EPS forecasting

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Introduction

- Academic studies empirically show that analysts are superior at predicting quarterly earnings compared to time series models
- Circumstances in which statistical models might be more accurate: smaller or younger firms, longer forecasting horizons
- More recently, *Ghysels et al (2015)* proposed a method to predict quarterly earnings *more accurately* than analysts using:
  - Quarterly accounting data
  - Higher frequency macroeconomic and firm-level stock return data

    14 variables, each used as predictor in linear regression

  - Generate 14 out-of-sample forecasts; combine them using principal component forecast combination (*MIDAS-combination*)
  - Back-tested with a very wide universe of US stocks (~1500 companies)

    14-28% lower forecast errors

  - Median absolute scaled error ratio

$$MASER = \frac{median(|F_{MIDAS,q}/\Delta EPS_q|)}{median(|F_{Benchmark,q}/\Delta EPS_q|)}$$

Measure of accuracy

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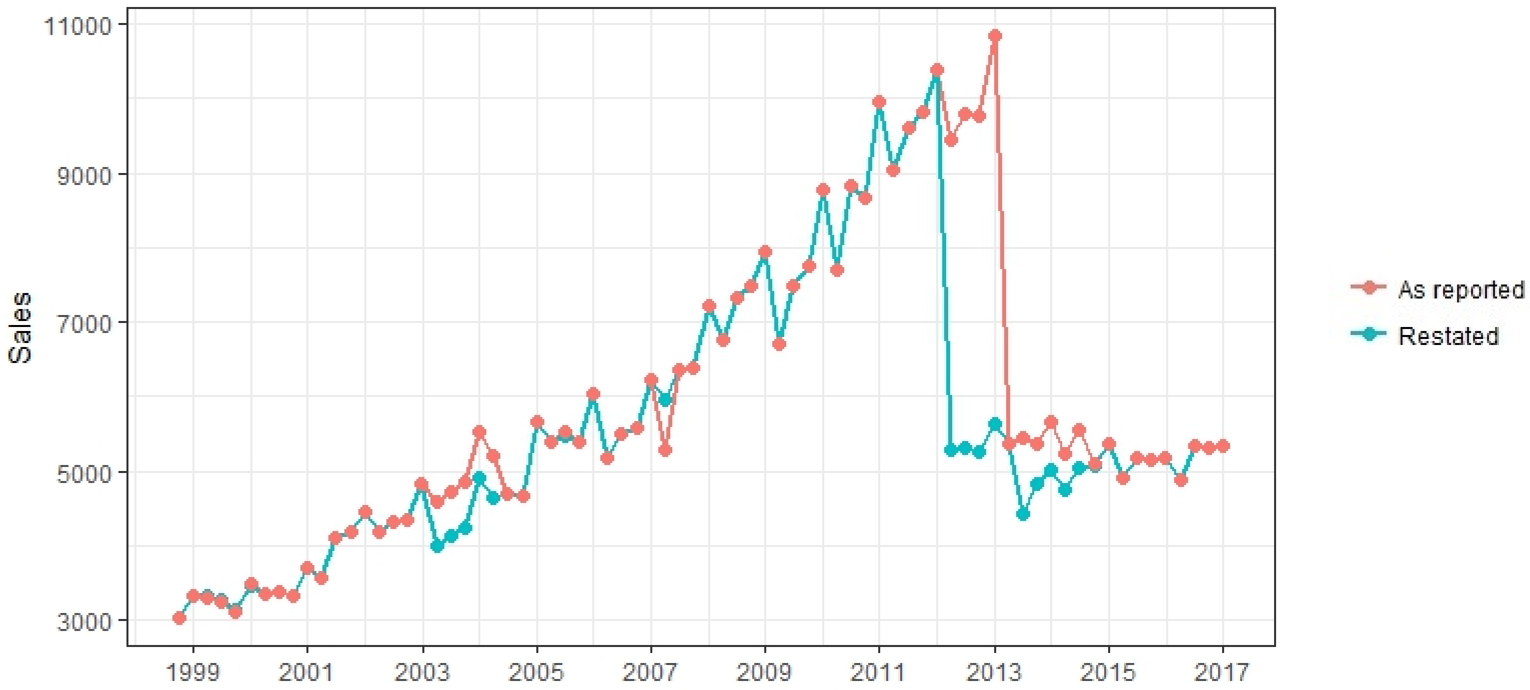
Accounting is messy

- Quarterly sales data from two data sources



Source: IBES, Compustat

- Some of the problems with accounting data
  - Quarterly numbers are unaudited
  - Companies often restate reported numbers
  - Income statement and balance sheet figures are easy to manipulate
- Focus on cash-based items (capex, cash flow from operations etc.)

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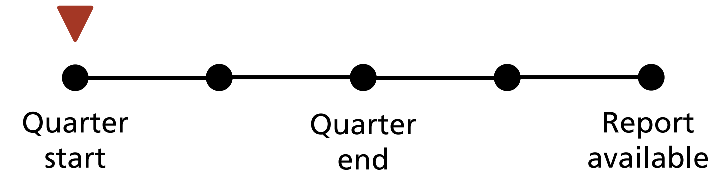
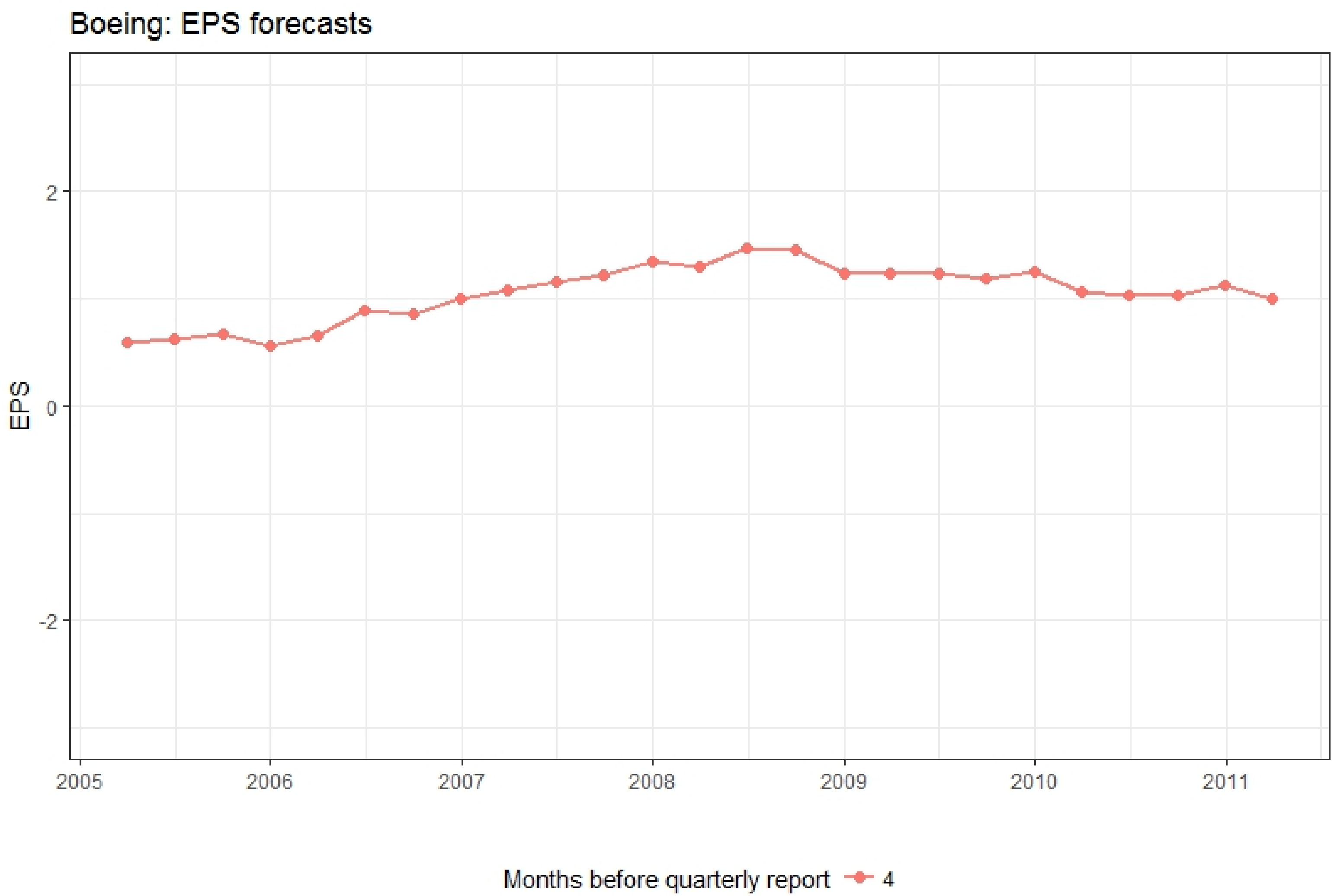
Why are analysts difficult to beat?

