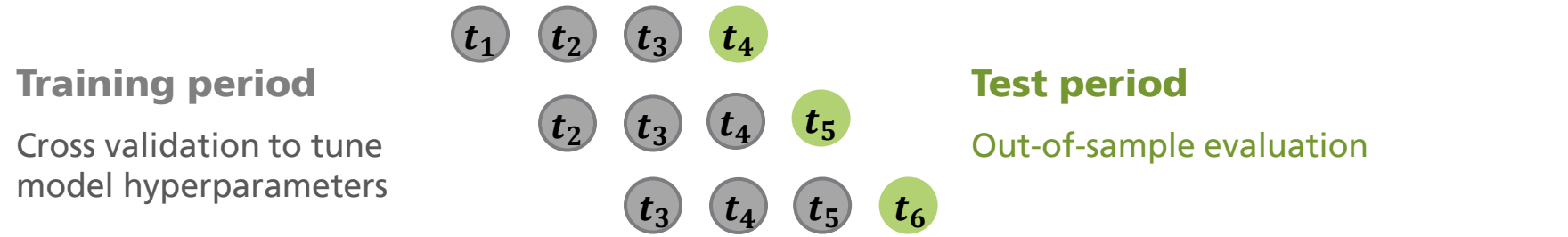
Source: UBS Quant, MSCI.

Section 7

What works best? "Horse race" between models

Setup

- **Task**: Given a set of stock-specific factors as inputs (fundamental and technical), predict next month return (output)
  - Regression problem
  - Measure of accuracy: mean squared error (MSE)
  - Evaluation protocol: cross validation
- Lookback period – 3 months, forecast 1 step ahead



Source: UBS Quant. For illustrative purposes only.

- Use out-of-sample predictions to rank stocks
  - Universe: MSCI Europe
  - Sample period: monthly data from Jan 2002 though Jan 2018
  - Equally weighted quintile portfolios, rebalanced monthly

Models considered

- Standard linear regression: **Baseline model**
- Linear with shrinkage
  - Elastic net
- Tree-based
  - Random forest
  - Extreme gradient boosting (XGBoost)
- Neural networks
  - Feed-forward fully connected (with and without regularisation)

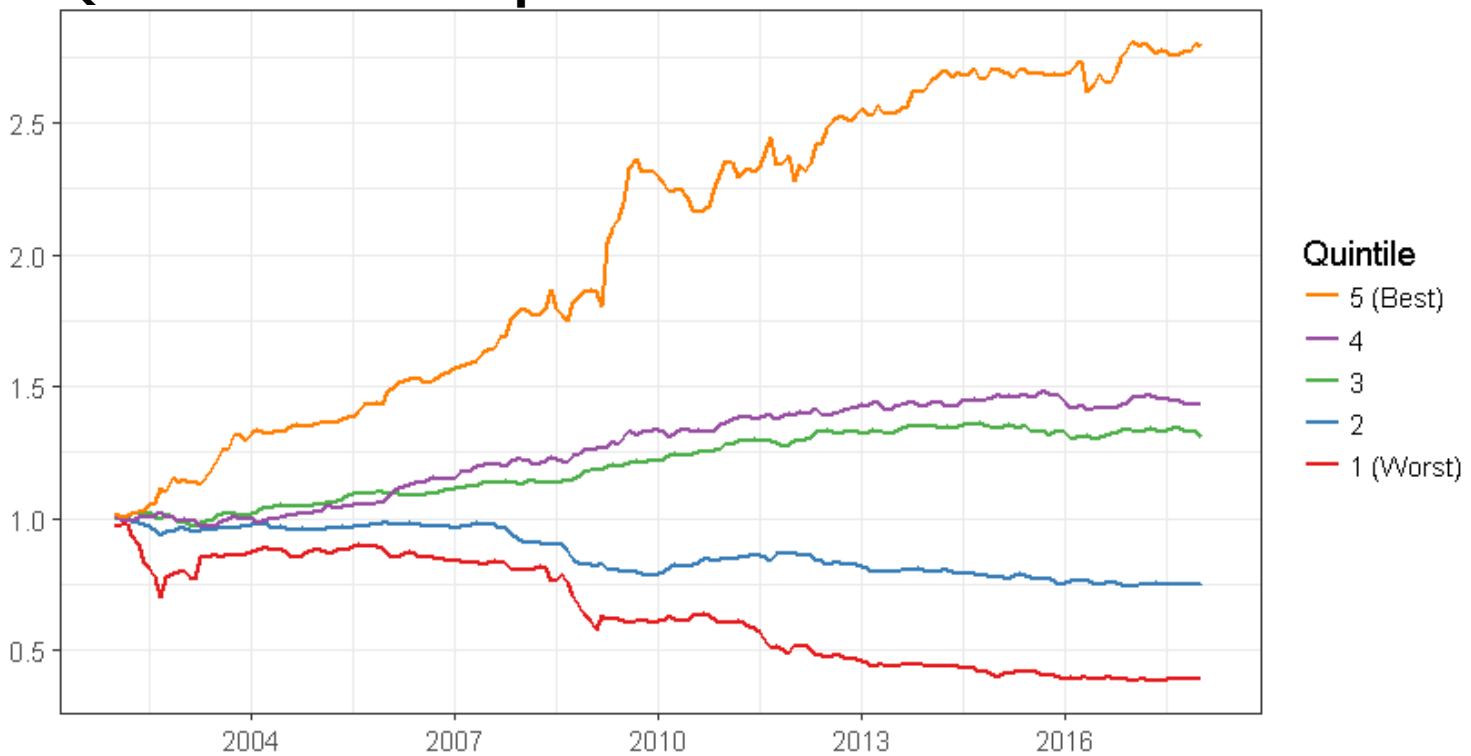
- Models compared on the basis of:
  - Absolute returns
  - Risk adjusted returns (Sharpe ratio)