- Analyst's forecast at the beginning of each quarter:

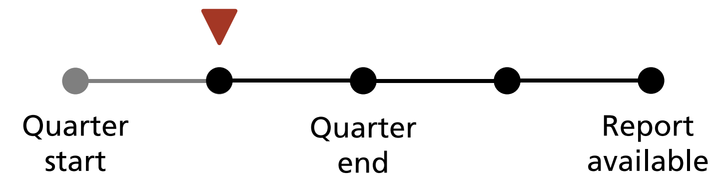


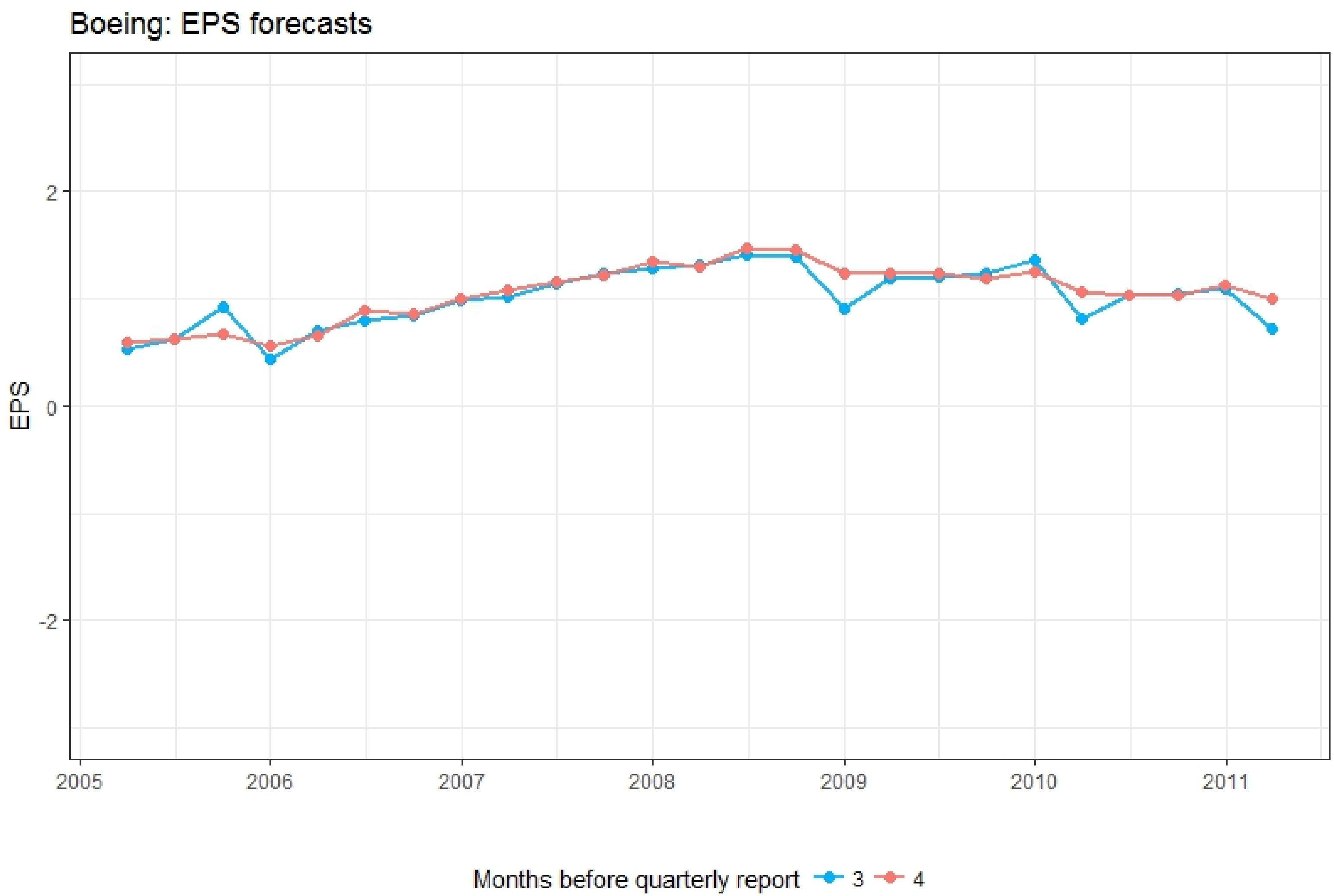


Source: IBES

Why are analysts difficult to beat?

- Analyst's forecast in the middle of the quarter:





Source: IBES

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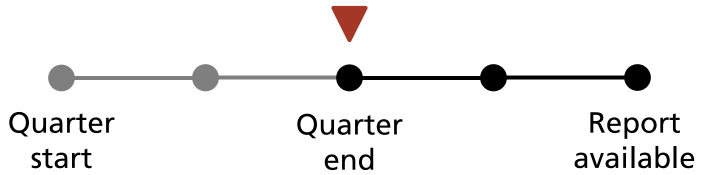
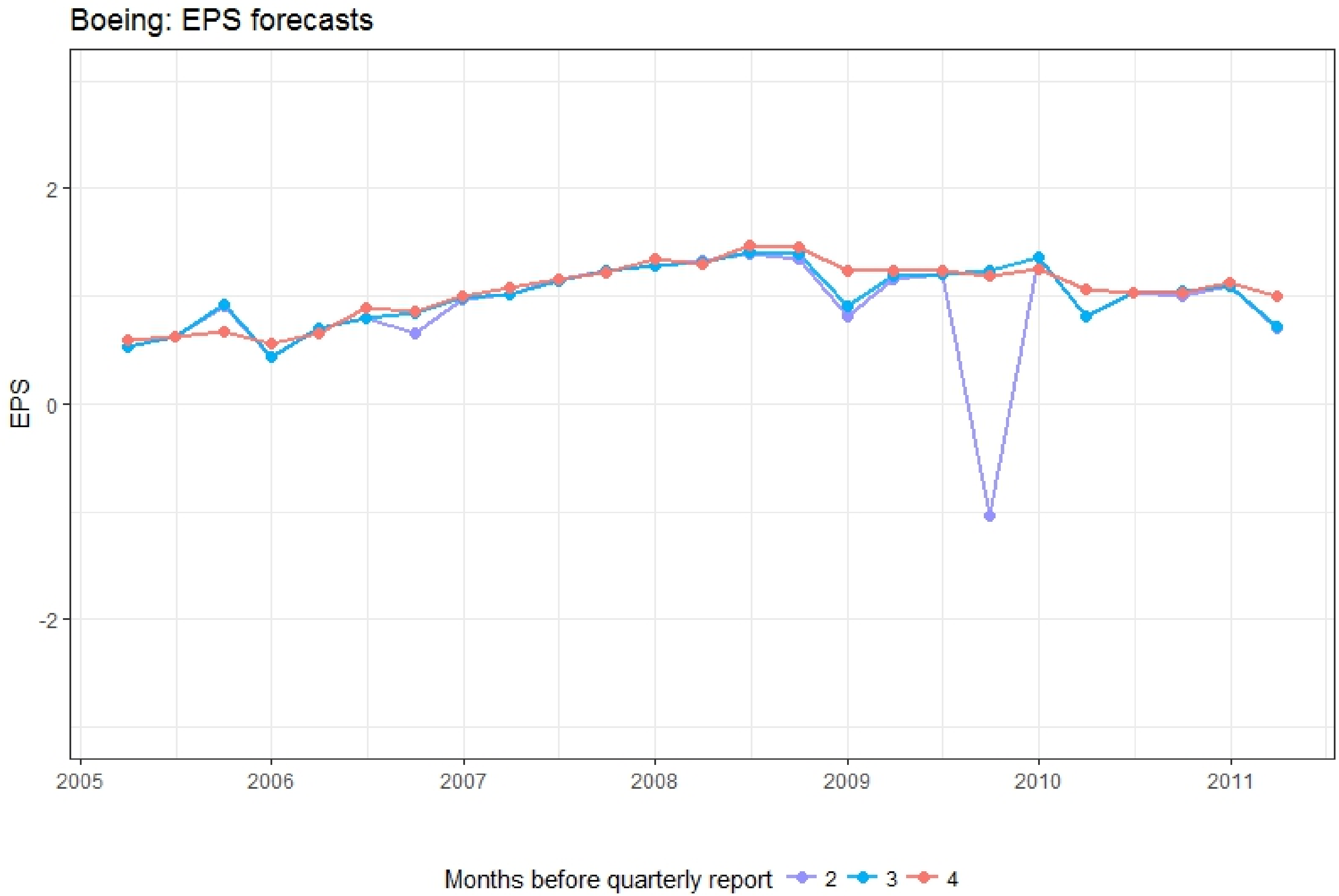
Why are analysts difficult to beat?