Baseline model: linear regression

- No tuning parameters

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	-5.67%	-1.74%	1.69%	2.26%	6.59%
Annualised Std Dev	8.19%	3.04%	2.40%	2.88%	6.24%
Sharpe (Rf=0%)	-0.69	-0.57	0.70	0.78	1.06

Quintile cumulative performance



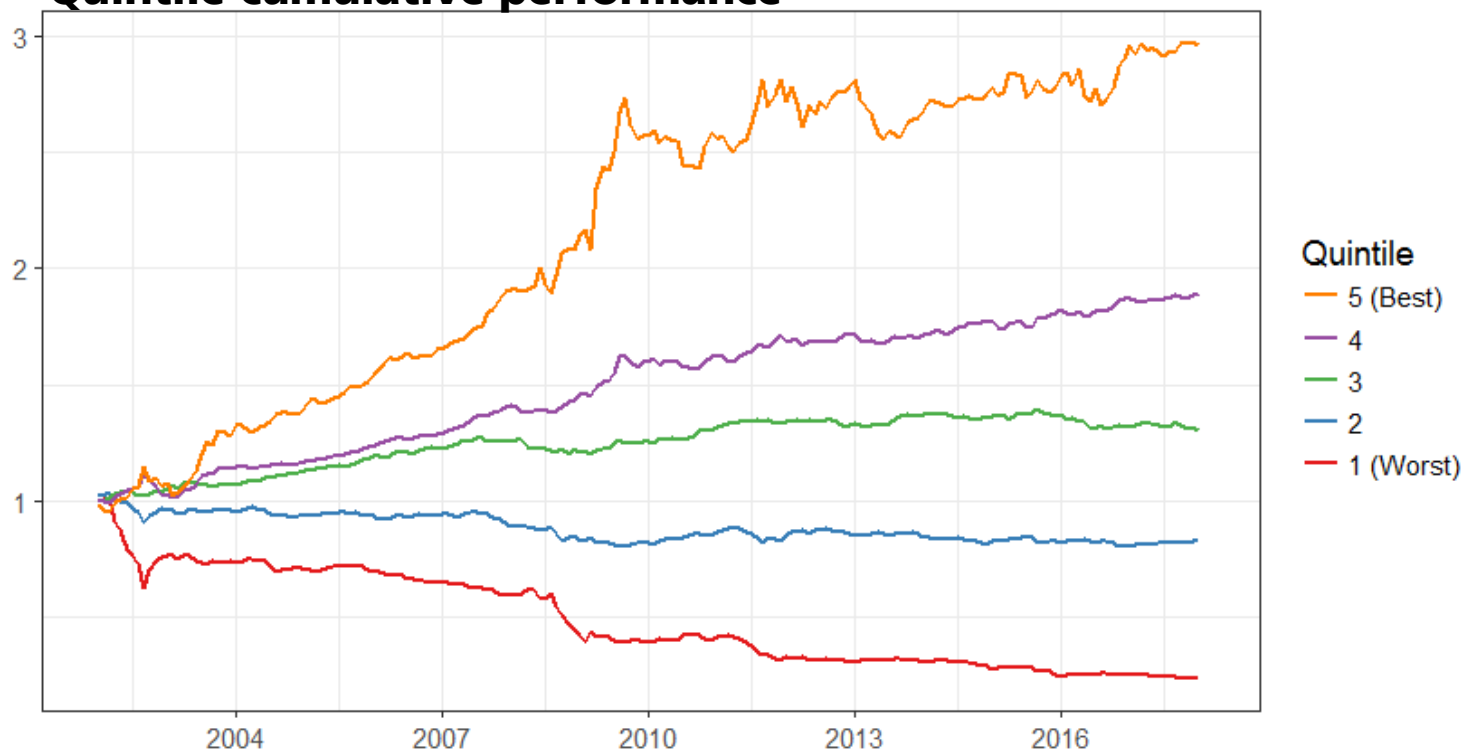
Source: UBS Quant, MSCI.