- Analyst's forecast at the end of the quarter:

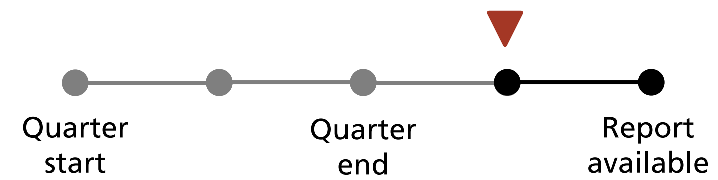


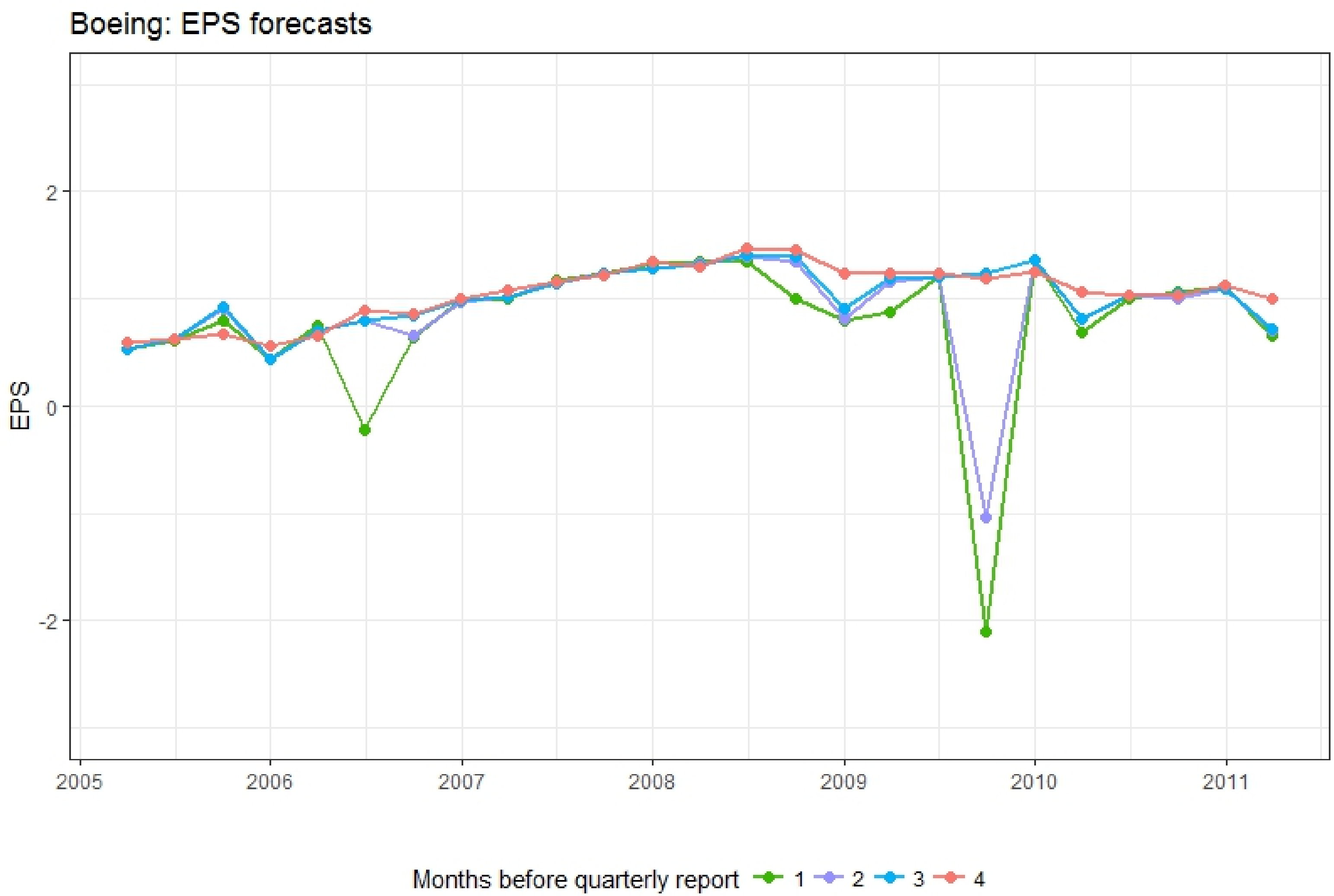


Source: IBES

Why are analysts difficult to beat?

- Analyst's forecast a month after the quarter end:

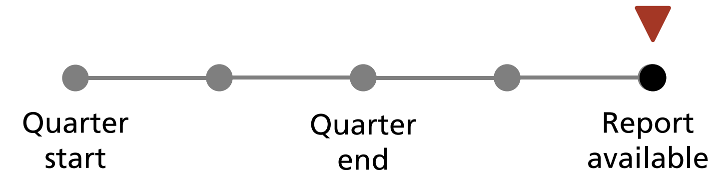


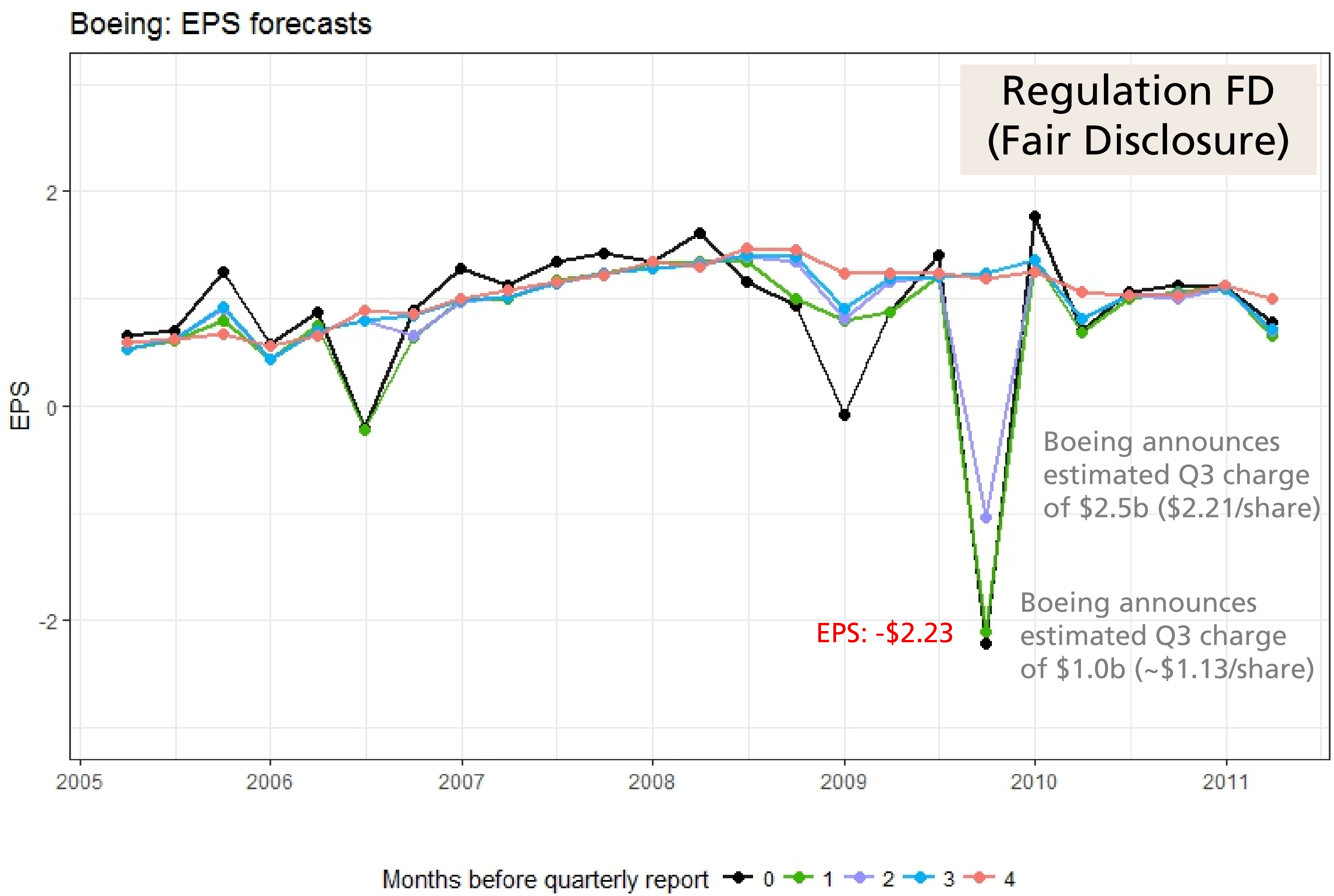


Source: IBES

Why are analysts difficult to beat?

- Reported Earnings per share:





Source: IBES, Boeing

Data

- Consensus and historical EPS data from IBES
  - Target variable: $\Delta EPS_q = EPS_q - EPS_{q-4}$
- Company data from Compustat
  - Consider cash-flow statement items only: Capex, CFO, CFF, CFI
- Macroeconomic data from Datastream
  - Monthly frequency
  - Year-over-year change in CPI, Industrial Production, Oil Price
  - First order difference: Term Spread, 3-month Treasury bill yield, VIX
- Market data:
  - Monthly stock returns in excess of the industry ones, return volatility
- Sample period: Jan 1990 through Feb 2017

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Rolling forecasting experiment

- 236 large- and mid-cap stocks
- Initial training period of 10 years
- Out-of-sample (OOS) one step ahead forecasting
- Predictions are made at the end of each quarter
- Performance metric: Normalised Root Mean Squared Error (NRMSE)

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(\hat{y}_t - y_t)^2}{n}}$$

$$NRMSE = \frac{RMSE}{y_{max} - y_{min}}$$

  – Facilitates comparison across sectors

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Section 1

Standard econometric models

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Econometric models

- Simple Autoregressive (AR) model:

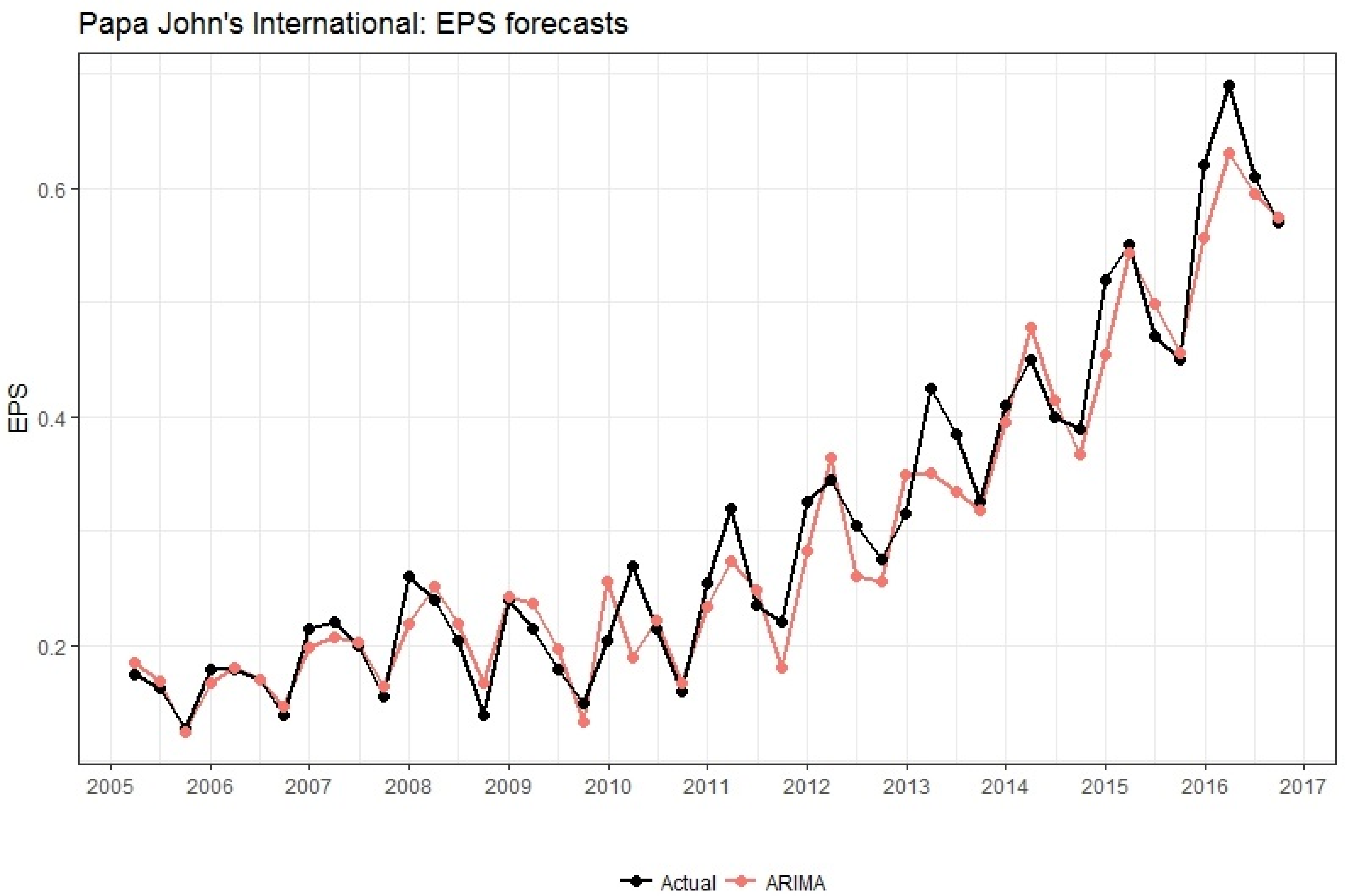
$$\Delta EPS_q = \alpha + \sum_{i=1}^{p} \varphi_i \, \Delta EPS_{q-p} + \epsilon_q, \qquad p \in \{1, 2, 3\}$$

  - Choose the model with the lowest AIC
  - Assumes ΔEPS is stationary

- A more robust approach: $ARIMA(p, d, q)(P, D, Q)_m$ model
  - $m = 4$ is the seasonal frequency
  - Step-wise approach to determine the rest of the parameters (*Hyndman et al, 2008*)

ARIMA forecasts

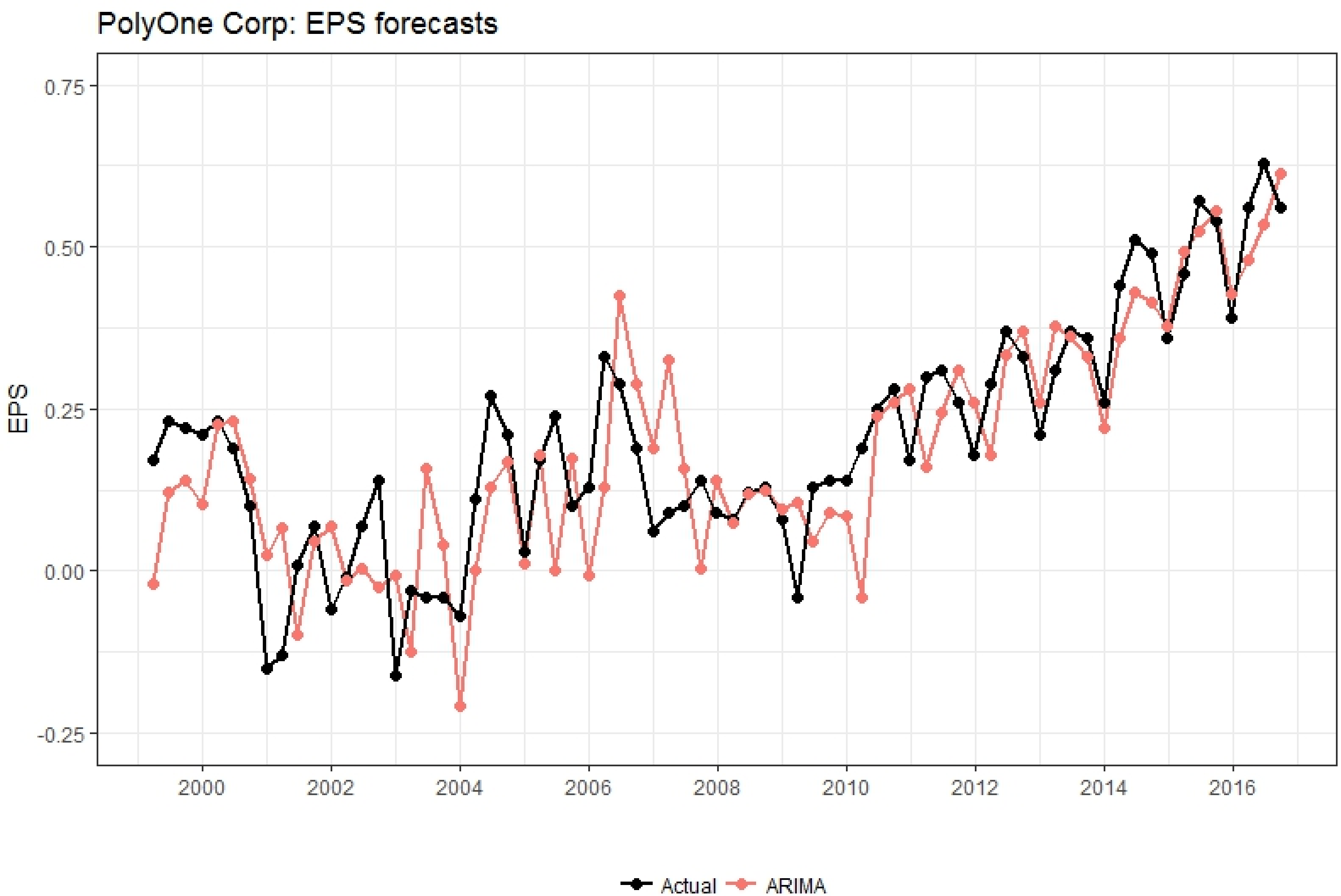
- In certain circumstances ARIMA works really well!



Source: IBES, UBS Quantitative Research

ARIMA forecasts

- And doesn't in others…



Source: IBES, UBS Quantitative Research

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Section 2

Machine learning models

Background

- Most machine learning algorithms are not designed for time series data
- Data pre-processing
  – Remove seasonality
  – Introduce lags
  – Handle missing values
- Algorithms considered:
  – Rule based: Random forest (RF)
  – Linear regression: principal component (PCR), partial least squares (PLS)
- Why?
  – Trees and linear regression tend to give different answers/capture different aspects of data
  – Linear vs non-linear dependency of response on features
  – Easy to tune and fit – all have a single tuning parameter

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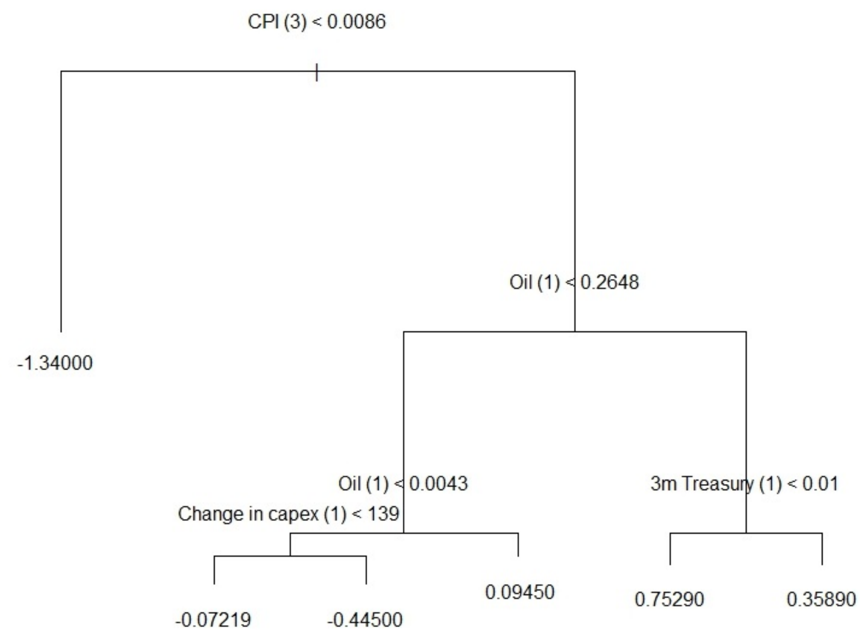
Random forest