Elastic net

- Tuning parameters: λ – regularisation term; α – mixing parameter

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	-8.58%	-1.19%	1.64%	4.04%	6.99%
Annualised Std Dev	10.28%	4.07%	2.69%	4.57%	7.84%
Sharpe (Rf=0%)	-0.83	-0.29	0.61	0.88	0.89

Quintile cumulative performance



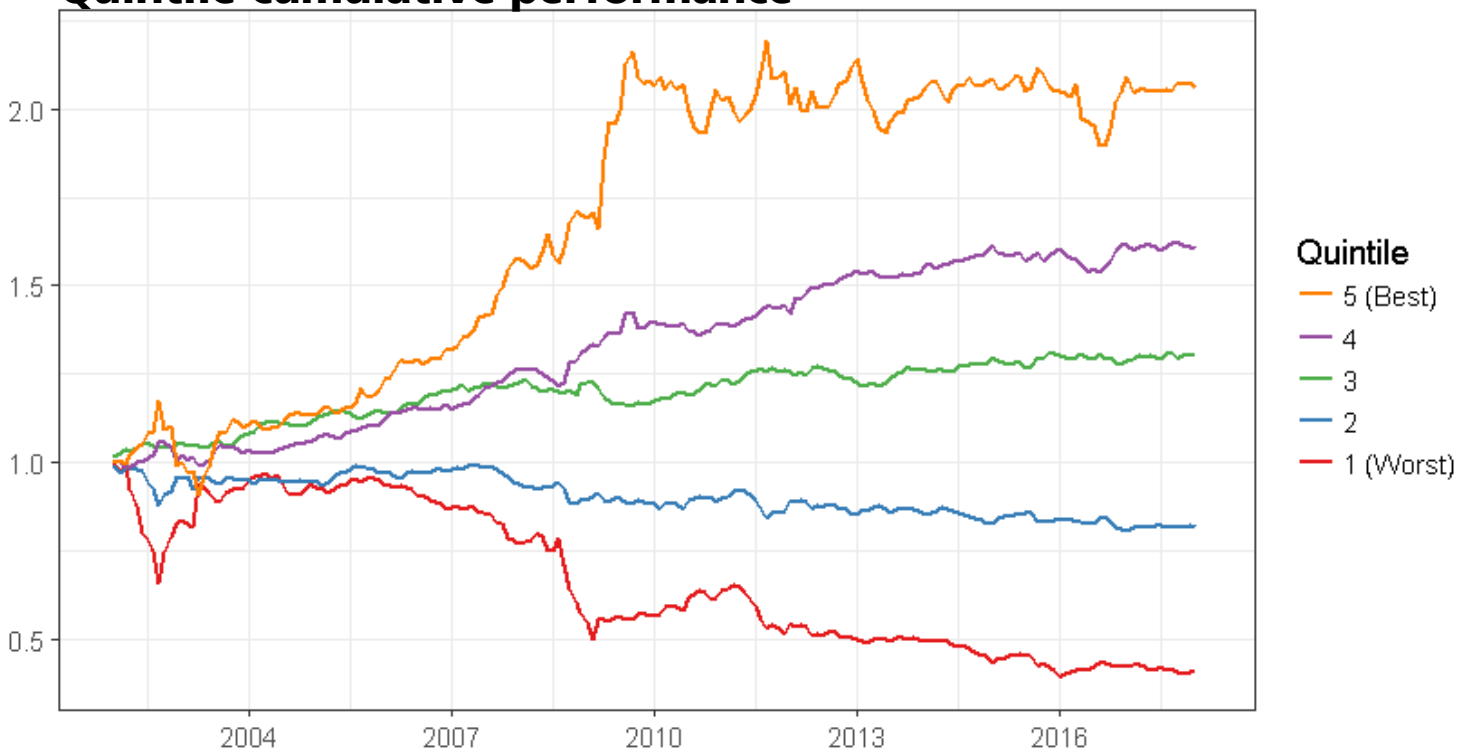
Source: UBS Quant, MSCI.

Random forest

- Tuning parameter: $mtry$ – number of variables randomly sampled as candidates at each split

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	-7.73%	-1.24%	1.65%	4.27%	6.04%
Annualised Std Dev	10.37%	4.30%	2.60%	4.61%	7.86%
Sharpe (Rf=0%)	-0.75	-0.29	0.63	0.93	0.77

Quintile cumulative performance



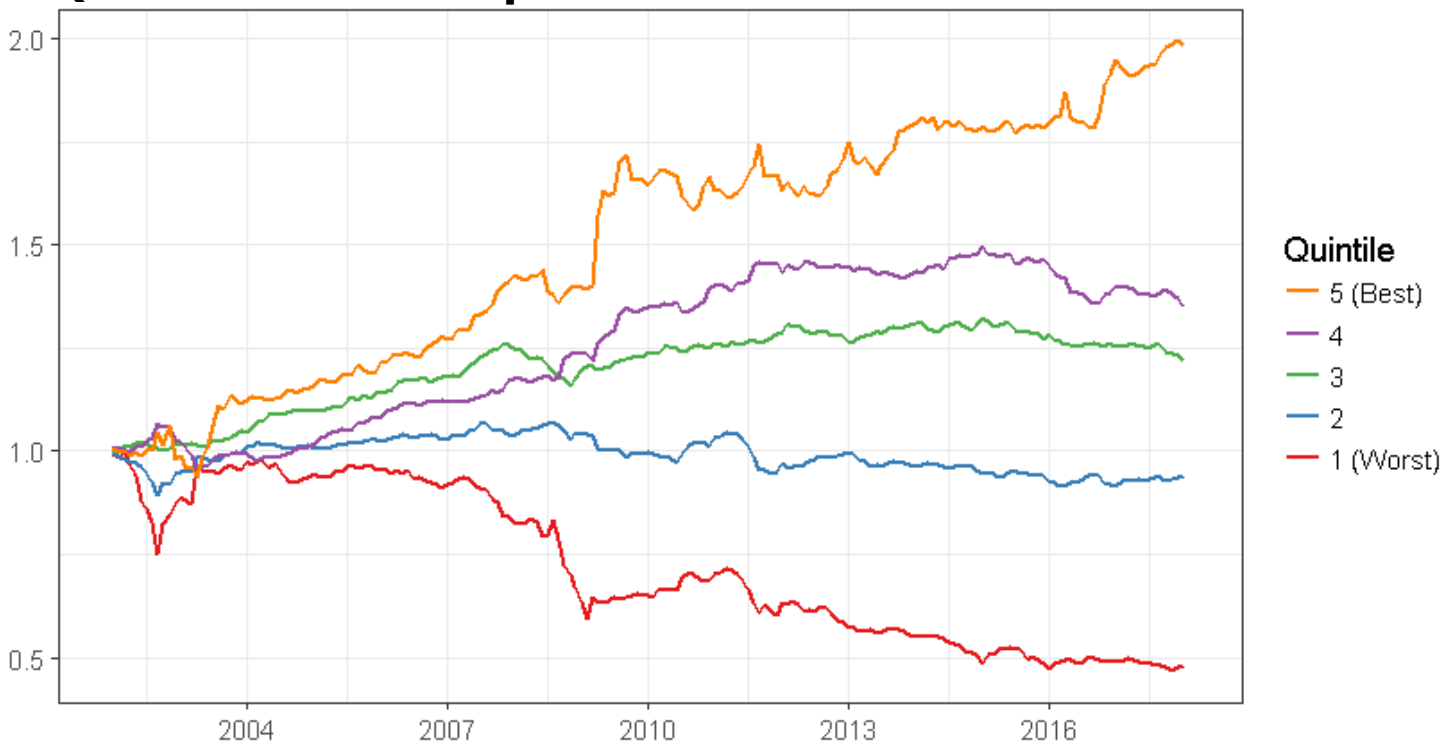
Source: UBS Quant, MSCI.