- Ensemble learning method based on decision trees
  - Build a large collection of de-correlated trees, m
  - Generate m predictions for a new sample
  - Take the average of these predictions
- Tuning parameter – number of randomly selected predictors to choose from at each split

Simple regression tree



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Advantages	Disadvantages
– Automatic variable selection – Don't overfit (*Breiman, 2001*) – Captures non-linearities	– Interpretability – Don't do well when extrapolation outside the range of the predictors/response is required

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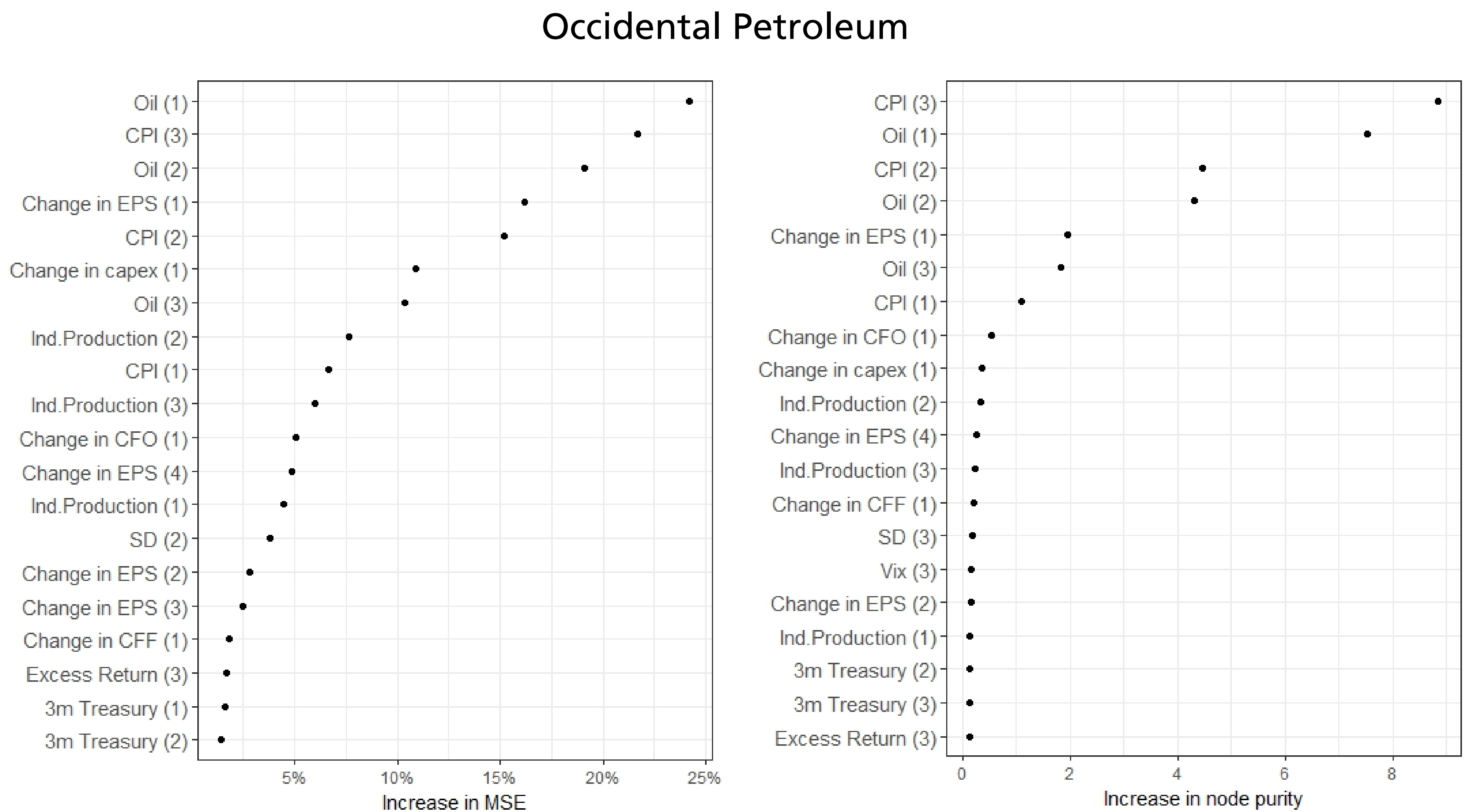
Variable importance (1)



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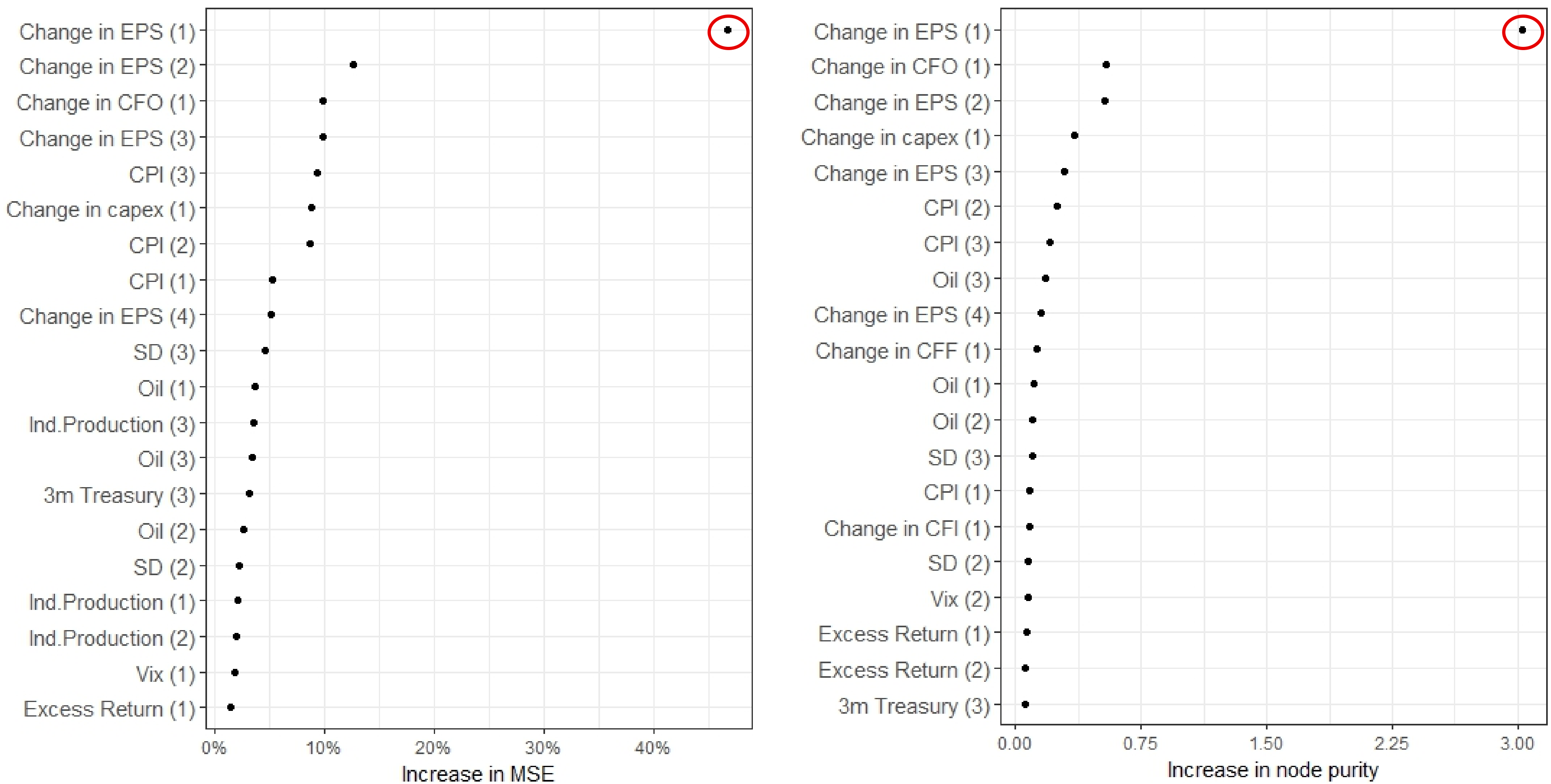
Variable importance (2)

Colgate-Palmolive



Source: UBS Quantitative Research
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Principal component regression

- Principal component regression (PCR) – a regression technique based on principal component analysis (PCA)
  - Calculate the principal components
  - Keep the first K
  - Use them as predictors in a standard linear regression framework
- Tuning parameter – number of components K

Summarise predictor space preserving as much variability as possible

Advantages	Disadvantages
– Dimensionality reduction	– Interpretability
– Avoids multicollinearity	– Does not consider aspects of the response when it selects its components
– Prevents overfitting	

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Partial least squares regression

- Partial least squares (PLS) regression:
  - Construct components that:
    - Summarise the variability of the predictors as much as possible…
    - Require these components to have maximum correlation with the response
- Essentially supervised dimensionality reduction technique
- Tuning parameter – number of components K
  - Number of components required generally lower than that of PCR