XGBoost

- Tuning parameters: $nrounds$ – max number of iterations, $gamma$ – loss reduction required to further partition, max_depth – max depth of a tree, eta – learning rate

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	-4.46%	-0.37%	1.25%	1.88%	4.35%
Annualised Std Dev	8.40%	3.43%	2.33%	3.32%	6.37%
Sharpe (Rf=0%)	-0.53	-0.11	0.54	0.57	0.68

Quintile cumulative performance



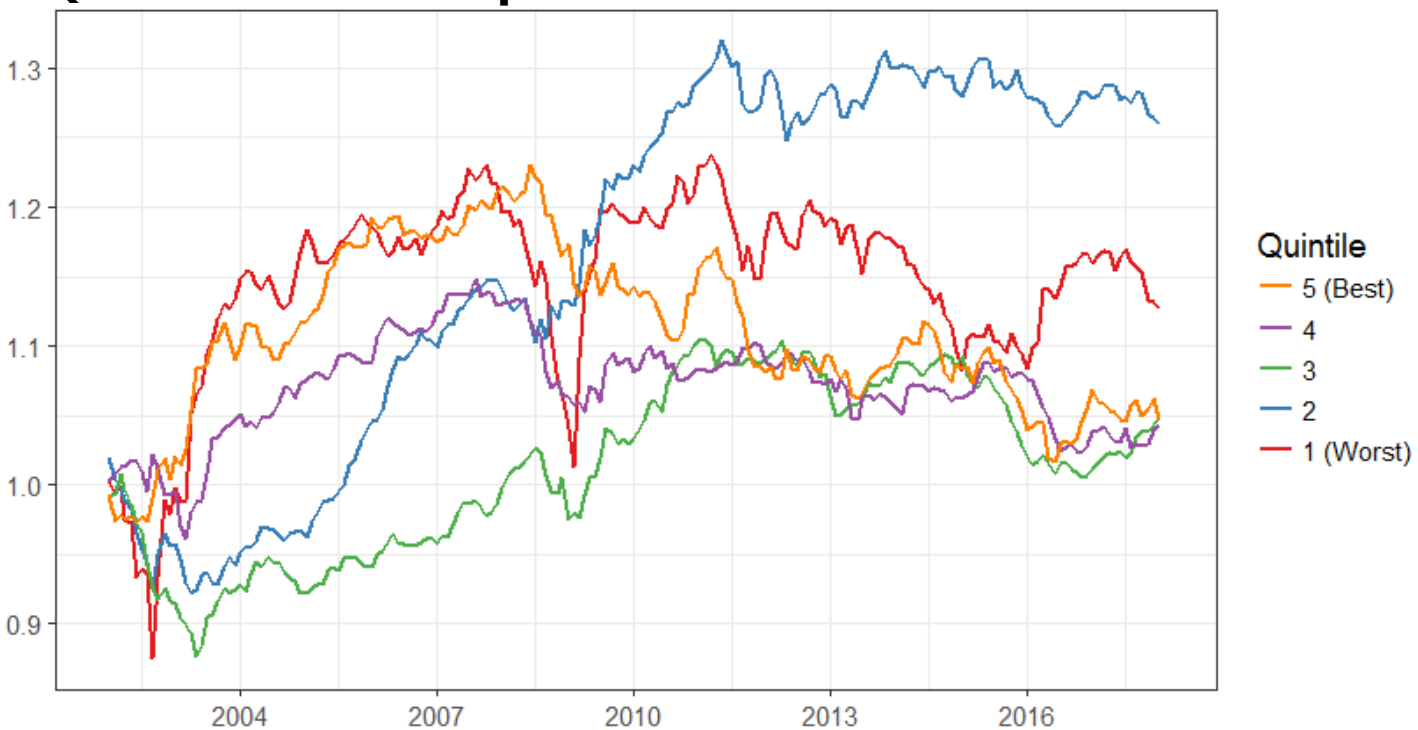
Source: UBS Quant, MSCI.

Neural network

- 3 hidden layers with ReLU activation, sizes of 256, 128 and 64; identity activation in the output layer. **Total number of parameters: $81,928$**

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	0.74%	1.44%	0.29%	0.26%	0.29%
Annualised Std Dev	5.41%	2.97%	2.72%	2.65%	3.21%
Sharpe (Rf=0%)	0.14	0.49	0.11	0.10	0.09

Quintile cumulative performance



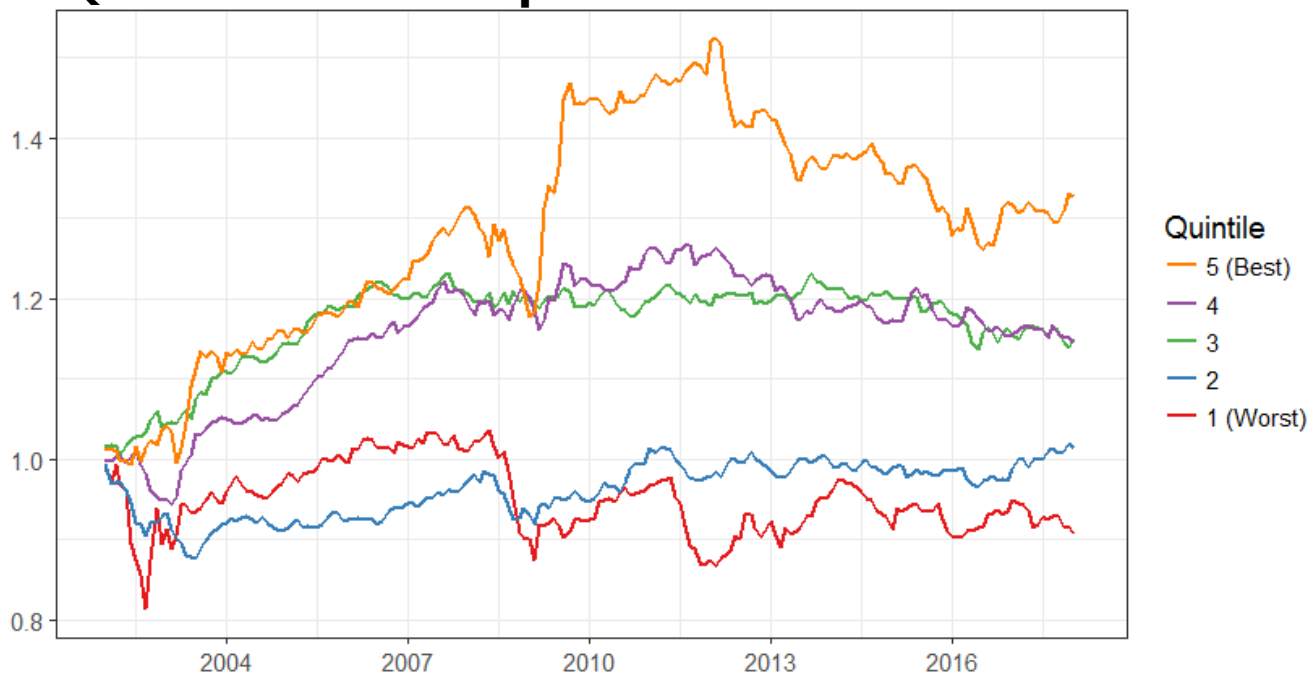
Source: UBS Quant, MSCI.

Tuning: Does regularisation help?

- Dropout: randomly drop a proportion of hidden (or visible) units (Srivastava *et al*, 2014)
  - Drop 30% of inputs, then 50%, 40%, 30% of units at each hidden layer

	Q1 (Worst)	Q2	Q3	Q4	Q5 (Best)
Annualised return	-0.61%	0.09%	0.88%	0.84%	1.77%
Annualised Std Dev	5.72%	2.81%	2.41%	2.98%	4.74%
Sharpe (Rf=0%)	-0.11	0.03	0.36	0.28	0.37