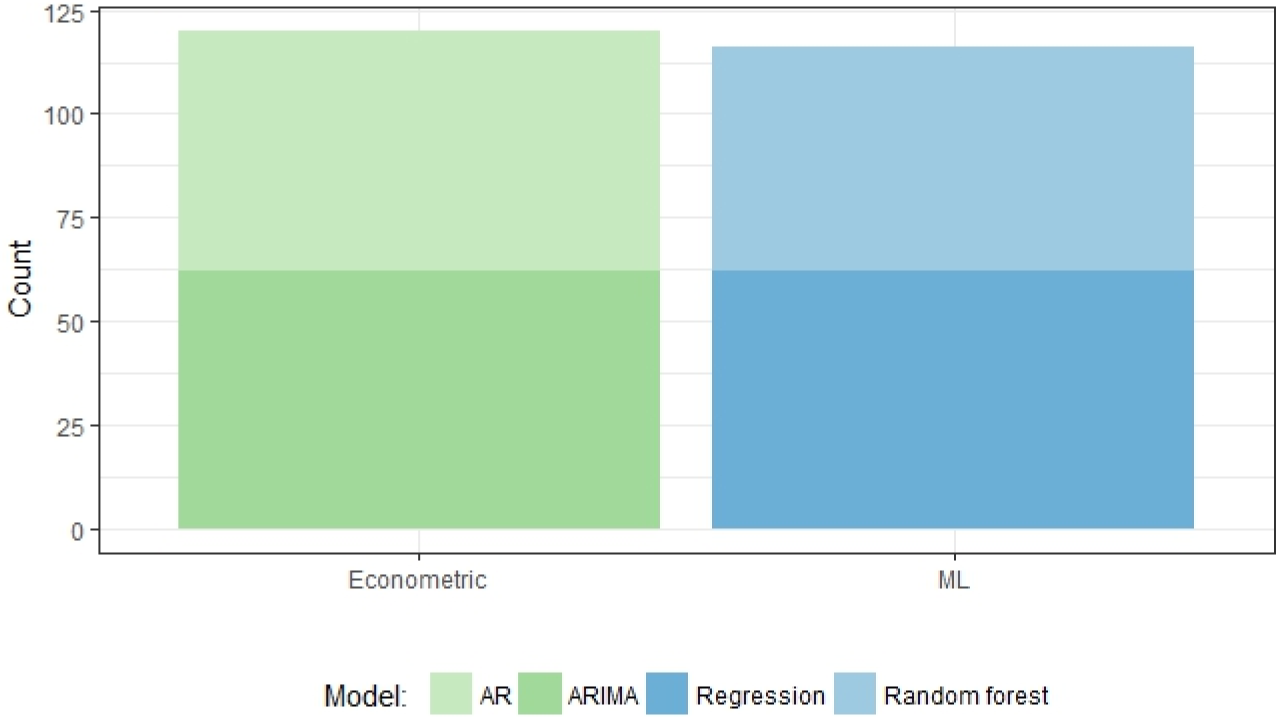
Summarise predictor space preserving as much covariance with the response as possible

Section 3

Empirical results

Empirical results

- For each stock, select the model with the lowest RMSE



Source: UBS Quantitative Research

- No absolute winner!
- All models perform equally well (or badly)

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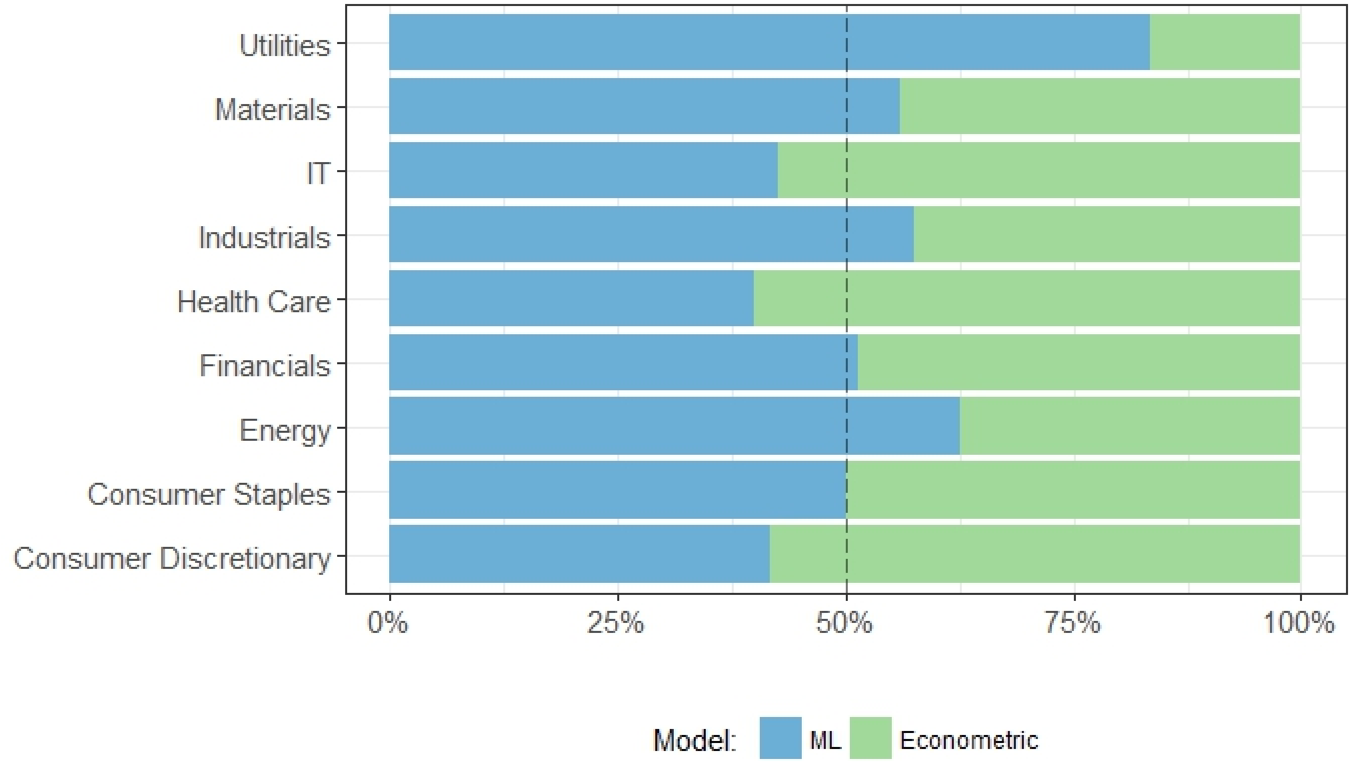
Performance by sector

- Were there any differences across sectors?



Source: UBS Quantitative Research

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Combining forecasts

- Regression and tree-based models tend to capture different aspects of the data, thus (generally) producing different results
- Combining the forecasts made by the predictive models should improve accuracy
- Ensembling predictions from regression is not straightforward
  - Linear methods:
    - Take an average of the predictions
    - Take a weighted average – e.g. determine weights through linear regression/PCR etc.
  - Non-linear methods:
    - Random forest, neural network etc.
  - Naïve: pick the one that performed best in the previous quarter (*stay on a winner)*

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Combining forecasts

- Similarly to *Ghysels et al,* combine the predictions through linear regression

$$\Delta EPS_{q-t} = \sum_{n=1}^{3} \beta_n \cdot f_{n,q-t} + \epsilon_{q-t}, t = 1, \dots, 20$$

$$F_q = \sum_{n=1}^{3} \beta_n \cdot f_{n,q}$$

  - ΔEPS_{q-t} is actual change in EPS, $f_{n,q-t}$ are the forecasts made by the models and F_q is the combined forecast
  - Method implies that the individual forecasts are systematically biased and the bias does not change (much) over time
  - The average NRMSE increased by $\sim 17\%$
- Taking the mean of individual forecasts reduced average NRMSE by $\sim 5\%$
- Staying on a winner also improved performance marginally

Improvement in average NRMSE for different forecast combinations

Source: UBS Quantitative Research

Question: Are forecasts biased?

- **Yes**
- But not in a way that is easily captured by linear transformations

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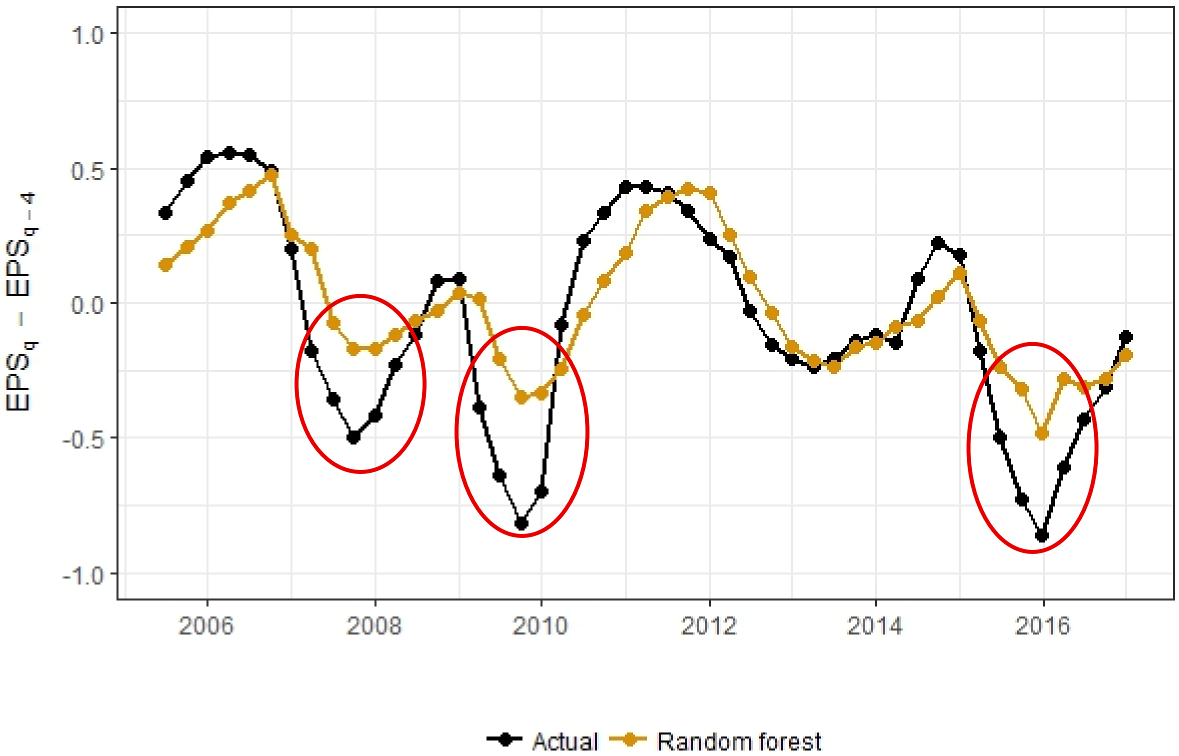
Bias in forecasts

- The output of the ML models is a *mean (expected value)*
- The mean is generally in line with the overall trend, but unable to capture extremes
  - Idiosyncraticities on a company level
- Need to adjust the for bias "locally"



Source: UBS Quantitative Research, IBES

Adjusting for the bias

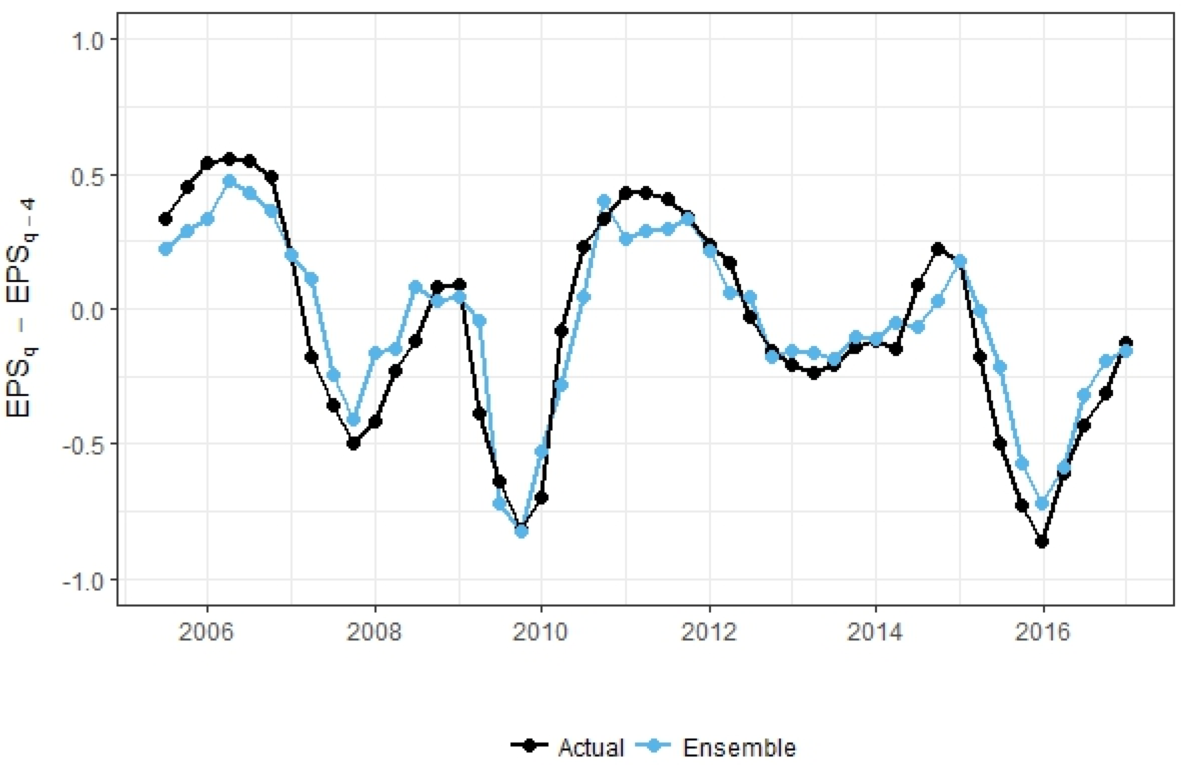
- In quarter q:
  - Calculate the error for each model:

    $$e_{n,q} = \Delta EPS_q - f_{n,q}$$

  - Select the model the model with the lowest absolute error, $f_{w,q}$
  - Define the forecast for the next quarter to be:

    $$F_{q+1} = f_{w,q+1} + \frac{e_{w,q}}{b}$$

    for some b



Source: UBS Quantitative Research, IBES

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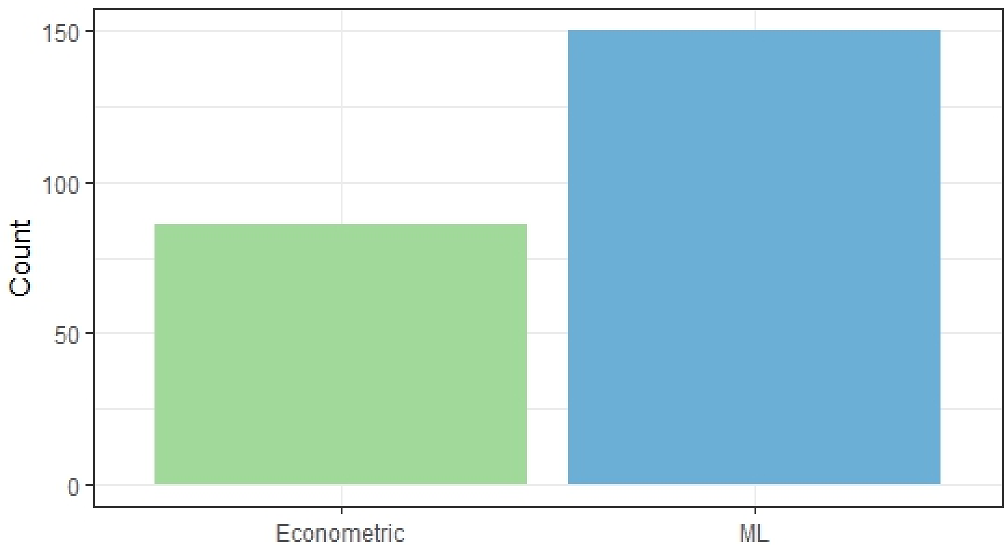
Adjusting for the bias

- Comparing the NRMSE of the combined forecast to the average NRMSE of the ML methods we see an improvement of just above 8%
  - Autocorrelation not entirely captured by the ML models

Source: UBS Quantitative Research



Source: UBS Quantitative Research

- Combine the predictions from the econometric models in the same way
  - Improvement not as impressive (~2%)
- Number of instances for which ML outperforms Econometric models almost doubles

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Section 4

IBES as a benchmark

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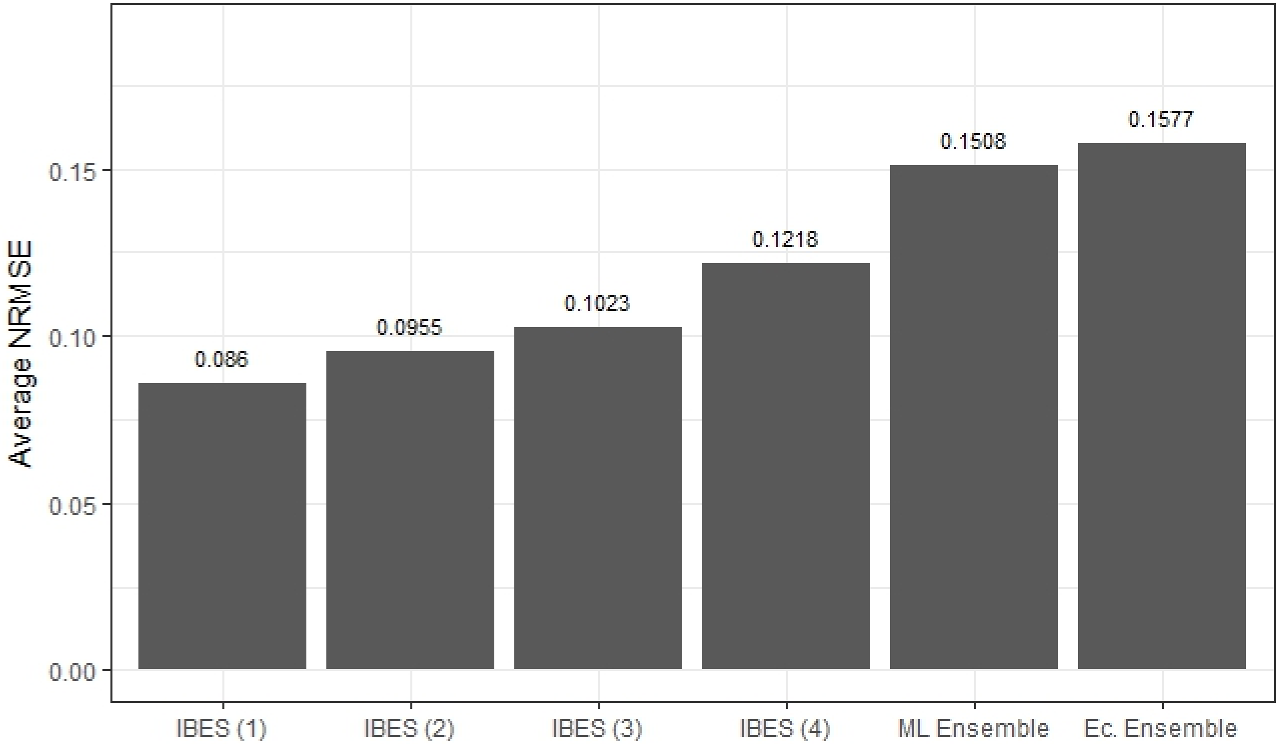
Predictive models vs the Analysts (1)