Quintile cumulative performance

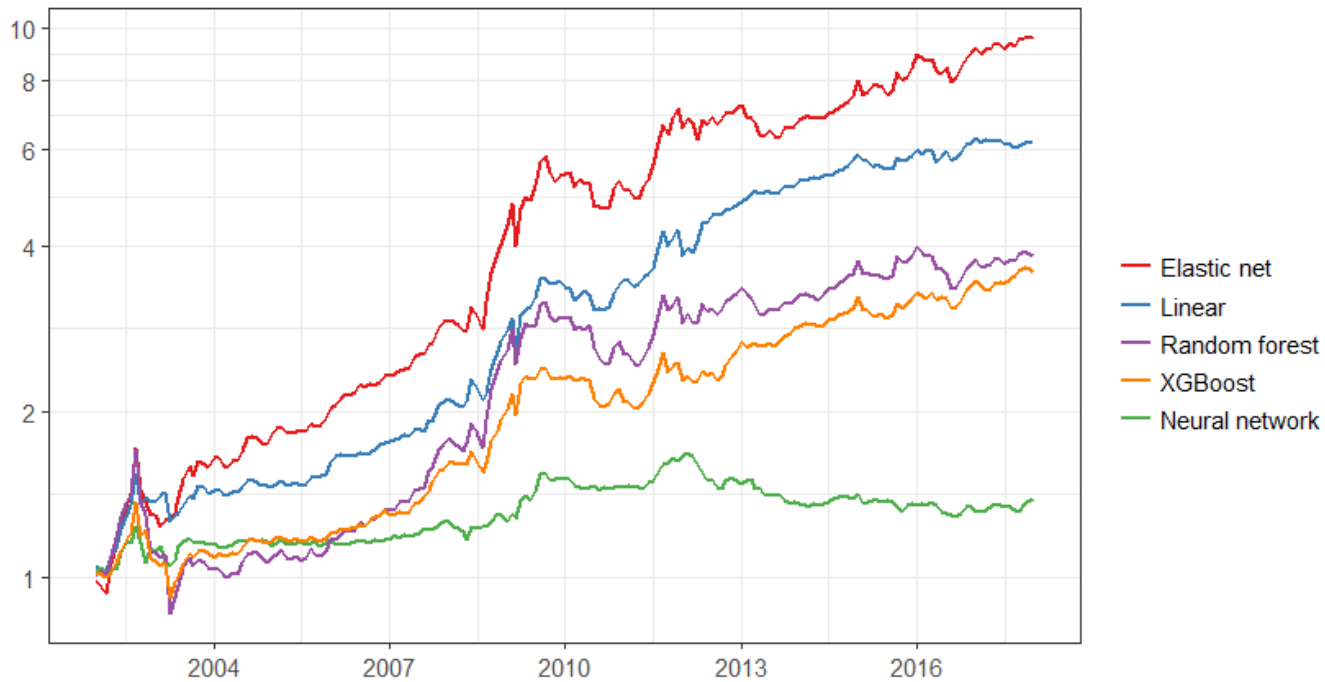


Source: UBS Quant, MSCI.

Comparing models: long-short

	Linear	Elastic net	Random forest	XGBoost	Neural network
Annualised return	11.96%	**15.11%**	13.09%	8.24%	2.06%
Annualised Std Dev	12.14%	16.43%	16.09%	11.97%	7.48%
Sharpe (Rf=0%)	**0.98**	0.92	0.81	0.69	0.28

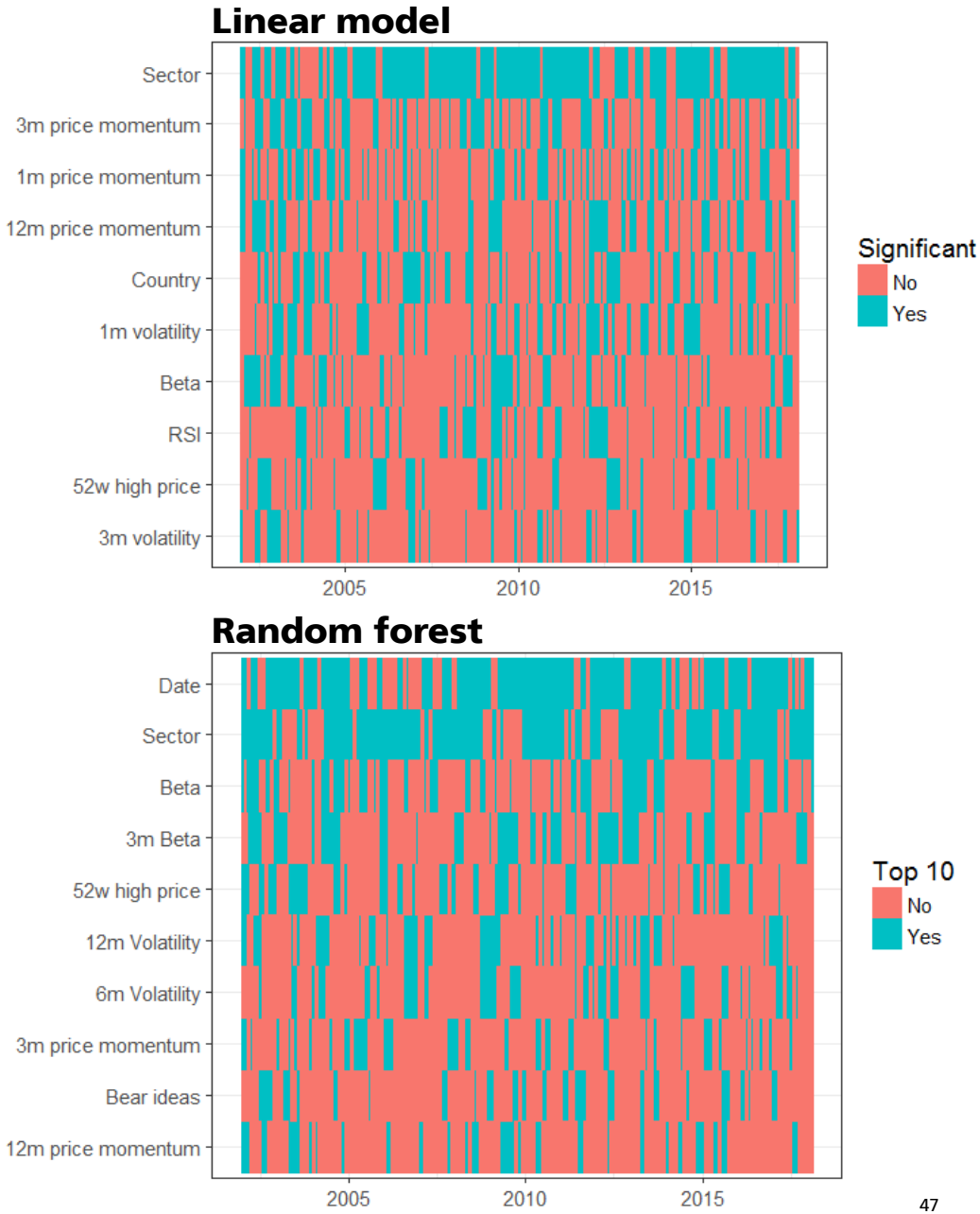
Long-short cumulative performance



Source: UBS Quant, MSCI.

Variable importance

- Linear and tree-based models appear to have similar returns
  - What variables drive the predictions?
- Linear models: look at significance of coefficients (at 5% level)
- Random forest: look at variable importance, measured by "mean decrease in accuracy" if that variable is omitted
- Charts show top 10 variables according to measures of importance
- Sector, market beta, short and long term price momentum



Source: UBS Quant.

AI in finance: limits & potential

Why is it hard to apply modern machine learning techniques (such as **deep learning** and **boosting**) to financial data?

- Compared to speech/text/images, financial time series have very different characteristics:
  - Low signal to noise ratio (image classifiers fail when noise is added – adversarial examples)
  - More data is hard (impossible) to generate
    "*Strong false assumptions can be better than weak true ones, because a learner with the latter needs more data to avoid overfitting*" (Domingos, 2012)
  - The past is not a good predictor of the future
    "*Machine learning, on the other hand, is applicable to datasets where the past is a good predictor of the future*" (Chollet, 2017)

So what could be the potential applications?

- Text analysis to generate sentiment scores
- (Satellite) Image analysis to gain insights into a given stock or industry
- ….

Conclusion

- Deep learning is a *relatively old* subfield of machine learning, which gained popularity in 2010s
  - Remarkable results on perceptual tasks involving unstructured data
- Boosting: XGBoost (2014)
  - State-of-the art for problems where structured data is available
- A "simple" exercise to predict monthly cross-sectional returns given a large set of inputs → stock-selection model for MSCI Europe
  - The standard linear model performs best (risk-adjusted return)
  - Regularisation (elastic net regression) might be a good idea
  - Non-linear models strictly underperform linear ones (risk-adjusted and absolute returns) in our empirical analysis
  - From the non-linear models random forest does best
  - Neural networks do not appear suitable for the task; dropout helps with overfitting but results remain unconvincing

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Our quantitative models rely on reported financial statement information, consensus earnings forecasts and stock prices. Errors in these numbers are sometimes impossible to prevent (as when an item is misstated by a company). Also, the models employ historical data to estimate the efficacy of stock selection strategies and the relationships among strategies, which may change in the future. Additionally, unusual company-specific events could overwhelm the systematic influence of the strategies used to rank and score stocks.

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Neutral	FSR is between -6% and 6% of the MRA.	39%	23%
Sell	FSR is > 6% below the MRA.	15%	12%
Short-Term Rating	**Definition**	**Coverage[3]**	**IB Services[4]**
Buy	Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%
Sell	Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%

Source: UBS. Rating allocations are as of 31 March 2018.
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