- Comparing the performance of the models to that of the analysts



Source: UBS Quantitative Research

- Average NRMSE of the automatic EPS forecasts
  - ~24-30% higher compared to analysts' forecasts at the beginning of the quarter (*IBES (4)*)
  - ~58-65% higher relative to consensus estimates made at the end of the quarter (*IBES (2)*)

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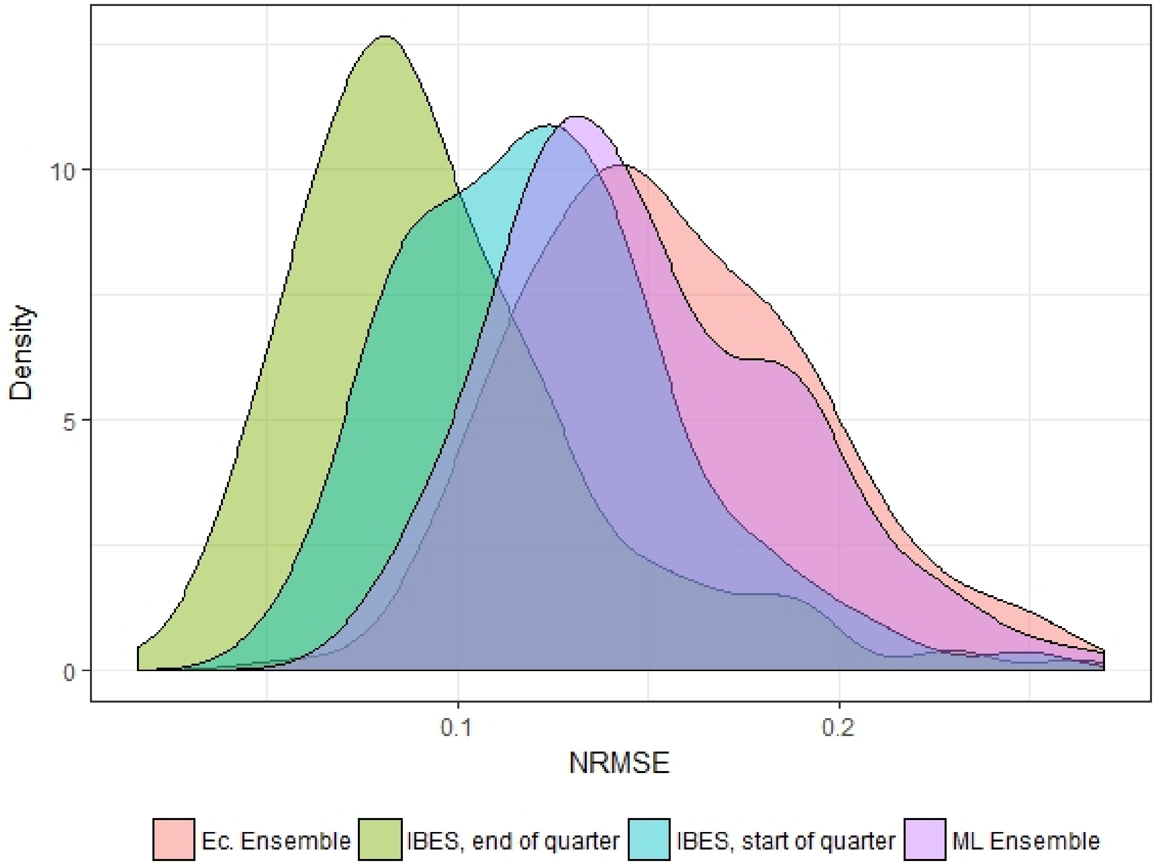
Predictive models vs the Analysts (2)

Distribution of NRMSE



Source: UBS Quantitative Research

- It is close to impossible to outperform analysts' forecast at the end of the quarter (in RMSE sense) without utilising company's guidance

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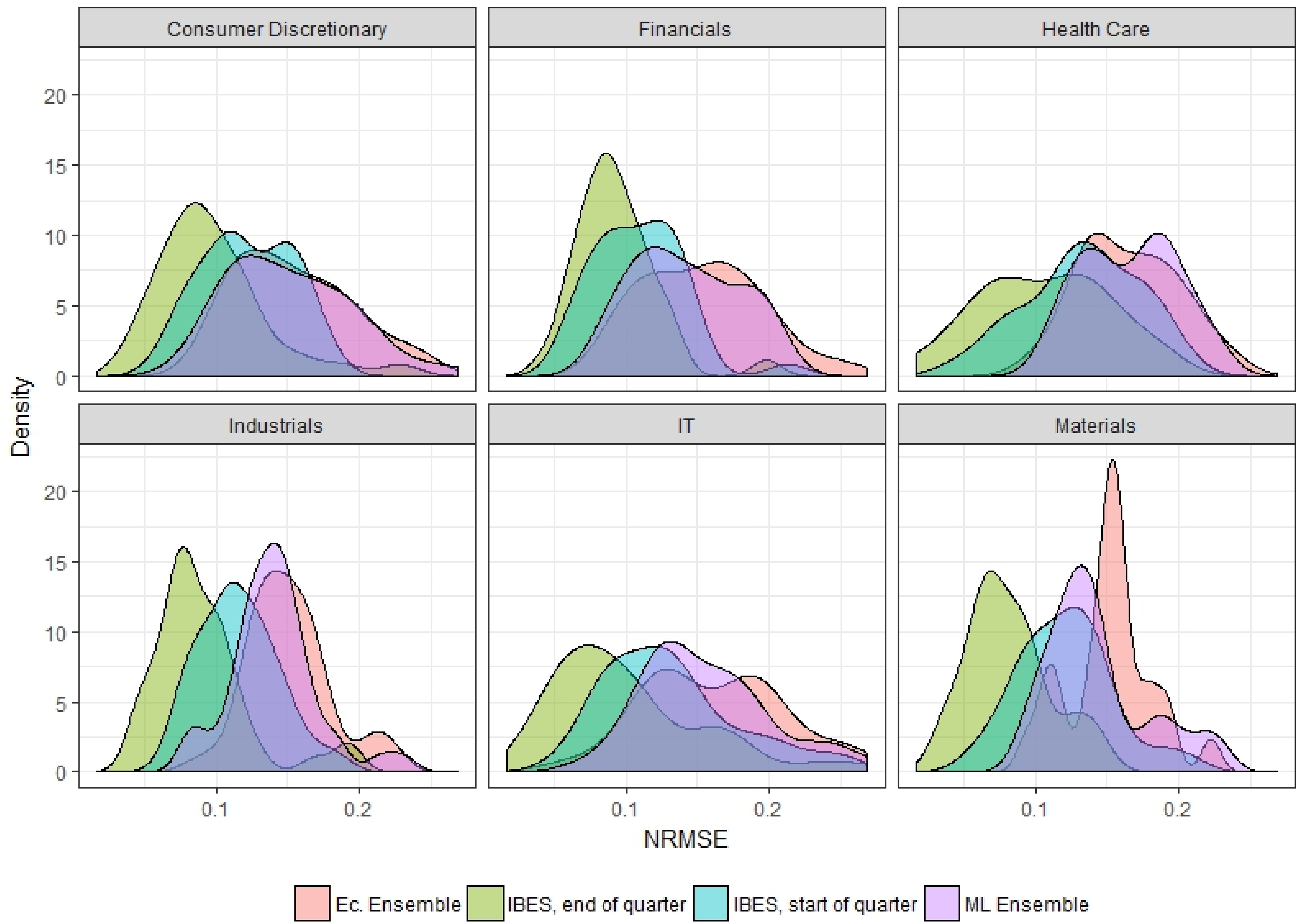
Predictive models vs the Analysts (3)

- Consider sectors with a sample of at least at least 20 companies

Distribution of NRMSE across sectors



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Source: UBS Quantitative Research

Conclusions

- EPS hard to predict
  - Influenced by accounting conventions
  - Could be manipulated

Consider industry-level EPS to reduce the noise

- Constructed simple ML and econometric predictive models to forecast firm-level earnings
  - More than just accounting and macro data is required to reach analysts' accuracy… **at least in the US**
- Nonetheless, automatic EPS forecasts are useful in their own right:
  - Provide forecasts that are free from idiosyncratic effects
  - Serve as a tool for the analyst to challenge their forecasts: what else is there that is driving company's EPS in addition to the current economic environment and historical trends?

Next steps

- Ways to improve the accuracy of the models:
  - Point-in-time accounting data: e.g. sales/inventory levels etc.
  - Make use of news/sentiment data
  - Incorporate guidance: scrape data from company news releases
- Train different predictive models
  - The ML tried so far were chosen for their simplicity
  - Recent research shows recurrent NN are able to handle temporal data; local methods e.g. KNN
  - More complex $\neq$ better predictive power

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